Hydrol. Earth Syst. Sci. Discuss., 6, 4961–4988, 2009
www.hydrol-earth-syst-sci-discuss.net/6/4961/2009/

Hydrology and Earth System Sciences Discussions

Papers published in *Hydrology and Earth System Sciences Discussions* are under open-access review for the journal *Hydrology and Earth System Sciences*

The European flood risk directive: challenges for research

E. Mostert and S. J. Junier

Delft University of Technology, Delft, The Netherlands

Received: 2 July 2009 – Accepted: 10 July 2009 – Published: 16 July 2009

Correspondence to: E. Mostert (e.mostert@tudelft.nl)

Published by Copernicus Publications on behalf of the European Geosciences Union.

Abstract

In recent years, flood management has shifted from protection against floods to managing the risks of floods. In Europe, this shift is reflected in the Flood risk directive of October 2007 (2007/60/EC; FRD). The FRD requires EU Member States to undertake a preliminary assessment of flood risks and, for areas with a significant flood risk, to prepare flood hazard and flood risk maps and flood risk management plans. The purpose of this paper is to introduce the FRD and discuss the challenges that the FRD poses to research. These challenges include the issue how to define and measure "flood risk", the selection of alternatives to be assessed, coping with uncertainty, risk communication, nurturing trust and promoting collaboration. These research challenges cannot be addressed properly within any single discipline and without involving the flood risk managers and other stakeholders. The paper therefore concludes that there is a large need for interdisciplinary and participatory research. This constitutes in fact the biggest research challenge.

1 Introduction

Throughout the centuries, Europe has suffered from many floods. Despite many efforts to protect against floods, it has proven impossible to eradicate them completely. For this reason attention in Europe has shifted in the past decades from protection against floods to managing flood risks (e.g. Klijn et al., 2008; Twigger-Ross et al., 2009; Hecker et al., 2009; Vinet, 2008; Manojlovic and Pasche, 2008).

Following the 2002 floods in the Danube and the Elbe, the European Community's Council of Ministers launched a European initiative on flooding (Commission of the European Communities, 2004; Dworak and Görlach, 2005). This resulted in January 2006 in the publication of a proposal for a directive on flood risk management (Commission of the European Communities, 2006). After some modifications, the proposal was officially adopted on 23 October 2007 (Council of the European Union, 2006a;

HESSD

6, 4961–4988, 2009

European Parliament, 2006; 2007; arts. 250 and 251 EC Treaty).

The aim of this paper is to introduce the Flood risk directive (FRD) and to discuss the challenges that it poses to research. The research challenges have been identified by analyzing the requirements of the FRD and comparing these with current research on flood risk management. In addition, literature from the field of science and technology studies has been used extensively (see also Mostert and Raadgever, 2008). The paper focuses on the research challenges that are specific for the management of flood risks, such as the definition of "flood risk" and flood risk communication. The core of the paper is formed by Sect. 3, which discusses the research challenges. Section 2 introduces the FRD and the Appendix scans the research in the field of flood risk management. The final section gives a number of recommendations for further research.

2 The flood risk directive

The flood risk directive – in full: Directive 2007/60/EC of the European Parliament and of the Council of 23 October 2007 on the assessment and management of flood risks – is the first European directive that deals specifically with floods. It requires EU Member States to undertake a preliminary assessment of flood risks and to prepare flood hazard maps, flood risk maps and flood risk management plans for areas with a significant flood risk. In addition, it requires the EU Member States to organize public participation and to coordinate the implementation of the FRD with the implementation of the European water framework directive (2000/60/EC), which focuses on water quality and ecology. If they do not implement the FRD correctly, the European Court of Justice may eventually impose hefty fines (art. 226 and 228 EC Treaty).

