Thieken, A. H., Kreibich, H., Müller, M., Merz, B. (2007): Coping with floods: preparedness, response and recovery of flood-affected residents in Germany in 2002. - Hydrological Sciences Journal - Journal des Sciences Hydrologiques, 52, 5, 1016-1037,

DOI: 10.1623/hysj.52.5.1016.

Submitted for publication in Hydrological Sciences Journal (IAHS)

Re-Revised version of HSJ-Paper No. 2352

Coping with floods: Preparedness, response and recovery of flood-affected residents in Germany in 2002

ANNEGRET H. THIEKEN[1], HEIDI KREIBICH[1], MEIKE MÜLLER[2], BRUNO MERZ[1]

[1] GeoForschungsZentrum Potsdam, Engineering Hydrology Section, Telegrafenberg, D-14473 Potsdam, Germany, thieken@gfz-potsdam.de

[2] Deutsche Rückversicherung AG, Hansaallee 177, D-40549 Düsseldorf, Germany

Abstract In August 2002, a severe flood event hit Central Europe. In the aftermath, a stratified poll was performed in Germany. 1697 private households at (1) the River Elbe, (2) the Elbe tributaries in Saxony and Saxony-Anhalt and (3) in the Bavarian Danube catchment were interviewed about flood characteristics, early warning, damage, recovery, preparedness and previously experienced floods. Preparedness, response, monetary losses and recovery differed in the three regions under study. This could be mainly attributed to differences in flood experience and flood impact. Knowledge about self-protection, homeownership and household size influenced the extent and kind of private precaution and the residents' capability of performing mitigation measures. To further improve preparedness and response during future flood events, flood warnings should include more information about possible protection measures. In addition, different information leaflets with flood mitigation options for specific groups of people, e.g. tenants, homeowners, elderly people or young families should be developed.

Keywords: flood impact, Germany, mitigation, recovery, flood warning

Faire face aux inondations: Préparation, réponse et rétablissement des ménages affectés par les crues d'août 2002 en Allemagne

Résumé En août 2002, une grave inondation a frappé l'Europe centrale. Ultérieurement, un sondage stratifié a été effectué en Allemagne. 1697 ménages le long (1) de la rivière Elbe, (2) des affluents de l'Elbe en Saxe et Saxe-Anhalt, et (3) dans le bassin du Danube en Bavière ont été interrogés sur les caractéristiques de la crue, l'alerte précoce, les dommages, le rétablissement, la préparation et les inondations expérimentés précédemment. La préparation, la réponse, les coûts monétaires et la reconstruction différaient dans les trois régions étudiées. Ce fait peut s'expliquer par les différences d'expérience par rapport aux inondations passées et impact de la crue. La connaissance sur l'autoprotection, la propriété d'habitation et la taille du ménage a influencé l'ampleur et le genre de précaution privée ainsi que l'efficacité des gens à effectuer des mesures d'urgence. Pour améliorer la préparation et la réponse durant des crues futures, le public doit être mieux informé sur les mesures de prévention des crues possibles. De plus, il faut développer des brochures d'information spécifiques avec les mesures de prévention de crues adaptées à chaque groupe de personnes, telles que locataires, propriétaires, personnes âgées ou jeunes ménages.

Mots clefs: impact des crues, Allemagne, prévention, reconstruction, alerte aux inondations

1. INTRODUCTION

Damage due to natural disasters has dramatically increased in the last decades. In 2002, floods accounted for about 50% of all economic losses due to natural disasters (Munich Re, 2003). The most severe flood event occurred in Central Europe (Germany, Austria, the Czech Republic and Slovakia) in August 2002 along the rivers Elbe and Danube and some of their tributaries (see Ulbrich et al., 2003; Engel, 2004). In Germany, 21 people were killed and substantial parts of the infrastructure were destroyed in some of the affected regions. The most affected German federal state was Saxony, where the total flood damage amounted to 8700 million Euro, followed by Saxony-Anhalt (1187 million Euro) and Bavaria (198 million Euro) (data from SSK, 2004; IKSE, 2004; Bavarian Ministry of Finance, pers. comm.). Altogether, damage of about 11600 million Euro was caused in Germany. This amount has by far exceeded the damage due to other disastrous events in Germany. Thus, it emphasizes the need to improve flood risk management. Many activities have been launched on the administrative and legislative levels thereafter (see DKKV, 2003).

In recent years a shift from a technology-oriented flood defence towards an integrated flood risk management has taken place (e.g. Takeuchi, 2001; PLANAT, 2004). Flood risk management is aimed at minimising adverse effects and at learning to live with floods (Vis et al., 2003). In general, it focuses on three aspects: 1) flood abatement with the aim to prevent peak flows, e.g. by an improvement of the water retention capacities in the whole catchment, 2) flood control that is aimed at preventing inundation by structural measures, e.g. embankments or detention areas and 3) flood alleviation with the goal to reduce flood impacts by non-structural measures (Parker, 2000; de Bruijn, 2005). The latter can be classified into preventive, precautionary and preparative measures. Prevention is aimed at completely avoiding damage in hazard-prone areas, e.g. by flood-adapted land use regulation. Precaution and preparation help to limit and manage adverse effects of a catastrophe and to build up coping capacities by flood-resilient design and construction, development of early warning systems, insurance, awareness campaigns, education,

training, putting rescue units on stand-by, etc. (e.g. Vis et al., 2003; DKKV, 2003; PLANAT, 2004; de Bruijn, 2005).

For an analysis how disasters have affected a society the disaster cycle offers a valuable framework. The concept has widely been used by international and national organisations and various versions have been published (e.g. Silver, 2001; DKKV, 2003; PLANAT 2004; FEMA 2004; Kienholz et al., 2004). In this paper, three consecutive phases will be distinguished: (emergency) response, recovery and disaster risk reduction (Fig. 1): When a hazardous event occurs, immediate measures will be undertaken with the priority to limit adverse effects and the duration of the event (emergency phase). During recovery, the affected society will start to repair damage and to regain the same or a similar standard of living than before the disaster happened. This phase is setting the stage for the society's next "disaster" (Olson, 2000): If the affected society is willing to learn from a disaster there will be a period of disaster risk reduction, in which measures that are aimed at minimising the vulnerability of people and their assets will be implemented. To enhance risk reduction, the disastrous event, the society's response and possibilities for prevention and preparation should be analysed carefully in the aftermath of an event (Kienholz et al., 2004).

This paper focuses on the coping capacities of private households in three different regions in Germany. The analysis gives some insights into what people learned from the flood in 2002 and what could further be done to stipulate private precaution and disaster preparedness.

In general, homeowners who have been flooded recently are more aware of the flood risk, are interested in mitigation and willing to invest in precautionary measures (e.g. Laska, 1986; Brilly & Polic, 2005; Grothmann & Reusswig, 2006). In a survey in Illinois, USA, 68% of 1236 respondents had spent some money on some kind of flood protection. The amount spent was proportional to the property values and household size, but did not depend on the age of the respondent (Brenniman, 1994). A recent study from Japan showed that the residents' preparedness for floods depends on the ownership of a home, fear of flooding and the amount of damage from previous floods rather than on previous experiences with and

anticipation of floods (Motoyoshi et al., 2004). Moreover, the socio-economic status is a significant predictor in pre- and post-disaster stages, as well as for the physical and psychological impacts. For example, poor people are less likely to prepare for disasters or buy insurance, but they have proportionally higher material losses and face more obstacles during the phases of response, recovery and reconstruction (Fothergill & Peek, 2004).

A survey among flood-affected people at the rivers Rhine and Danube in Germany showed that floods are perceived as danger because of the potential damage and because the possibilities for self-protection are perceived as low (see Plapp, 2003; Werner et al., 2003). A further aspect that controls the perception of flood hazard is the perceived ability of the community to cope with the flood (Werner et al., 2003). Therefore, local governments should better involve residents in flood prevention programs, e.g., by providing better information about the flood hazard, effective dissemination of flood warnings and communication of possibilities of private mitigation measures (Krasovskaia et al., 2001; Werner et al., 2003; Krasovskaia et al., 2007). To stimulate precautionary behaviour of residents in flood-prone areas, it is essential to communicate not only the flood hazard and its potential consequences, e.g. by flood hazard/risk maps, but also available private precautionary measures, their effectiveness and their costs (Grothmann & Reusswig, 2006). For example, Kreibich et al. (2005) showed that different precautionary measures can reduce flood losses up to 50% even during severe flood events.

