LESSONS LEARNED FROM THE ELBE RIVER FLOODS IN AUGUST 2002 - WITH A SPECIAL FOCUS ON FLOOD WARNING

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Abstract- The severe floods in August 2002 caused 21 fatalities and about 11.9 billion € of direct economic damage in Germany. In the aftermath, initiated by the German Committee for Disaster Reduction, a Lessons Learned study was carried out. The interdisciplinary analysis evaluated strengths and weaknesses of the current flood protection and developed recommendations for an improved flood risk management in Germany. An overview of the findings, according to the disaster cycle, is presented as well as some detailed investigations about flood warning. After the floods in 2002, many activities to improve the flood risk management in Germany were introduced at different private and administrative levels. Still, risk awareness and prevention have to be further strengthened and preparedness has to be kept over time.

Keywords: disaster cycle; emergency measures; flood management; flood warning

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1. Analysis of Flood Risk Management Following the Disaster Cycle

The flood in August 2002 has dramatically demonstrated the weaknesses of flood protection, of the condition of levees and water bodies and of the organization of the flood response. In the aftermath, at various levels, e.g. federal states and river basin commissions, flood action programs have been developed (IKSE, 2003; LAWA 2004), and various commissions and organizations analyzed the event critically (von Kirchbach et al., 2002; DKKV, 2003; IKSE, 2004).

Initiated by the German Committee for Disaster Reduction the current flood protection was analyzed, evaluating strengths and weaknesses following the disaster cycle (DKKV, 2003). The disaster cycle (Fig. 1) shows the consecutive phases that a society undergoes after it was hit by a disaster and is therefore a valuable framework for an integrated analysis of flood risk management (Olson, 2000).

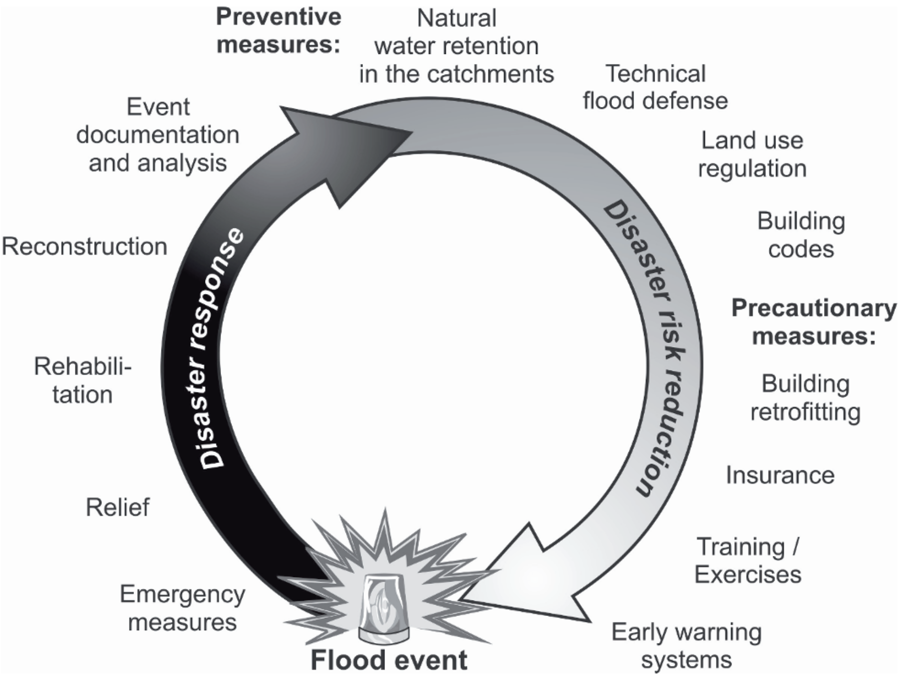

Figure 1. Concept of the disaster cycle adapted to flood risk (Thieken et al., 2005a)

When a flood event occurs, it is important to minimize the extent of damage by a rapid alert, professional and fast rescue and by taking care of the victims, as well as undertaking emergency measures and provisional reconditioning of important infrastructure. The type and the effectiveness of the response depend on the preparedness of the society at risk. In August 2002, insufficient flood forecasts, but particularly failure of timely warning and of forwarding information to the population in the valleys of the Ore Mountains (Erzgebirge) constricted an effective response (see section 2).