2.1 Purpose and scope

The purpose of the FRD is to establish a framework for the assessment and management of flood risks (art. 1) in order to reduce these risks (cf. recital 3). The FRD

HESSD
6, 4961–4988, 2009

defines flood risk as "the combination of the probability of a flood event and of the potential adverse consequences for human health, the environment, cultural heritage and economic activity (. . .)" (art. 2.2). Hence, flood risk management should consider not only the probability of floods, but also a broad range of possible consequences. The FRD defines "flood" as "the temporary covering by water of land not normally covered by water" (art. 2.1). This includes floods from rivers, mountain torrents, Mediterranean ephemeral water courses and floods from the sea (art. 2.1), as well as groundwater flooding (art. 6.7) and any other type of temporary covering of land by water (cf. Council of the European Union, 2006b). The only type of floods that may be excluded are floods from sewerage systems (art. 2.1). Arguably, "sewerage systems" include mixed systems but not stormwater drains.[1]

2.2 Preliminary flood risk assessment

Flood risk management according to the FRD is a three-stage process. First, EU Member States have to undertake by 22 December 2011 a preliminary flood risk assessment for their river basins and identify the areas with a potential significant flood risk (arts. 4 and 5). Member States do not have to undertake a preliminary flood risk assessment for areas if they decide before 22 December 2010 to prepare flood hazard

[1] Other language versions of the FRD use wordings that cover stormwater drains as well, such as Abwassersystemen (German), redes de alcantarillado (Spanish), réseaux d'égouts (French) and rioolstelsels (Dutch). When different language versions conflict with each other, the European Court of Justice, the highest authority for interpreting the text of directives, looks at the purpose of the directive as expressed in for instance the recitals. Recital 3 of the FRD shows that the objective of the directive is to reduce adverse consequences for human health etc. This suggests that Abwassersystemen etc. should be interpreted in a restrictive way and that only flooding from sewers carrying wastewater can be excluded. The intention that the Council of Ministers had in introducing the possibility to exclude floods from "sewerage systems" is not clear from public documents (see Council of the European Union, 2006b, p. 3) and hence will not be considered by the European Court of Justice.

maps, flood risk maps and flood risk management plans for these areas (art. 13.1).

2.3 Flood hazard and flood risk maps

The second stage is the preparation of flood hazard maps and flood risk maps for areas with potential significant flood risks (or where art. 13.1 has been applied). The flood hazard maps have to give information on the flood extent, water depths and, where appropriate, flow velocities or the relevant water flows in the following three scenarios (art. 6.3):
(a) floods with a low probability, or extreme event scenarios;
(b) floods with a medium probability (likely return period≥100 years);
(c) floods with a high probability, where appropriate.

The flood risk maps have to show the potential adverse consequences in these three scenarios, expressed in terms of:

(a) the indicative number of inhabitants potentially affected
(b) type of economic activity of the area potentially affected
(c) the IPPC installations (larger industrial installations) that might cause accidental pollution
(d) potentially affected areas that have been designated for the production of drinking water or for water recreation, including bathing, or are protected under the Birds Directive (79/409/EEC) or the Habitat Directive (92/43/EEC)
(e) other information that the Member State considers useful.

The deadline for the flood hazard and flood risk maps is 22 December 2013.

HESSD
6, 4961–4988, 2009

2.4 Flood risk management plans

The third stage is the preparation of flood risk management plans by 22 December 2015 and the revision of the plans every six years (art. 7.1). The plans have to contain "appropriate objectives" for the management of flood risks, focusing on the reduction of potential adverse consequences of flooding for human health, the environment, cultural heritage and economic activity, and, if considered appropriate, on nonstructural initiatives and/or on the reduction of the likelihood of flooding (art. 7.2). Moreover, the plans have to include measures for achieving the objectives. They have to take relevant aspects into account, such as costs and benefits, areas with a potential for retaining flood water, such as natural floodplains, the environmental objectives of the Water Framework Directive (2000/60/EC), soil and water management, spatial planning, land use, nature conservation, navigation and port infrastructure. Moreover, the plans have to address all aspects of flood risk management, focusing on prevention, protection and preparedness, and including flood forecasts and early warning systems (art. 7.3). The plans should probably cover rescue and recovery measures as well.[2] The plans "may also include the promotion of sustainable land use practices, improvement of water retention as well as the controlled flooding of certain areas in the case of a flood event" (art. 7.3).