Besides long-term precautionary measures people's reaction during the disaster and their response to flood warnings can help to limit losses. For example, flood damage due to the Meuse flood in 1995 was 35% lower than in 1993, when a similar flood hit the same municipalities (Wind et al., 1999). The loss reduction in 1995 may be explained by the increase in warning time and experiences gained from the flood in 1993. Penning-Rowsell & Green (2000), however, found that only about 13% of potential damage was avoided by flood warnings, since damage reduction depends on the reliability of the flood warning system, the proportion of residents available to respond to a warning, the proportion of residents able to respond to a warning and the proportion of residents who responded effectively. They

concluded that benefits of early warning systems can only be realised when the total system of forecasting, warning and responding is operating effectively. Therefore, more attention needs to be given to the design of the whole system. Ensuring response by the public to flood warnings should be just as much the responsibility of the agencies concerned as is their role in flood forecasting and warning dissemination (Penning-Rowsell et al., 2000).

The kind of people's reaction to an event might also depend on the type of flooding. People face slow-onset flooding (riverine floods) with elaborate responses, which are not very limited by warning, delay or "labour force" (Torterotot et al., 1992). For fast-onset flooding (flash floods), flood-proofing appears to be the most immediate response, but necessitates a minimum warning because of the speed of water rise (Torterotot et al., 1992).

Research from Canada revealed that reduction measures based on designation and mapping of floodplains have had no impact on occupancy of floodplains, have failed to reduce flood damages and not even halted increases in damage (Robert et al., 2003). A successful integrated risk management has to involve different stakeholders (water management, spatial planning, insurers, emergency management, fire brigades, etc.), scientists, NGOs as well as local residents and companies (e.g. Weichselgartner & Obersteiner, 2002; Pearce, 2003). Disasters – and their mitigation – have to be seen as the products of the social, political and economic environment, as well as the natural event that cause them (Blaikie et al., 1994, p.3).

Although there are a number of studies that deal with the vulnerability of people and their willingness and their ability to prepare for disasters, Brilly & Polic (2005) state that we need further knowledge about the vulnerability of people. Fothergill & Peek (2004) propose – among other things – to conduct in-depth, comparative studies regarding vulnerability issues in different regions and to do more research on risk perception, preparation and warning communication. Therefore a large survey was conducted in the aftermath of the August 2002 flood. The main aim of the survey was to identify factors that influence the flood damage in the residential sector. This paper investigates how flood-affected private households in three different regions in Germany that varied in flood type, flood severity, previously experienced

floods and socio-economy were able to cope with the flood in 2002. Following the phases of the disaster cycle (Fig. 1), it is analysed how private households contribute to disaster mitigation in the three different regions and how preparedness, response and recovery are correlated to socio-economic variables, flood experience and flood impact. The analysis gives some insights into the weaknesses and strengths of the preparedness of residents in the three regions, what people learned from the flood and what could further be done to stipulate private precautionary behaviour.

2. DATA AND METHODS

2.1. Procedure of sampling flood-affected private households

The data set contains private households that suffered from property damage due to the August 2002 flood. In April and May 2003, 1697 private households were interviewed in the most affected German federal states, i.e. Saxony, Saxony-Anhalt and Bavaria (Fig. 2). The survey was stratified into A) the river Elbe and the lower Mulde river, B) the *Erzgebirge* (Ore Mountains) and the river Mulde in Saxony and C) the Bavarian Danube catchment. The stratification was based on the following ideas:

During the August 2002 flood, two flood types, slow-onset river floods along the big rivers and flash floods in the headwaters, could be distinguished (see Ulbrich et al., 2003). While riverine floods were predominant along the Elbe and the lower Mulde River (stratum A), severe flash floods dominated at rivers in the *Erzgebirge* (stratum B). In stratum C, the Bavarian Danube catchment, both flood types occurred.

The flood event was more severe in the Elbe catchment than in the Danube catchment. Return periods at the Elbe tributaries partly amounted up to 200-500 years (IKSE, 2004). Along the river Elbe the return period was estimated to be about 100-200 years at the gauge Dresden (IKSE, 2004), but became shorter further downstream due to levee breaches, water detention etc. (Engel, 2004). In the Danube catchment, the flood was most severe at the river Regen, where a return period of 100 years was assigned to the discharge (Gewässerkundlicher Dienst Bayern, 2002).

Furthermore, experiences from previous floods were likely to differ in the three regions. In the Danube catchment, severe flooding occurred in December 1993 ("Christmas Flood") and particularly in May 1999 ("Whitsun Flood"). The Whitsun Flood caused 347 million Euro damage in Bavaria (Müller, 2000). In contrast, the last severe floods at the Elbe River occurred in 1940, in 1954 and in winter 1974/75. The water levels at the Elbe in August 2002 were, however, more extreme. Widespread flooding in the *Erzgebirge* took place in 1954 and 1958. Apart from these events more localized floods occurred in several years, e.g. in July 1957 along the river Müglitz or in winter 1974 at the river Mulde (see Fügner, 2003; Pohl, 2004, for details).

The strata also differ in socio-economic structure, i.e. in income, purchasing power and building structure. For example, the average purchasing power in Bavarian communities amounted to 17841 Euro per person in 2001, whereas it was 11555 Euro in Saxony and 11702 Euro in Saxony-Anhalt according to census data of INFAS Geodaten GmbH (2001).

On the basis of information from the affected communities and districts, lists of affected streets in the investigated areas were comprised. A random sample was generated on the condition that each street should be present in the data set at least once and that each building should be included only once. Thus, only one household was selected in multifamily houses so that the sample is representative for buildings. In total, 11146 households with their telephone number were selected. Computer-aided telephone interviews were undertaken with the VOXCO software package by the SOKO-Institute, Bielefeld, Germany, from 8 April 2003 to 10 June 2003. Always the person in the household who had the best knowledge about the flood event was questioned. Tenants were only asked about their household and the content damage. To complete the interview the building owner was questioned about the building and its damage. In total, 1697 interviews were undertaken; on average, an interview lasted 30 minutes.

2.2. Contents of the questionnaire and data processing

For this investigation a new questionnaire was elaborated following the phases of the disaster cycle (Fig. 1) and including suggestions of Parker et al. (1987), Penning-Rowsell (1999), Statistisches Bundesamt (1999), Grothmann (pers. comm.), Scharfschwerdt (2002) and Schmidtke (pers. comm.). Altogether, the questionnaire contained about 180 questions addressing the following topics: flood impact, contamination of the flood water, flood warning, emergency measures, evacuation, cleaning-up, characteristics of and damage to household contents and buildings, recovery of the affected household, precautionary measures, flood experience as well as socio-economic variables.

In a number of questions people were asked to assess qualitative or descriptive variables on a rank scale from 1 to 6, where “1” described the best case and “6” the worst case. The meaning of the end points of the scales was given to the interviewee. The intermediate ranks could be used to graduate the evaluation. For flow velocity, contamination, flood warning, emergency measures, precautionary measures (flood-proofing), flood experience and socio-economic variables indicator variables were generated by aggregation of several items concerning one particular topic. A detailed description of the survey, the data processing and the development of indicators can be found in Kreibich et al. (2005) and Thieken et al. (2005). The variables and indicators chosen for this paper are listed in Tab. 1.

Data analysis in this paper comprised the following steps: First, it was tested which variables significantly differ between the three strata with the help of the Mann-Whitney-U test for two samples and the Kruskal-Wallis-H test if all three samples were compared. Significantly differing variables were then analysed in detail for the three regions. Correlations between variables were determined by Spearman’s rho (i.e. rank correlation). Only correlation coefficients that were significant on a level of 0.05 and that were equal to or higher than 0.20 are presented in this paper.

3. RESULTS AND DISCUSSION

3.1. General characteristics of the three strata

According to the Kruskal-Wallis-H test all variables listed in Tab. 1 differ between the three strata on a significance level of ≤ 0.05, except for the number of elderly people in a household, the perceived quality of the building and the perceived credibility of the flood warning.

To characterise the three strata, statistics of the flood impact, socio-economic variables and flood experience are summarised in Tab. 2. As expected, socio-economic variables differed less between the strata A and B in comparison to stratum C (Bavaria). In stratum C the respondents were a little younger than in the strata A and B, had less frequent a high school graduation (*Abitur*), but owned more frequently the building they live in. The households in Bavaria were also slightly bigger, as was the mean living area per person. Further, there was a considerably lower share of households with less than 1500 Euro monthly net income (Tab. 2).

Significant differences in flood experience were also found in the data. Whereas only 9.5% at the river Elbe and 20.2% at the Elbe tributaries had experienced at least one flood before August 2002, this applied to 41.9% of the interviewed people in the Bavarian Danube catchment (Tab. 2). The share of people who had experienced a flood in the last ten years was also considerably higher in stratum C (Tab. 2). Moreover, only 9.8% of the people with flood experience along the river Elbe had already had flood losses of more than 1000 Euro, whereas this share amounted to 37.4% in stratum B and to 47.3% in the Danube catchment. Altogether the flood experience was highest in the Danube catchment (recurrent experience), it was achieved more recently and was combined with monetary losses more often than in the other two regions.