The analysis of the disaster response revealed four structural failings: (1) Poor coordination of the different response organizations; (2) Self-orientation of the response organizations with insufficient focus on the situation as a whole; (3) Weaknesses of value-setting official channels; (4) Isolation of the operative-tactical subsystem makes innovations difficult (DKKV, 2003). But, flood risk reduction and flood response are cross-sectional tasks and require a great deal of communication, cooperation and management. Therefore, all participants from different specialist and spatial areas must be better integrated with each other. Interfaces are weak points and must be regularly tested and updated.

In the next phase, during recovery, the affected community will try to repair damage and to regain the same or a similar standard of living than before the disaster happened. The reconstruction of buildings and infrastructure are top priority – as well as the analysis of the disaster. This phase is setting the stage for the society's next "disaster": If the affected area is essentially rebuilt as it was, with little attention to land-use regulation, building codes etc., then its vulnerability is replicated (Olson, 2000). Otherwise, there will be a period of disaster risk reduction, undertaking improvements of the land use management, building precaution, risk and financial precaution, behavioral and informational precaution as well as improving natural retention and technical flood defense (DKKV, 2003).

A weakness in the German flood management system is the frequent conflict between flood precaution and the economic development on available open land in the flood plains. The communal authorities play the key role in area precaution because they assign a specific land use to a land parcel. However, they are dependent on the local taxes they charge. For example, the city of Dresden had kept huge flood plains and two inundation channels free of settlements for many years. But after the reunification of Germany, Dresden faced an increased interest in investments. In the 1990s, the city established industrial areas within the flood plains, which were severely damaged in August 2002. Therefore, an interdisciplinary space oriented risk management is needed, which demands a stronger integration of water (resources) management, land (resources) management and spatial planning.

Where settlements already exist, flood damage must be mitigated effectively, e.g. by building precautionary measures. Suitable means are, for instance, elevated building configuration or flood adapted use. In Saxony, the affected households had little flood experience, i.e. only 15% had experienced a flood before August 2002, and 59% stated that they did not know that they lived in a flood prone area (Kreibich et al., 2005c). Thus, households and companies were not well prepared, e.g. just 12% of the households had used their house in a flood-adapted way and only 6% of the companies had a flood-adapted building structure (Kreibich et al., 2005b). It is believed that these measures are very effective especially in areas with frequent flood events and low flood water levels (ICPR, 2002), but even during this extreme flood, building precautionary measures reduced the residential and commercial damage significantly (Kreibich et al., 2005b, 2005c). The 2002 flood motivated a relatively large number of households and companies to implement private precautionary measures, but still much more could be done. More information campaigns and financial incentives should be issued to encourage precautionary measures (DKKV, 2003).

Despite the availability of insurance against damage due to natural disasters governmental funding and public donations played an important role in the compensation of flood losses of the August 2002 flood (Thieken et al., 2005c). However, governmental disaster assistance is often criticized to be an ineffective and insecure way to deal with flood losses (Schwarze and Wagner, 2004). Since governmental aid in Germany is not based on legal commitment, it depends mainly on the extent of the disaster and the media coverage. Affected people cannot rely on it. In contrast, insurance coverage provides a right of compensation agreed upon by a contract, and loss compensation is reliable and fast (Platt, 1999). Therefore, a better communication should encourage more people to sign flood insurance contracts, or even a coupling of building loans with appropriate insurance coverage might be possible. In addition, insurance companies should acknowledge mitigation activities of private households by incentives (DKKV, 2003).

An integral part of behavioral risk prevention are flood protection information and punctual flood warnings (see also section 2). Potentially affected households and companies need to know what to do when a flood warning reaches them. Helpful are for example emergency plans, or check lists indicating which things should be available for an emergency. Communicating information about flood risks, including brochures, information tables and high water marks, as well as emergency exercises are important for building preparedness (DKKV, 2003).