An important provision for international basins is art. 7.4, which states that, in the interests of solidarity, flood risk management plans may not include measures that

[2]The Commission proposal read that the plan shall address "all phases of the flood risk management cycle" (art. 9.3), to which the Eurpopean Parliament in its first reading added "The flood risk management plan shall also include an assessment of rescue and recovery measures" (amendment 58). The Council of Ministers did not take over this amendment and moreover changed "all phases of the flood risk management cycle" into "all aspects." The reason that it gave for this was not very clear: it "did not wish to lay stress on the review of flood events" (Council of the European Union, 2006b, p. 5). Yet, rescue and recovery measures are still referred to in the preamble of the FRD, recital 7 and 8, and it would be in keeping with the objective of the FRD to include them in the plans.

HESSD
6, 4961–4988, 2009

significantly increase flood risks in other countries in the basin, unless these measures have been coordinated and an agreed solution has been found by the Member States concerned. Moreover, when a Member State identifies an issue that it cannot solve on its own, it may report the issue to the Commission and make recommendations on how to resolve the issue. The Commission then has to respond within six months (art. 8.5).

Member States have much freedom in setting the appropriate objectives (cf. recital 10), but it is not very clear how binding the objectives are once they have been set. According to art. 7.3, the plans have to include measures "for achieving the objectives", and this suggests that the objectives are binding. The Annex to the FRD, however, states that the plans should contain "a summary of the measures and their prioritisation aiming to achieve the appropriate objectives" (Annex A.I.4). "Aiming to achieve" is less strict than "for achieving", and "prioritisation" implies that some measures get a lower priority. In addition, Annex B3 states explicitly that the updated plans should contain a description of and explanation for the measures that were planned but not implemented. Hence, there may be good reasons for not implementing measures. On the other hand, the Annex also mentions the possibility of additional measures that were not planned (B.4).

2.5 Coordination with the Water Framework Directive

The implementation of the FRD has to be coordinated with the implementation of the Water Framework Directive (2000/60/EC, see on this directive Holzwarth, 2002; Kaika and Page, 2003; Page and Kaika, 2003; Mostert, 2009). The management units for the FRD are in principle the same as for the WFD: river basin districts consisting of one or more river basins. Member States may, however, for the implementation of the FRD assign coastal areas or individual river basins to a different unit of management (art. 3). Moreover, Member States may decide not to make one plan for each national river basin district (or other management unit), but a set of coordinated plans (art. 8.1).

The approach to international river basin districts (or other international management units) is again comparable. Member States have to ensure coordination with the aim of

producing one single international flood risk management plan. Failing to do so, they have to produce flood risk management plans covering at least their part of the river basin district, as far as possible coordinated at the river basin district level (art. 8.2, cf. art. 13.2 WFD). If a river basin district or other management unit extends beyond the boundaries of the EU, the EU Member States have to "endeavour" to produce a single plan (art. 8.3, cf. art. 13.3 WFD).

To allow coordination, the implementation of the FRD and the WFD has been synchronized. The first flood hazard and flood risk maps, due by 22 December 2013, have to be coordinated and may be integrated with the first review of the characterization of the river basin district, the review of the impact of human activity and the economic analysis of water use required under art. 5 WFD, which are due by the same date (art. 9.1). Similarly, the development of the first flood risk management plans, due by 22 December 2015, has to be coordinated and may be integrated with the first review of the river basin management plans under the WFD (art. 9.2).

2.6 Public participation

Finally, the FRD requires the Member States to "encourage active involvement of interested parties in the production, review and updating of the flood risk management plans" (art. 10.2). A similar requirement can be found in art. 14 WFD, and art. 9.3 FRD requires coordination between the implementation of the FRD and the WFD on this point ("as appropriate").