The knowledge about being at risk among people without flood experience was lowest at the Elbe tributaries: Only 25.5% in stratum B, in contrast to 35.1% along the river Elbe, and 30.1% in the Danube catchment knew that they live in a flood-prone area (Tab. 2).

The impact of the 2002 flood in terms of water level, flood duration and additional contamination was the most severe in the Elbe stratum. Very high flow velocities were most frequently recorded at the Elbe tributaries (Tab. 2). Altogether, a broad variation of socio-economic and hydrological conditions was captured by the survey.

3.2. Preparedness before the flood event in August 2002

Before the flood event in August 2002, 71.2% of the interviewed households in the Elbe stratum, 72.6% at the Elbe tributaries and 65.3% of the interviewed households in the Danube catchment had undertaken at least one precautionary action. However, the kind of the measures considerably differed in the three regions (Fig. 3). In the Elbe catchment there was a large share of people who were insured against flood damage, in fact 49.5% in stratum A and 49.9% in stratum B in contrast to only 17.8% in stratum C. This is due to historical reasons: Flood loss compensation was generally included in the household insurance in the former GDR, where Saxony and Saxony-Anhalt were part of. A lot of people in East Germany still have comparable contracts. In the rest of Germany, except for Baden-Württemberg, flood insurance is not widespread (Thieken et al., 2006).

Informational precaution, i.e. gathering information about flood precaution or participating in (neighbourhood or flood) networks, was more popular than precaution by flood-proofing or building retrofitting (Fig. 3). Informational and particularly flood-proofing measures were undertaken to a higher percentage in the Danube catchment. The most frequently performed measures were flood-adapted interior decoration and furnishing of storeys at risk, flood-adapted building use and the purchase of water barriers (Fig. 3). In general, the level of precaution dropped sharply if only building precaution was considered: The percentage of households that had undertaken at least one (building) precautionary action before August 2002 decreased to 21.0% in the Elbe stratum, to 28.2% at the Elbe tributaries and to 39.6% in the Danube catchment. This is alarming since only flood-proofing or retrofitting measures significantly reduce flood damage (see ICPR, 2002; Kreibich et al., 2005).

Moreover, the surveyed people in the Elbe catchment evaluated the effectiveness of private precautionary measures lower than people in the Danube catchment. On a scale from 1 (= private precautionary measures can reduce flood damage very effectively) to 6 (= private precautionary measures are totally ineffective for flood damage reduction) 31.1% of the interviewed households at the river Elbe and 36.1% at the Elbe tributaries gave a score of “1” or “2”, whereas in the Danube catchment this percentage stepped up to 50.6%. Furthermore, the interviewees in stratum C estimated a higher probability of being affected by future floods than people in the Elbe catchment: On a scale from 1 (= it is very unlikely that I will be affected by future floods) to 6 (= it is very likely that I will be affected by future floods) only 18.5% in stratum A (Elbe) and 22.8% in stratum B (Elbe tributaries) chose a rank of “5” or “6” while 40.8% in stratum C (Danube catchment) gave this answer.

A correlation analysis was performed to investigate which factors influenced precautionary behaviour. For flood insurance no coefficient was higher than 0.16. Especially in stratum C, informational precaution was, however, positively correlated with flood experience, the knowledge about the flood hazard and the perceived risk of future floods (Tab. 3).

In all three regions, building precaution was significantly correlated with the collection of information about self-protection. Further, the ownership of a flat or building was important for flood-proofing of the building in stratum B, as was flood experience in stratum C (Tab. 3).

Informational and building precaution in the Danube catchment refer more clearly to flood experience or to the knowledge of being at risk than in the other two regions. People with flood experience showed more precautionary behaviour (54.8%) than people without flood experience, but with knowledge about being at risk (37.2%), and much more than people without flood experience and without knowledge of being at risk (25%). In all three sub-groups, the percentage of people who undertook some flood-proofing action is the highest in the Danube catchment and the lowest in the Elbe stratum (Tab. 4).

The overall level of precaution is comparable to precaution in an investigation in Illinois, USA (Brenniman, 1994), where 68% of the respondents had spent some money on

some kind of flood precaution. The dependency of precautionary behaviour on socio-economic variables is, however, not noticeable in our data.

The regional differences in precautionary behaviour in the three areas can best be explained by the differences in flood experience and the historical circumstances, not by a wider spread of flood insurance in Saxony and Saxony-Anhalt. Thieken et al. (2006) showed that there is no significant difference in precautionary behaviour of insured and uninsured households in the Elbe catchment. Flood experience seems to be the most important motivation for gathering information about private precaution. Building precaution itself relies on the extent of informational precaution and to a lesser degree on flood experience. Since the simple knowledge about the flood hazard also stipulates people to inform themselves about precaution - in the case of the Elbe stratum it is as effective as flood experience (Tab. 4) - the publication of flood hazard maps is an important part of flood risk management. However, the dissemination of hazard maps should be accompanied by information material about possible precautionary actions. The material should be prepared for different groups, i.e. building/flat owners and tenants.

3.3. Response to the August 2002 flood

Flood warning: Flood warnings disseminated by the authorities reached more than 40% of all surveyed people (Tab. 5). These warnings were spread mainly by loudspeakers, sirens, flyers or posters, followed by local radio stations (data not shown). One third of the people became aware of the danger of flooding by own observation. Nationwide news and warning by neighbours, friends or relatives contributed each with about 13%. More than a quarter of the people, however, was not warned at all (Tab. 5).

According to the Mann-Kendall-U-test flood warning differed significantly between all three strata with respect to the warning source and information, lead time and the people's knowledge how to protect themselves and their property. While the percentage of people who were not warned at all is about 11% in stratum A, this figure rose to 28.5% in stratum C and even 42% in stratum B (Tab. 5). Furthermore, warnings were disseminated in large parts of stratum B and stratum C only a few hours before the houses were flooded, whilst along

the river Elbe a lead time of several days was reached (Tab. 5). The different lead times are explained by the different hydrological boundary conditions, e.g. the fast response of the mountainous catchments in stratum B.

Warnings from the authorities were investigated in more detail. Warnings in the Danube catchment included information about the maximum water level and the time to peak water level as well as advices for damage mitigation more often than in the other two regions, where considerably more information about evacuation was disseminated (Tab. 6). The information content was the worst along the Elbe tributaries: More than 17% of the warnings contained no detailed information about the flood and possible mitigation measures (Tab. 6). An indicator that assessed the most reliable warning source (ranging from 0: no warning to 4: warning by local authorities) and an indicator that summarized the warning information as introduced by Thieken et al. (2005) were further used in this paper.

The broad information content of warnings in the Danube catchment supported people's knowledge about how to protect themselves and their households against the flood. On a scale from 1 (= I knew exactly what to do) to 6 (= I had no idea what to do) 43% of the people in the Danube catchment chose a "1" or "2", while in the stratum A and B this percentage dropped to 24.4% and 25.4%, respectively. Nonetheless, 21% (94 interviews) of all interviewed people in the Danube catchment did not undertake any emergency measures, while this percentage amounted to only 11% in the Elbe stratum (68 interviews), but to 20% in the Elbe tributaries (122 interviews). This might be due to the dominance of fast onset floods in the Danube catchment as well as to the fact that the flood happened during the summer holiday season. Accordingly, the main reason, why people did not perform emergency measures, was a lack of time followed by the fact that people were not at home (on vacation, business trips, etc., see Tab. 7).

30% of the people along the river Elbe who did not carry out emergency measures were not warned. This applied to 58% along the Elbe tributaries and 57% in the Danube catchment. 42% of the interviewees in stratum A, 64% in stratum B and 47% in stratum C affirmed that they could have done more if they had been warned earlier. This underlines that

official flood warnings are an important pre-condition for the performance of emergency measures. The highest potential for further damage reduction is in mountainous regions, where, however, flood warning is difficult.

Emergency measures: Emergency measures that were undertaken by more than 50% of all respondents were safeguarding of movable household contents, vehicles, documents and valuables as well as protecting the building against inflowing water. Fig. 4 reveals that there was a higher percentage in the Elbe stratum who accomplished measures for their own safety (e.g. switching off electricity or gas). In contrast, in the Danube stratum there was a larger share of people who performed actions that were aimed at keeping the water out of the building, e.g. by installing barriers or water pumps. Moreover, oil tanks were protected more often (Fig. 4). This might be explained by the experience made during the Whitsun-flood in May 1999, where severe damage was caused by oil (Müller, 2000). Furthermore, the share of buildings that are heated with oil was much higher in the Danube catchment (53% of the interviews) than in the other two strata (16%).