The motto “more room for rivers” has gained much attention and became one of the governing principles for flood reduction after August 2002. Possible measures include, for instance, the moving of dikes further away from river banks and the conservation or restoration of flood plains. However, the effectiveness of these possibilities for flood risk reduction, particularly for extreme events, is probably overestimated (DKKV, 2003). They need to be supplemented with technical flood defense. In the case of extreme events the water volume is too large to be completely retained, therefore, the flood peaks must be reduced through controlled water retention measures, like polders or reservoirs. In August 2002, the flood retention basins managed by the state dam administration of Saxony were able to reduce the peak flow and delay it (DKKV, 2003). Additionally, the flood level was reduced more than 50 cm on the river Elbe at Wittenberge when the Havel polders, which had been erected in 1955, were used for the first time. But, due to the decay of flooded vegetation in the polders, the oxygen concentration in the water dropped to approximately 3 mg l^{-1}, which led to a total collapse of the fish population along 40 km of the river (Bronstert, 2004). The fatality of 15 to 20 Mio fish stresses the importance of a flood-adapted agricultural use of flood polders.

The International Commission for the Protection of the Elbe stated in 2001 that levees with a length of 511 km along the Elbe river and the mouth reaches of its tributaries do not comply with the technical requirements (IKSE, 2001). For retrofitting, about 450 Mio € would have been necessary. Due to the bad conditions of the levees, 125 levee failures occurred at the Mulde river and 21 at the Elbe river. Despite calls for action by specialists (e.g. Heerten, 2003), a rapid and thorough improvement of the dikes' condition is unlikely. It is therefore particularly important to keep the disaster protection authorities informed at all times on the state of the dikes in their respective areas of responsibility (DKKV, 2003).

In conclusion, the different stakeholders in flood management in Germany have to act across states and administrative borders pertaining to the catchment areas. Their tasks in disaster reduction and response are cross-functional and demand intensive communication, cooperation and guidance. The traditional safety mentality or promise of protection must be replaced by a risk culture, which is aware of the flood risk and which enables a transparent and interdisciplinary dialog about the different alternatives for flood mitigation and prevention (DKKV, 2003).

2. Flood Warning and Emergency Measures

Flood warning as one of the above mentioned building blocks of an integrated effective flood management will be analyzed in more detail in the following.

For a successful flood early warning system the following components must interact with each other: noting the situation, developing forecasts, warning helpers and affected people and taking the correct action and behavior adapted to the situation (Parker et al., 1994). However, the whole system is more than simply a series of individual components, critical is their interaction. Often biased investments are undertaken in the development of flood forecasting systems without adequately taking into consideration the distribution of warnings or their implementation (Grünewald et al., 2001).

In August 2002, it was criticized that the weather warnings of the German Weather Service came too late or were too imprecise. An explanation was that, although the models provided information about impending extreme weather situations, their accuracy was evidently not sufficient for an earlier warning (Rudolph and Rapp, 2003). Hence a preliminary warning of a rainstorm was only issued on 11 August 2002, at 13:59 CET and at 23:08 CET this was updated to a rainstorm warning. The dramatic increase of runoff, for instance in the rivers Müglitz and Weißeritz, occurred already on 12 August 2003. In the catchment area of the River Elbe 214 flood report and forecasting gauges are located (IKSE, 2001). But in August 2002, many automatic gauges failed because they were flooded or because of power blackouts. Additionally, forecasts based on extrapolation were complicated due to the outstanding water levels. At the river Elbe in Mecklenburg-Western Pomerania for instance, water level forecasts were almost half a meter higher than the actual water levels reached. Additionally, there was strong criticism regarding the flood reports and their forwarding (von Kirchbach et al., 2002). Reports were delayed at intermediate stations and reached the disaster protection staff too late, the feedback of the rural districts to the flood forecast centers was poor and because of the responsibility of different flood forecast centers for the same river area (e.g. at the river Mulde) forecasts were not consistent with each other. Therefore, many people did not receive a flood warning or received it too late, particularly on the tributaries of the river Elbe. Warnings did rarely contain instructions on what to do, which meant that emergency measures could not everywhere be implemented effectively. Furthermore, the non-existence of a working siren warning system was criticized (DKKV, 2003).