Neither the FRD nor the WFD clearly define "active involvement" and "interested party." These terms have, however, been interpreted in the Guidance on Public Participation that was prepared in the framework of the Common Implementation Strategy for the WFD (CIS, 2002). According to this guidance document, "active involvement" is more than consultation and implies that all stakeholders are invited to contribute actively to the planning process by discussing issues and contributing to their solution. "Interested party" is defined as any person, group or organisation with an interest or "stake" in an issue, either because they will be directly affected or because they may

have some influence on its outcome. This includes members of the public who are not yet aware that they will be affected (CIS, 2002, p. 18; cf. Ridder et al., 2005).

3 Research challenges

The implementation of the FRD requires a lot of research. All EU Member States will have to prepare preliminary risk assessments (or apply art. 13.1), flood hazard maps, flood risk maps, and flood risk management plans. In many countries there is already a lot of information available, but not necessarily all that the FRD requires or in the required format. Much of the research needed for implementing the FRD will have an applied character, but a number of fundamental choices will have to be made.

3.1 Measuring "flood risk"

The first choice concerns the meaning of "flood risk". As discussed, the FRD defines flood risk as a combination of the probability and the consequences of a flood event, but it does not state how these two should be combined. A very popular approach in the flood risk management literature is to multiply probabilities and consequences or, to be more accurate, to multiply the probability of each possible flood event per year with the consequences of that event and then add up the results (e.g. Kaiser et al., 2009; Hoes and Schuurmans, 2006; Bruijn et al., 2009; Dawson et al., 2009; Morita, 2009; Jongejan, 2008, p. 159). Hazard times exposure times vulnerability is an alternative expression for the same approach (Gouldby and Samuels, 2005, p. 13–14; Klijn et al., 2008; Merz et al., 2007).

Usually only economic damage and casualties are considered. This results in simple risk measures such as average annual economic damage (AAD) and average annual number of casualties (AAC). These measures make it possible to compare risks quantitatively, but in the process a lot of important information is lost. For instance, regular flooding with limited consequences and exceptional flooding with huge conse-

HESSD
6, 4961–4988, 2009

quences may have the same AAD, but in practice they differ significantly: individuals and societies may be quite able to cope with the first type of floods but not with the second (cf. Hall et al., 2003).

Similar problems occur with respect to AAC. In practice, large disasters are usually considered disproportionately more serious than small disasters. This can be expressed quantitatively by using a measure that does not use the number of casualties, but the number of casualties to the power 1.5 or 2 (Jonkman et al., 2003). Another issue is whether to express casualties in terms of lives lost or in terms of life expectancy (numbers of years) lost. The first option treats a young person and a octogenarian equally, whereas the second gives more weight to the life of the young person (Fischhoff et al., 1984; cf. Douglas, 2005; Sjöberg, 2002; Slovic, 1999).

AAD and AAC are both measures for "collective risk": the total risk for a specific area. In addition, individual risk measures can be used, such as the individual probability of drowning. The choice of individual or collective risk measures is not a neutral one. If we take for example two flood-prone areas, A and B, that are identical in all respects, except that in A hundred persons live and in B only one, the individual flood risks in A and B will be the same but the collective risk in A will be a hundred times higher than in B. The implications for flood risk management are quite different. In general, measures of individual risk suggest equal protection for everybody, wherever they may live, whereas measures of collective risk suggest higher protection levels in more developed areas.

The FRD requires that, in addition to economic damage and casualties, attention is paid to assessing health effects, environmental effects and effects on cultural heritage of flooding. There is, however, limited experience with assessing these other effects. In the UK, substantial research has been conducted on the wellbeing of the flood victims after a flood event (e.g. Hendy, 2009; Tapsell et al., 2009). The environmental effects of flood risk management measures such as reservoirs and dykes have been assessed in many Environmental Impact Statements, but there is far less research on the effects of flooding on water quality and ecology (Gautam and Van Der Hoek, 2003; Istomina

HESSD
6, 4961–4988, 2009

et al., 2005; see for exeptions: Meyer et al., 2009; Huber et al., 2009; Sauer et al., 2009; Stuyt et al., 2007). Damage to historic buildings is considered in assessing economic damage, but often imperfectly. Historic buildings are often more sensitive to flooding than the average new building, and the real damage exceeds the repair costs or replacement costs. This is because a repaired building is less original than before and a replacement is not original at all (cf. Nieuwenhuizen, 2003).