Whether emergency measures can reduce flood damage also depends on their effectiveness. People who accomplished emergency measures were asked to evaluate the effectiveness of each activity on a scale from 1 (= very effective) to 6 (= totally ineffective). Fig. 5 illustrates the effectiveness as average rank per measure in the three areas of interest. Actions like safeguarding important documents and valuables as well as switching off electricity and gas were easily and effectively to perform whereas it was more difficult to make effective arrangements for safeguarding household contents or for the protection of the building. Fig. 5 highlights that the latter were more effective in the Danube catchment, where people had more flood experience and where water levels were not as high as in the other two strata (see below).

For an overall assessment of the emergency measures the following indicator was calculated: Each performed measure received seven points whereof the respective rank for efficiency was subtracted. Further, the individual measures were weighted in relation to their

damage reducing effect (see Thieken et al., 2005). Tab. 8 shows how this indicator correlates with other parameters.

In all three regions, the time that was spent on emergency measures, the lead time and the number of people involved in emergency measures were positively correlated to emergency measures, i.e. the more time and people were available to take action, the more successful were emergency measures. Additional factors were determined in stratum B: At the Elbe tributaries the household size and the ownership of the house influenced emergency measures positively, whereas the flood impact in terms of water level and duration hampered the effectiveness of emergency measures. In stratum C (Danube catchment), the indicators for the flood warning source and information as well as the knowledge about being at risk showed considerable correlation with the overall indicator for emergency measures (Tab. 8). Only the perceived knowledge about how to protect against floods had a negative correlation coefficient, i.e. the more people knew (= rank 1), the better they succeeded in performing emergency measures effectively. Socio-economic variables like household characteristics, age, education, net income etc. influenced the performance of emergency measures only slightly (coefficients were smaller than 0.2, though significant). However, there was a tendency that younger people or people with better education and more income were more capable of performing effective emergency measures, whereas households with elderly people had more difficulties (data not shown).

The analysis shows that flood warnings are an important pre-condition for the performance of emergency measures. Their effectiveness is, however, better in an area where people have more knowledge about self-protection, e.g. where flood warnings contained detailed information about the hazard in terms of water levels and time to peak flow as well as information on appropriate actions. Besides warning characteristics the number of people available to take action also determines the success of emergency measures. Efforts to improve early warning systems, especially in mountainous regions, should be done with regard to longer lead times, but also with regard to the warning content. Only if people know how to react in the case of flooding, how high the water levels will be

and how much time they have to react damage can be prevented or reduced to a considerable amount.

3.4. Flood damage and recovery

Adverse effects of the flood: 1273 of the 1697 surveyed households specified their monetary damage to household contents and 1079 their monetary building damage in terms of repair and replacement costs. The mean damage amounted to 16,335 Euro and 42,093 Euro, respectively (cf. Tab. 9). Losses significantly differed between the three strata: The damage to household contents and particularly to buildings was the highest in the Elbe stratum, followed by the stratum of the Elbe tributaries. The damage in the Danube catchment was considerable lower (Tab. 9). In all regions, monetary damage was correlated with other adverse effects, such as duration of evacuation and cleaning-up (Tab. 9).

In addition, Tab. 9 reveals which parameters mostly influenced the amount of monetary loss. Damage to household contents was particularly influenced by the flood water level, the contamination of the flood water and in the strata A and B by the ownership structure, whereas in stratum C the credibility of the warning was more important. Building damage was also considerably influenced by the water level and the contamination of the flood water, followed by the knowledge about the flood hazard in stratum A and the flow velocity in the strata B and C (Tab. 9).

In the strata A and B emergency measures as well as building precaution were negatively correlated to building damage indicating the potential to reduce flood damage by private precaution also during extreme events. This was analyzed in detail by Kreibich et al. (2005). More details about the relation of several parameters to flood damage are given in Thieken et al. (2005).

Recovery: After the August 2002 flood the German government launched an emergency fund for reconstruction (*Sonderfond Aufbauhilfe*) of 7100 million Euro. Furthermore, money from the European Union (444 million Euro), donations (350 million Euro) and insurance compensation (1800 million Euro) were available for loss compensation

and enabled a rapid recovery (Mechler & Weichselgartner, 2003; Schwarze & Wagner, 2004; DZI, 2004).

In our survey, people were asked to compare the state of their household contents and their building before the flood and at the time of the interview and to evaluate the difference on a scale from 1 (= household contents/buildings are already replaced/restored completely) to 6 (= there is still considerable damage to household contents/to the building). At the time of interview, i.e. about 8-9 months after the flood, 31.5% of the people at the River Elbe evaluated the building status with a “1” or “2”, i.e. had already recovered well. For the household contents this share increased to 56.0%. At the Elbe tributaries recovery was a little faster: 46.9% reported a good recovery of the building, 60.6% a good recovery of the household contents. Recovery was at best in the Danube catchment: More than 60% evaluated their recovery with a “1” or “2” for both, building and content damage.

Besides the characteristics of the flood (water level, flood duration and contamination), the amount of damage had the highest correlation with the level of recovery in all three strata (Tab. 10). This is further illustrated by Fig. 6: Recovery decreases with an increasing median of building damage.

Moreover, knowledge about self-protection and perceived efficiency of private precaution were also advantageous for a fast recovery, e.g. a slow recovery was connected to a lack of knowledge about self-protection in stratum B. This demonstrates that not only flood impact affects recovery, but also people’s preparedness and knowledge about flood mitigation.

3.5. Lessons Learned – will people be better prepared for future floods?

The interviewees were also questioned whether they undertook any precautionary measures after the flood and whether they were planning to undertake some within the next six months. The extent of informational and building precaution as well as the number of insured households increased enormously. For some precautionary actions the percentage of involved households nearly doubled (Fig. 3). In total, only about 4% of all interviewed households had not undertaken or were not planning to undertake any precautionary action.

However, the differences between the three regions outlined in section 3.2 remained. Flood insurance is still more important in the Elbe catchment, i.e. in the strata A and B (Fig. 3), whereas people in the Danube catchment (stratum C) concentrate more on building retrofitting, particularly on flood-adapted building use and furnishing, building sealing and the purchase of water barriers (Fig. 3).

Tab. 11 shows what influenced the different kinds of precautionary action. In region A (River Elbe) no significant correlation that was higher than 0.16 was found. All kinds of precaution tended to correlate with the age of the interviewee (the younger, the more precaution) and the household size, i.e. particularly young families seem to invest in flood insurance and building precaution (data not shown since correlation coefficients were lower than 0.20). In stratum B building owners were more willing to invest in building retrofitting, as did people who believe that private precaution are effective (Tab. 11). In stratum C the amount of damage and the loss compensation were important for building retrofitting. Moreover people who had not been affected by floods before or who did not know enough about the hazard and about self-protection informed themselves about precaution after the flood and were also willing to flood-proof their building (Tab. 11).

About 3% of all interviewed households wanted to avoid flooding in the future and decided to move to a flood-safe area. Tab. 11 reveals that this option was particularly considered by tenants.

To further improve the level of precaution and to stipulate people to invest in flood-proofing measures it seems to be important to provide information about precautionary options. Particularly after a flood event there is a window of opportunity for initiating precautionary measures. In order to convince people, the effectiveness of private precautionary actions, i.e. the potential damage reduction, should gain more attention in the discussion of flood risk management. Besides different recommendations for homeowners and tenants, special offers of information for elderly people might be necessary.

4. RECOMMENDATIONS AND CONCLUSIONS

The analysis of how preparedness, response and recovery of residents in three different regions in Germany are correlated to socio-economic variables, experience with previous floods and flood impact of the event in 2002 leads us to the following recommendations:

The pure knowledge of living in a flood-prone area stimulates the collection of information about self-protection. This does, however, not necessarily lead to building precaution. Therefore, more information about the effectiveness and the cost-benefit-ratios of different precautionary measures is needed. Further, specific information, e.g. different information leaflets with flood mitigation options for different groups of people, are helpful. Tenants, homeowners, elderly people or large households have all different abilities to perform precautionary and emergency measures. Therefore, information about private precaution has to meet people's interests and capabilities in order to convince them that they are able to reduce their potential flood damage significantly.

Despite the potential to mitigate flood losses, the flood impact, particularly the water level and the contamination of the flood water, influence monetary damage and recovery to a great extent. Therefore, financial precaution, i.e. flood insurance, should be stipulated especially in areas with a low insurance cover.