After the floods in 2002, many activities were introduced to improve the flood warning system. For instance, the German Weather Service (DWD) is further developing and improving its numerical weather forecast models and its warning management. Federal states started to design the flood warning gauges in a flood-proofed way and equip them with redundant data collection, transmission and power supply systems. The flood routing model "ELBA" was updated with new stage-discharge relations and new components. In addition a new flood forecast model "WAVOS" (water level forecast system) is developed for the river Elbe in Germany. In Saxony the four existing regional flood centers were integrated into one state flood center (Landeshochwasserzentrum LHWZ). The authorities worked on information and reaction chains to ensure that in a flood emergency everyone knows what information can be obtained from whom and to whom this information should then be forwarded (DKKV, 2003). These chains must be tested in regular exercises to make sure that they are up to date and functioning properly.

Generally, it is believed that flood warning is able to reduce flood damage significantly (Smith, 1994; ICPR, 2002; Thieken et al., 2005b). For instance, during the flood in Lismore (Australia) in 1974 with a warning time of about 12 hours, damage in the residential sector were only 50% and in the commercial sector only 24% of the economic damage expected without emergency measures (Smith, 1981). The ICPR (2002) estimates that the contents-damage reducing effect of flood warning ranges between 20 and 80%. After the flood of the Georges river in Sydney in 1986, damage evaluators documented all objects which have been saved due to emergency measures, particularly due to lifting the objects above the water level, in 71 residential buildings (Lustig et al., 1988). On average, the damage reduction was 25%. Additionally, a correlation between the damage reduction and lead time, water level and flood experience became evident. Based on more recent Australian studies, two functions distinguishing between flood experience during the last five years or not were published (Queensland Government, 2002). Both studies estimate a damage reduction of about 10-30% for Australian households without flood experience, for households with flood experience, the estimated range is much broader (Lustig et al., 1988; Queensland Government, 2002). Comprehensive investigations in Britain revealed in contrast, that only 13% of the potential damage that could be prevented by a warning was actually prevented (Penning-Rowsell and Green, 2000a, 2000b). Reasons for this relatively small damage reduction were that only a fraction of the endangered population was reached by a warning, and an even smaller fraction was warned sufficiently early to undertake damage reducing actions, and again of this group, only a fraction had the capacity to react and actually reacted effectively.

Therefore, important factors influencing the damage reducing effect of flood warning seem to be the lead time, the flood water level and the ability of the people to undertake emergency measures effectively. The longer the lead time, the longer the time for the people to undertake emergency measures. With shallow water levels, damage can be reduced easily by sealing the building or lifting the movable contents e.g. onto tables. With increasing water level, this is getting more and more difficult. With high water levels, the ingress of water can not be prevented. The ability to undertake effective measures is again dependent on different factors, e.g. flood experience (Smith et al., 1990; Smith, 1994). People which had experienced a flood before tend to be better prepared and tend to know better what to do in case of a flood emergency.

The influence of these factors has been investigated for 415 affected companies during the August 2002 flood in the German Free state of Saxony. The survey (data collection) and the data set have been described in detail by Kreibich et al. (2005a, 2005b). Comparing the damage to equipment of companies which had received a warning with damage of companies which had not received a warning shows, that the warning alone was not able to reduce the damage (Fig. 2). Only in areas with a flood water level of one meter and below, the companies which had received a warning had on average lower damage to equipment, goods, products and stocks in contrast to the ones which had not received a warning. But the difference in damage was only significant, for damage to goods, products and stocks of companies which had received a warning 12 hours or more before the flooding in contrast to the damage of companies which had received a warning shortly before the flooding or no warning at all.

To investigate in more detail, which factors may support the effectiveness of undertaken emergency measures, the enterprises were split into two subgroups, the ones which had undertaken emergency measures effectively and the others. Enterprises were included in the first group, when they were able to save their equipment or their goods, products and stocks completely, and also when they were able to save their equipment and goods, products and stocks largely. Relatively recent flood experience seems to support effective emergency measures (Table 1). General knowledge about the flood hazard was not significantly different between the two groups. The ICPR (2002) even states, that flood experience fades within seven years, when no information about the flood hazard is given regularly. As expected, if an emergency plan was available, measures could be undertaken more effectively (Table 1). But surprisingly, undertaken emergency exercises were not significantly different between the two groups. Warnings, and specially the ones of authorities, were favorable as well as relatively long lead times. Additionally, large companies seem to be more efficient with their emergency measures. And again, the significant effect of the water level was apparent. The enterprises which had been affected by high water levels, had relatively more problems to undertake effective emergency measures than the once with lower flood water levels (Table 1).