People's knowledge about the flood hazard and about self-protection as well as good warning information help people to better perform emergency measures. Therefore, flood warnings should be released with more detailed information about expected water levels, time to peak flows and recommendations for appropriate response. However, the time and the number of people available to undertake emergency measures are the most important factors during the response phase. Therefore, longer lead times of early warnings are needed, especially in mountainous regions. Further, it would be worthwhile to think about improved response capacities in flood situations, e.g. by activating neighbourhood help or disaster management assistance.

Acknowledgements The survey was undertaken within the German Research Network Natural Disasters (DFNK) as a joint venture between the GeoForschungsZentrum Potsdam and the Deutsche Rückversicherung AG, Düsseldorf. We thank the Deutsche Rückversicherung AG and the German Ministry for Education and Research (BMBF) (No. 01SFR9969/5) for financial support. We are indebted to Frank Faulbaum (University of Duisburg, Germany), Torsten Grothmann (Potsdam Institute for Climate Impact Research, Germany), Michael Bertram, Friedolf Ossyssek and Henry Puhe (SOKO Institute, Bielefeld, Germany) as well as to Armin Petraschek (Agency of Water and Geology, Biel, Switzerland) for commenting the questionnaire.

REFERENCES

Blaikie, P., Cannon, T, Davis, I. & Wisner, B (1994) *At risk. Natural hazards, people's vulnerability and disasters*. Routledge, London.

Brenniman, G. R. (1994) Flood damage in the Upper Des Plaines river basin of north-eastern Illinois. *Environmental Professional* **16**, 73-78.

Brilly, M. & Polic, M. (2005) Public perception of flood risk, flood forecasting and mitigation. *Nat. Hazards Earth System Sci.* **5**, 345-355.

De Bruijn, K.M. (2005) *Resilience and flood risk management, A systems approach applied to lowland rivers*. PhD Thesis, DUP Science, Delft, The Netherlands.

DKKV (Deutsches Komitee für Katastrophenvorsorge - German Committee for Disaster Prevention, Ed.) (2003) *Hochwasservorsorge in Deutschland. Lernen aus der Katastrophe 2002 im Elbegebiet*. DKKV-Report 29, Bonn, Germany.

DZI (Deutsches Zentralinstitut für soziale Fragen) (2004) *DZI-Spenden-Almanach 2004/5*. Berlin.

Engel, H. (2004) The flood event 2002 in the Elbe river basin: causes of the flood, its course, statistical assessment and flood damages. *Houille Blanche* **6**, 33-36.

FEMA (Federal Emergency Management Agency) (2004) About FEMA – What we do. (http://www.fema.gov/about/what.shtm) Access on 28th October 2004.

Fothergill, A. & Peek, L. A. (2004) Poverty and Disasters in the United States: A Review of Recent Sociological Findings. *Natural Hazards* **32**, 89-110.

Fügner, D. (2003) *Hochwasserkatastrophen in Sachsen*. Tauchaer Verlag.

Gewässerkundlicher Dienst Bayern (2002) Hochwasser im August 2002. Report of the Bavarian Agency of Water Resources, 16 p. (www.hnd.bayern.de; access on 6 April 2007).

Grothmann, T. (pers. comm.) Questionnaire on risk awareness and private precautionary behaviour in flood affected private households. Potsdam-Institute for Climate Impact Research.

Grothmann, T. & Reusswig, F. (2006) People at risk of flooding: Why some residents take precautionary action while others do not. *Natural Hazards* **38**(1-2), 101-120.

ICPR (2002) Non-Structural Flood Plain Management - Measures and their Effectiveness. ICPR-Report, Koblenz, Germany.

IKSE (International Commission for the Protection of the Elbe) (2004): Dokumentation des Hochwassers vom August 2002 im Einzugsgebiet der Elbe. Report Magdeburg, 207 pp.

INFAS Geodaten GmbH (2001) Das Data Wherehouse. INFAS GEOdaten GmbH, Bonn, Status: Dezember 2001.

Kienholz, H., Krummenacher, B., Kipfer, A. & Perret, S. (2004) Aspects of Integral Risk Management in Practice-Considerations with respect to Mountain Hazards in Switzerland. *Österreichische Wasser- und Abfallwirtschaft* **56**, 43-50.

Krasovskaia, I., Gottschalk, L., Berg, H., Mcerlain, A. Ngu, D. & Geissler T. R. (2007): Combating flooding together. In: *Reducing the Vulnerability of Societies Against Water Related Risks at the Basin Scale* (ed. by A. H. Schumann, M. Pahlow, J.J. Bogardi & P. van der Zaag), IAHS Publ. (in press).

Krasovskaia, I., Gottschalk, L., Saelthun, N.R. & Berg, H. (2001) Perception of the risk of flooding: the case of the 1995 flood in Norway. *Hydrol. Sci. J.* **46**(6), 855-868.

Kreibich, H., Thieken, A.H., Petrow, Th., Müller, M. & Merz, B. (2005) Flood loss reduction of private households due to building retrofitting - Lessons learned from the Elbe floods in August 2002. *Nat. Hazards Earth System Sci.* **5**, 117-126.

Laska, S. B. (1986) Involving homeowners in flood mitigation. *J. Am. Planning Association* **1986**(3), 452-466.

Mechler, R. & Weichselgartner, J. (2003) Disaster Loss Financing in Germany – The Case of the Elbe River Floods 2002. *IIASA Interim Report IR-03-021*, International Institute for Applied Systems Analysis, Austria, 44 pp.

Motoyoshi, T., Sato, T., Fukuzono, T., Seo, K. & Ikeda, S. (2004) Factors determining residents' preparedness for floods in modern megalopolises: the case of the Tokai flood disaster in Japan. *J. Risk Research* **7**, 775-787.

Müller, M. (2000) Die Auswirkungen von Deichbrüchen und Heizöllagerung auf Überschwemmungsschäden bei Wohngebäuden. *Versicherungswirtschaft* **151**(10), 693-696.

Munich Re (2003): Topics Annual Review: Natural Catastrophes 2002. Munich Re Group.

Olson, R. S. 2000. Toward a Politics of Disaster: Losses, Values, Agendas, and Blame. *Int. J. Mass Emergencies and Disasters* **18**: 265-287.

Parker, D.J. (ed., 2000) *Floods*. Volume 1, Routledge, London, UK.

Parker, D.J., Green, C.H. & Thompson, P.M. (1987) *Urban flood protection benefits: A project appraisal guide*. Gower Technical Press, Aldershot. 284 pp.

Pearce, L. (2003) Disaster Management and Community Planning, and Public Participation: How to Achieve Sustainable Hazard Mitigation. *Natural Hazards* **28**, 211-228.

Penning-Rowsell, E. (1999) Flood hazard assessment, modelling and management: Results from the EUROflood project. *Environments* **27**(1), 79-95.

Penning-Rowsell, E.C., Tunstall, S.M., Tapsell, S.M. & Parker, D.J. (2000) The Benefits of Flood Warnings: Real but Elusive, and Politically Significant. *J. Chartered Inst. Water Environm. Management* **14**, 7-14.

Formatiert: Deutsch (Deutschland)

Penning-Rowsell, E.C. & Green, C. (2000) New Insights into the appraisal of flood-alleviation benefits: (1) Flood damage and flood loss information. *J. Chart. Inst. Water E*. **14**, 347-353.

PLANAT (National Platform for Natural Hazards) (2004). The cycle of integrated risk management. Switzerland (www.planat.ch - risk management) (access on 28th October 2004).

Plapp, T. (2003) Wahrnehmung von Risiken aus Naturkatastrophen. Eine empirische Untersuchung in sechs gefährdeten Gebieten Westdeutschlands. PhD-Thesis, University of Karlsruhe, Germany.

Pohl, R. (2004) Historische Hochwasser aus dem Erzgebirge. *Wasserbauliche Mitteilungen Vol. 28*, Institut für Wasserbau und Technische Hydromechanik TU Dresden.

Robert, B., Forget, S. & Rousselle, J. (2003) The Effectiveness of Flood Damage Reduction Measures in the Montreal Region. *Natural Hazards* **28**, 367-385.

Schmidtke, R. (pers. comm.): Questionnaire used for recording flood damage for the HOWAS data base. Bavarian Agency of Water Resources.

Schwarze, R. & Wagner, G.G. (2004) In the Aftermath of Dresden: New Directions in German Flood Insurance. *Geneva Papers on Risk and Insurance – Issues and Practise*, **29**(2), 154-168.

Silver, M.L. (2001) International best practices in disaster mitigation and management recommended for Mongolia. UNDP. Disaster management conference. December 2001, Mongolia, p. 1-9.

SSK (Sächsische Staatskanzlei) (2004) Der Stand des Wiederaufbaus. Materialien zur Kabinetts-Pressekonferenz, 3 February 2004, Dresden, 3 pp..

Statistisches Bundesamt (Federal Agency of Statistics) (1999) *Demographische Standards – Methoden – Verfahren – Entwicklungen*. 3rd Edition. Materialien und Berichte. Statistisches Bundesamt: Wiesbaden. 94 pp.

Takeuchi, K. (2001) Increasing vulnerability to extreme floods and societal needs of hydrological forecasting. *Hydrol. Sci. J.* **46**, 869-881.

Thieken, A.H., Müller, M., Kreibich, H. & Merz, B. (2005) Flood damage and influencing factors: New insights from the August 2002 flood in Germany. *Water Resour. Res.* **41**(12), W12430.

Thieken, A.H., Petrow, Th., Kreibich, H. & Merz, B. (2006) Insurability and mitigation of flood losses in private households in Germany. *Risk Analysis* **26**(2), 383-395.

Torterotot, J.-P., Kauark-Leite, L. A. & Roche, P.-A. (1992) Analysis of individual real-time response to flooding and influence on damage to households. In: *Floods and flood management* (ed. by A.J. Saul), 363-387, Kluwer.

Ulbrich, U., Brücher, T., Fink, A.H., Leckebusch, G.C., Krüger, A. & Pinto, J.G. (2003) The central European floods of August 2002: Part 1 - Rainfall periods and flood development. *Weather* **58**, 371-376.

Vis, M., Klijn, F., de Bruijn, K.M & van Buuren, M. (2003) Resilience strategies for flood risk management in the Netherlands. *Int. J. River Basin Management* **1**, 33-40.

Weichselgartner, J. & Obersteiner, M. (2002) Knowing sufficient and applying more: challenges in hazard management. *Environmental Hazards* **4**, 73-77.

Werner, U., Mechler, R. & Plapp, T. (2003) Hochwasser 2002 – Wechselwirkungen zwischen der Finanzierung von Überschwemmungsschäden und der Wahrnehmung von Hochwasserrisiken. *Zeitschrift für Versicherungswesen* **23**(3), 722-729.

Wind, H.G, Nierop, T.M., de Blois, C.J. & de Kok, J.L. (1999) Analysis of flood damages from the 1993 and 1995 Meuse flood. *Water Resour. Res.* **35**(11), 3459-3465.

Tables

Table 1 Items of the survey that were used in this paper.

Item	Units and labels
Socio-economic variables	
Age of the interviewee	Number of years
Education	Rank from 1 (no graduation) to 5 (high school graduation - *Abitur*)
Household size	Number of people
Children (< 14 a)	
Elderly people (> 65 a)	
Monthly net income of the household	Euro
Living area per person	m²
Ownership structure	1: tenant of a flat, 2: tenant of a house, 3: flat-owner, 4: homeowner
Perceived quality of the building / household contents	Rank from 1 (building/household contents are of very good quality or luxurious) to 6 (building/household contents are of poor quality)
Flood experience BEFORE August 2002	
Previously experienced floods	Number of events
Time period since the last flood event	Number of years
Indicator of flood experience	Rank from 0 (no experience) to 10 (very well experienced)
Knowledge about the flood hazard of the residence/plot	0: no knowledge, 1: knowledge of flood hazard
Preparedness (BEFORE/AFTER the flood) and risk awareness	
Informational precaution	Number of measures (range: 0 to 3)
Flood Insurance	0: no insurance, 1: insurance
Flood-proofing measures and retrofitting	Number of measures (range: 0 to 7)
Perceived efficiency of private precaution	Rank from 1 (flood damage can be significantly reduced by private precautionary measures) to 6 (flood damage cannot be reduced by private precautionary at all)
Perceived risk of future floods	Rank from 1 (it is very UNlikely that I will be affected by future floods) to 6 (it is very likely that I will be affected by future floods)
Characteristics of the flood in 2002	
Water level	cm above top ground surface
Flood duration	Hours
Flow velocity	Rank from 0 (no flow) to 3 (very high flow velocity)
Contamination of the flood water	0: no contamination, 1: sewage, 2: chemicals (and sewage), 3: oil (and chemicals or sewage)
Warning and response in 2002	
Flood warning source indicator	Rank from 0 (no warning) to 4 (official flood warning)
Flood warning information indicator	Rank from 0 (no information) to 14 (detailed information about flood event and advices for damage reduction)
Lead time	Hours
Perceived credibility of the warning	Rank from 1 (warning was absolutely believable) to 6 (warning was absolutely UNbelievable)
Perceived knowledge about self-protection	Rank from 1 (I knew exactly what to do) to 6 (I did not know what to do)
Time spent on emergency measures	Hours
People involved in emergency measures	Number of people
Overall assessment of efficient emergency measures (indicator)	Rank from 0 (no performed emergency measures) to 78 (several efficient emergency measure were successfully performed)
Adverse effects of the flood in 2002	
Duration of evacuation	Days
Time spent on cleaning-up	Hours
Damage to the building	Euro
Damage to household contents	Euro
Recovery	
Perceived status of restoration of the building/replacement of household contents at the time of the interview	Rank from 1 (buildings/household contents are already completely restored/replaced) to 6 (there is still considerable damage to the building/to household contents)
Received loss compensation	Euro

Table 2 Description of the three strata with respect to socio-economic variables, previously experienced floods and flood impact in 2002.

Stratum	**A**	**B**	**C**	**All**
Name of the stratum	River Elbe	Elbe tributaries	Danube catchment	
Total number of interviews	639	609	449	1697
Socio-economic variables				
Mean age of the interviewees [a]	54	52	49	52
People with high school graduation (*Abitur*) [%]	24.5%	24.2%	15.8%	22.1%
Mean household size [number of people]	2.7	2.7	3.2	2.8
Households with a monthly net income < 1500 Euro [%]	38.6%	44.4%	25.1%	37.4%
Mean living area per person [m²]	47.85	44.41	52.84	47.87
Homeowners [%]	74.8%	69.0%	86.6%	75.8%
Flood experience BEFORE August 2002				
People who experienced at least one previous flood [%]	9.5%	20.2%	41.9%	21.9%
People who experienced a flood in the last ten years [%]	3.6%	7.4%	33.0%	12.7%
People without flood experience, but with knowledge about the flood hazard of their property [%]	35.1%	25.5%	30.1%	30.6%
Characteristics of the flood impact in 2002				
Mean water level above top ground surface [cm]	113.24	78.57	-25.29	64.22
Mean flood duration [hours]	256	102	39	143
Interviews that reported very high flow velocity [%]	1.1%	5.4%	0.7%	2.6%
Interviews that reported oil contamination [%]	49.5%	39.8%	23.3%	39.1%

Table 3 Rank correlation (Spearman's rho) between precautionary behaviour (BEFORE the flood event) and other parameters; only coefficients significant on a 0.05-level and ≥ 0.2 are shown.

Item (see Table 1 for units and labels)	**Informational precaution BEFORE the flood**			**Flood-proofing and retrofitting BEFORE the flood**		
	A	B	C	A	B	C
Ownership structure					0.26	
Flood experience			0.28			0.30
Knowledge about flood hazard	0.23		0.28			
Perceived risk of future floods			0.20			
Informational precaution (BEFORE)	1.00	1.00	1.00	0.24	0.32	0.51

A: Stratum of the River Elbe, B: Stratum of Elbe tributaries, C: Stratum of Danube catchment.

Table 4 Relation between flood experience, knowledge about the flood hazard and precautionary behaviour (only flood-proofing measures or retrofitting).

Sub-group description		**A**	**B**	**C**
Residents with flood experience	portion in stratum	9.5%	20.2%	41.9%
	thereof: precautionary behaviour	23.0%	38.2%	54.8%
Residents without flood experience, but with knowledge about the flood hazard	portion in stratum	31.6%	20.4%	17.4%
	thereof: precautionary behaviour	25.7%	33.1%	37.2%
Residents without flood experience or knowledge about the flood hazard	portion in stratum	58.2%	59.3%	40.1%
	thereof: precautionary behaviour	17.7%	23.3%	25.0%

A: Stratum of the River Elbe, B: Stratum of Elbe tributaries, C: Stratum of Danube catchment.

Table 5 Answers to the question: “How did you become aware of the danger of flooding?”; given in percentage of all interviewed people per stratum (multiple answers possible) and average lead time per stratum.

	A	B	C	Total data set
Flood warning by authorities	63.4%	23.2%	31.6%	40.5%
Own observation	29.7%	34.8%	36.5%	33.4%
Nationwide news	23.0%	6.9%	10.5%	13.9%
Warning by neighbours, friends etc.	14.7%	9.4%	16.5%	13.3%
Warning and evacuation at the same time	2.2%	1.1%	0.0%	1.2%
Other warning sources	0.5%	0.2%	0.4%	0.4%
No warning received	11.0%	42.0%	28.5%	26.8%
Not specified / no answer	0.8%	0.8%	0.4%	0.7%
Number of relevant interviews	639	609	449	1697
Average lead time [hours]	65	11	17	37
Number of relevant interviews	464	284	257	1005

A: Stratum of the River Elbe, B: Stratum of Elbe tributaries, C: Stratum of Danube catchment.