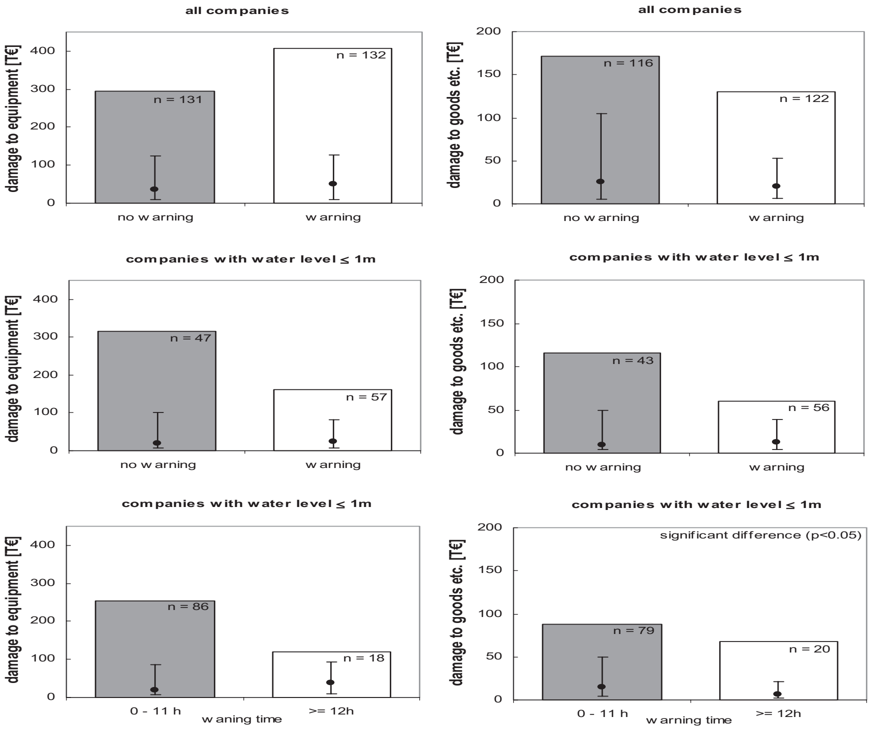

Figure 2. Damage to equipment and damage to goods, products and stocks of companies which had received a warning or not, or which had received a warning 12 hours or more before the flooding in comparison with ones without or with shorter warning time (bars = means, points = medians and 25-75% percentiles, significant differences were checked with the Mann-Whitney-U Test)

TABLE 1. Selected parameters which are significantly different ($p<0.05$) between the two subgroups of enterprises: the ones which had undertaken emergency measures effectively (n=61) and the ones which had undertaken emergency measures ineffectively (n=210).

	emergency measures undertaken	
	effectively	Ineffectively
Average time since last flood event [years]	33	41
% of enterprises which had an emergency plan available	18	9
% of enterprises which had not received any warning	25	40
% of enterprises which were warned by authorities	36	23
Average lead time of flood warning [h]	27	22
Average number of employees	44	32
Average business volume in 2001 [mill. €]	6.1	2.8
Average water level at premise [cm]	115	145

3. Conclusions

Integrated concepts for risk management are needed, where the whole chain from weather extremes, runoff generation and concentration in the catchment, flood routing, failure of flood defense systems, flood-adapted land use, to preparedness and mitigation are taken into account. Effective early warning systems relay on precise and timely results as well as on an effective information chain and the preparedness of administrations, response organizations and the people at risk. After the floods in 2002, many activities were introduced to improve the flood warning system, but it also has to be maintained and tested regularly. Flood warning is able to reduce flood damage significantly, specially with long lead times, low water levels and many people able to undertake emergency measures effectively. To ensure adequate reaction, risk awareness has to be strengthened and people at risk and decision makers must be informed about opportunities for prevention. The greatest challenge is probably to keep good maintenance of flood protection and prevention measures as well as preparedness over time.

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