Table 6 Information content of official flood warnings (multiple answers possible).

	A	B	C	Total data set
Residential areas at risk	60.3%	50.8%	53.3%	57.0%
Advice for damage reduction	33.4%	32.6%	43.3%	35.1%
Maximal water level	29.9%	20.5%	57.5%	33.1%
Time to peak water level	22.5%	17.4%	46.7%	26.0%
Information about evacuation	30.6%	18.2%	0.8%	22.6%
Other useful information (levee breaches, streets etc.)	2.8%	2.3%	0.0%	2.2%
None of this information	8.4%	17.4%	8.3%	10.2%
Not specified / no answer	4.8%	6.1%	6.7%	5.4%
Number of relevant interviews (i.e. people warned by authorities)	395	132	120	647

A: Stratum of the River Elbe, B: Stratum of Elbe tributaries, C: Stratum of Danube catchment.

Table 7 Reasons why people did not perform emergency measures (multiple answers possible).

	A	B	C	Total data set
It was too late to do anything	60.3%	72.1%	59.6%	65.1%
Nobody was at home	17.6%	18.0%	19.1%	18.3%
I thought emergency measures wouldn’t be necessary	10.3%	6.6%	10.6%	8.8%
I did not think the flood would become so severe	5.9%	2.5%	8.5%	5.3%
I did not know what to do	2.9%	2.5%	5.3%	3.5%
I was not capable of doing anything	8.8%	1.6%	0.0%	2.8%
I thought emergency measures would be useless	2.9%	0.0%	4.3%	2.1%
Others	2.9%	1.6%	1.1%	1.8%
Not specified / no answer	1.5%	4.1%	3.2%	3.2%
Number of relevant interviews	68	122	94	284

A: Stratum of the River Elbe, B: Stratum of Elbe tributaries, C: Stratum of Danube catchment.

Table 8 Rank correlation (Spearman's rho) between effectively performed emergency measures (indicator) and other parameters; only coefficients significant on a 0.05-level and ≥ 0.2 are shown.

Item (see Table 1 for units and labels)	**A**	**B**	**C**
Household size		0.20	
Ownership structure		0.23	
Knowledge about flood hazard			0.23
Flood water level		-0.24	
Flood duration		-0.20	0.20
Warning source			0.31
Warning information			0.23
Lead time	0.22	0.28	0.38
Perceived knowledge about self-protection			-0.22
Time spent on emergency measures	0.38	0.47	0.24
Number of people involved in emergency measures	0.20	0.24	0.25

A: Stratum of the River Elbe, B: Stratum of Elbe tributaries, C: Stratum of Danube catchment.

Tab. 9: Mean flood damage and rank correlations (Spearman's rho) between flood damage and other parameters; only coefficients significant on a 0.05-level and ≥ 0.2 are shown.

Item (see Table 1 for units and labels)	**Damage to household contents**			**Damage to residential building**		
	A	**B**	**C**	**A**	**B**	**C**
Mean damage [Euro]	20770	13088	13536	57829	45824	16834
Duration of evacuation	0.49	0.43	0.24	0.33	0.48	0.20
Duration of cleaning-up	0.44	0.37	0.35	0.28	0.45	0.45
Ownership structure	0.52	0.32			-0.23	
Perceived quality of household contents	-0.21		-0.21			
Knowledge about flood hazard				0.20		
Perceived efficiency of private precaution	0.24				0.23	
Flood-proofing / retrofitting (BEFORE)					-0.30	
Flood water level	0.47	0.47	0.50	0.53	0.66	0.52
Flood duration	0.26				0.23	
Flow velocity			0.22		0.31	0.25
Contamination of the flood water	0.28	0.30	0.33	0.30	0.43	0.32
Perceived credibility of the warning			0.31			
Overall assessment of emergency measures				-0.20	-0.26	

A: Stratum of the River Elbe, B: Stratum of Elbe tributaries, C: Stratum of Danube catchment.

Tab. 10: Rank correlation (Spearman's rho) between recovery and other parameters; only coefficients significant on a 0.05-level and ≥ 0.2 are shown.

Item (see Table 1 for units and labels)	**Perceived level of replacement of damaged contents**			**Perceived level of repair of damaged building**		
	A	**B**	**C**	**A**	**B**	**C**
Flood water level			0.23		0.31	0.23
Flood duration			0.20	0.20		0.23
Contamination of the flood water				0.25	0.24	
Perceived credibility of the warning		0.27				
Perceived knowledge about self-protection					0.24	
Perceived efficiency of private precaution					0.20	0.21
Duration of evacuation						0.23
Duration of cleaning-up					0.23	
Damage to household contents	0.25	0.26	0.30	0.20	0.27	0.21
Damage to building	0.26	0.27	0.29	0.25	0.43	0.32
Received loss compensation					0.25	

A: Stratum of the River Elbe, B: Stratum of Elbe tributaries, C: Stratum of Danube catchment.

Tab. 11: Rank correlation (Spearman's rho) between the changes in precautionary behaviour after 2002 and other parameters; only coefficients significant on a 0.05-level and ≥ 0.2 are shown.

Item (see Table 1 for units and labels)	**Change in flood insurance**			**Change in informational precaution**			**Change in flood-proofing and retrofitting**			**Moving to a flood-safe area**		
	A	**B**	**C**	**A**	**B**	**C**	**A**	**B**	**C**	**A**	**B**	**C**
Ownership structure								0.22		-0.24	-0.21	-0.22
Flood experience						-0.20						
Knowledge about flood hazard						-0.20						
Perceived efficiency of private precaution								-0.20				
Perceived knowledge about self-protection			0.23			0.21			0.31			
Damage to building									0.21			
Received loss compensation									0.22			
Change in informational precaution			0.20	1	1	1		0.20	0.30			

A: Stratum of the River Elbe, B: Stratum of Elbe tributaries, C: Stratum of Danube catchment.

Figure captions:

Fig. 1: Disaster cycle adapted to flood risk (modified from DKKV, 2003).

Fig. 2: Zipcodes with interviews in the three areas under investigation (Data sources: DLM1000, VG250 © BKG, Frankfurt am Main, 2004; ESRIDATA).

Fig. 3: Precautionary measures undertaken in private households before and after the flood event in August 2002 and measures that are planned for the next six months; figures are given in percentage of all interviews per stratum (A: River Elbe: n = 639, B: Elbe tributaries: n = 609, C: Danube catchment: n = 449).

Fig. 4: Performed emergency measures (in descending order) given in percentage of all interviewed people per stratum (multiple answers possible).

Fig. 5: Average effectiveness of emergency measures as evaluated by the interviewed people on a scale from 1 (= measure was very effective) to 6 (= measure was very ineffective).

Fig. 6: Relation between the status of recovery at the time of the interview (evaluated on a scale from 1 to 6) and the median of the building damage.

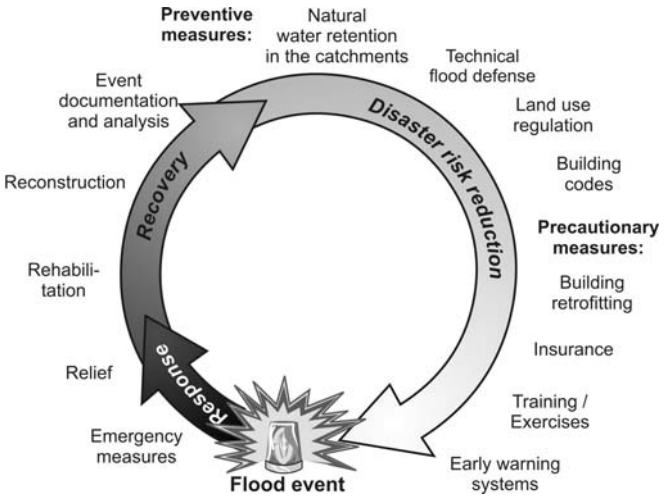

Figure 1

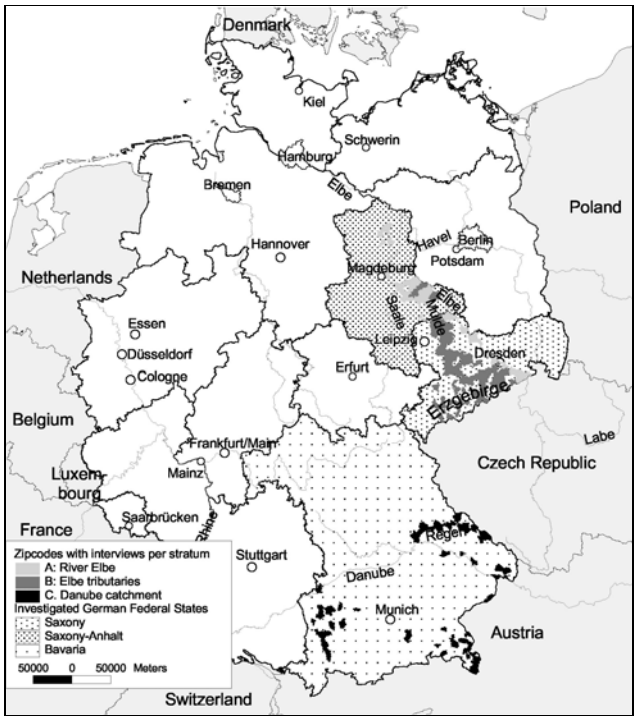

Figure 2

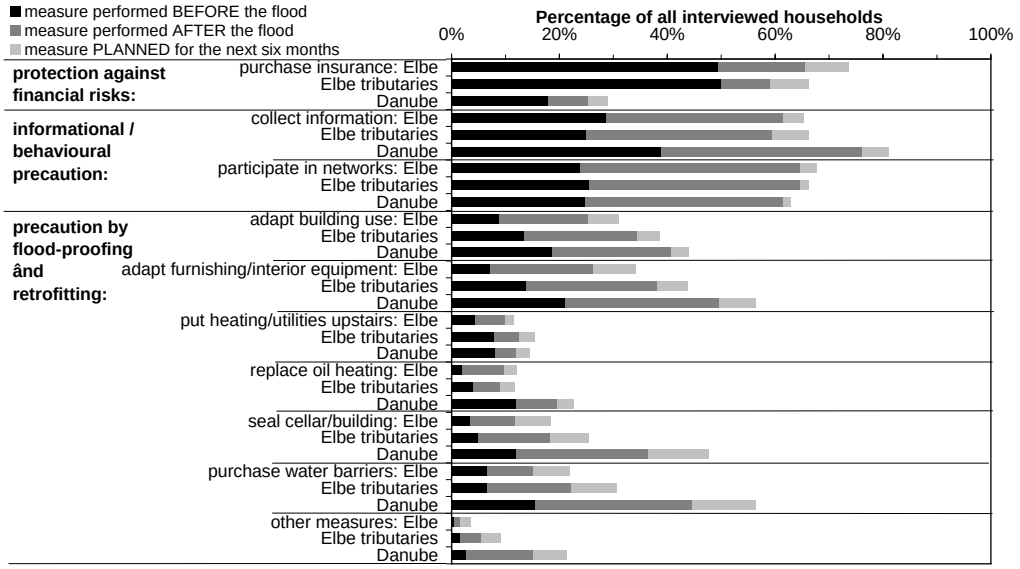

Figure 3

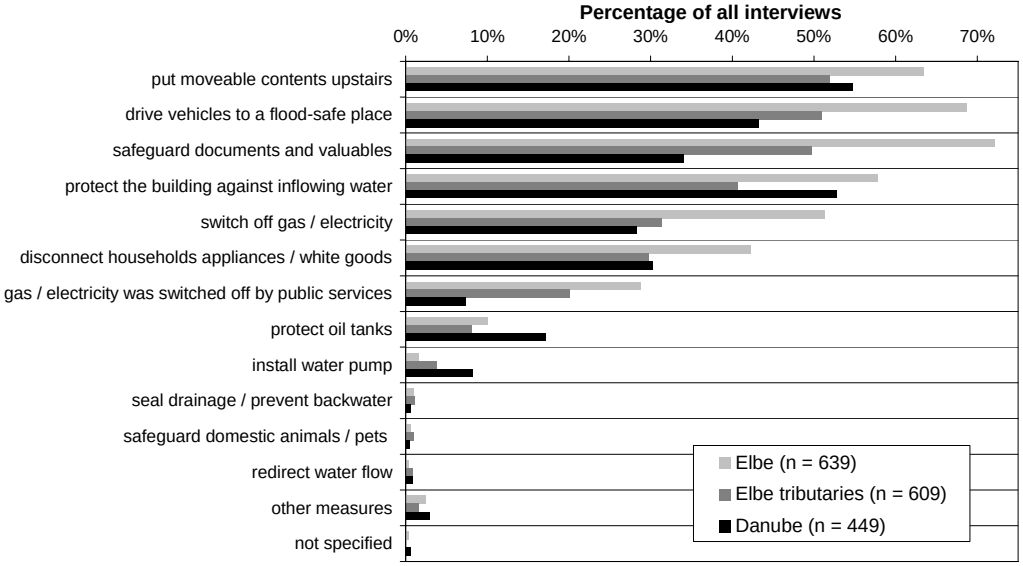

Figure 4

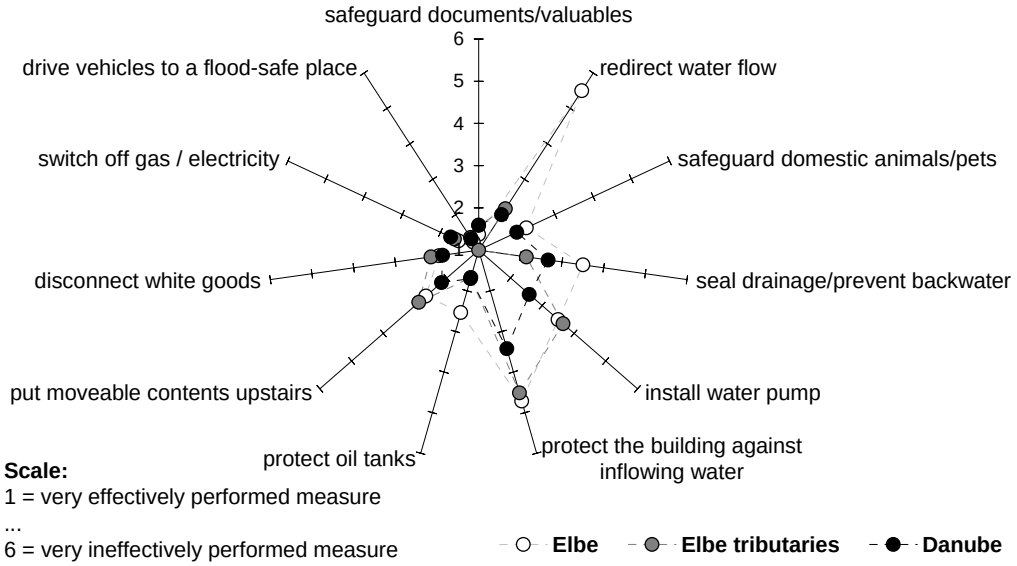

Figure 5

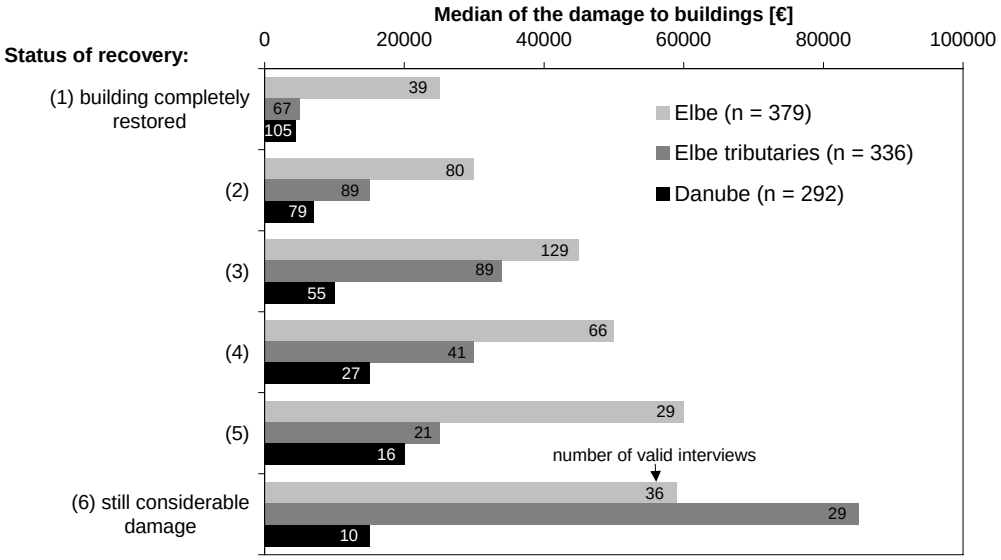

Figure 6