3.2 Maps

Choices have to be made concerning the flood hazard maps and flood risk maps as well. Many countries already have some form of flood risk mapping (Merz et al., 2007). In England and Wales, for instance, the Environment Agency has put flood maps online (www.environment-agency.gov.uk/homeandleisure/37837.aspx, but these only include river and sea-borne floods and leave out flooding from malfunctioning drains, groundwater flooding, ponding, flooding from small water courses and culverts, and flooding caused by failure of flood protection infrastructure (Hankin et al., 2008). In The Netherlands provincial "risk maps" have been published on the Internet that include many different types of hazards, including the location of different industrial installations (www.risicokaarten.nl). With respect to floods, these maps only present inundation depths caused by breaches of the flood defences along the coast and the major rivers. Other types of floods are not included. Moreover, inundation depths depend on the exact location of the breach or breaches and on factors such as wind speed and direction, but only a limited number of combinations of these factors have been assessed.

A lot of work will be needed to include all different types of floods in all three FRD scenarios and to indicate the potential consequences on the maps. This work should be guided by the functions that the maps are meant to perform and their target audience or audiences. Flood maps could for instance be used in land use planning, for determining eligibility for insurance, for planning flood protection and crisis management measures, and for raising public awareness of flood risks. On the downside, they

may give a false sense of safety to citizens living outside of the indicated flood zones (Bell and Tobin, 2007; Hecker et al., 2009). To counteract this danger, uncertainties could be indicated, but this may make the maps more complex and may reduce their accessibility and effectiveness (cf. Fuchs et al., 2009). In addition, some fear that admitting uncertainty in flood maps may open the "floodgates", so to speak, to floodplain development (Faulkner et al., 2007, p. 698).

3.3 Plans

Most likely, researchers will play a significant role in the preparation of the flood risk management plans. Researchers may for instance assess the economically optimal level of flood protection and propose and assess measures to reach this level. Yet, the plans will eventually have to be adopted by the responsible authorities.

In theory, the roles of the researchers and the authorities can be separated neatly, the latter providing the subjective values to be considered and taking the final decisions and the former supplying the objective facts. The practice is, however, more complex. Flood risk research involves many choices concerning for instance the thematic, geographic and temporal scope and the measures to include or exclude. These choices cannot be based completely on scientific grounds or on the expressed values of the authorities. Authorities may have difficulties in expressing their values in the abstract, may disagree among themselves or for strategic reasons may not be willing to reveal their preferences. And as to the scientific grounds: these may differ. Ecologists, for instance, are likely to focus on different issues and aspects and come up with different solutions than hydrologists or economists (cf. Mostert and Raadgever, 2008).

The FRD offers some guidance for developing the plans. It mentions a number of types of measures and aspects that should be considered, including the effects of climate change (cf. recitals 2 and 4, art. 4.2). Moreover, there is third party that should be involved: the "interested parties" (art. 10.2). Nonetheless, researchers have to make many choices, not the least being the definition of "risk", discussed above.

3.4 Uncertainties

The assessment of flood risks faces many uncertainties. Hydrological and other data are often far from complete, their reliability is usually not perfect, and they can be analyzed in different ways, resulting in slightly or very different outcomes (e.g. Faulkner et al., 2007). In addition, flood risks depend on many uncertain social factors. These include for instance decision-making on controlled flooding, the performance of the crisis management organization, the behaviour of individual flood victims, and the quality of flood relief operations (e.g. Hendy, 2009; Tapsell et al., 2009). The further ahead we look, the bigger the uncertainties become.

Researchers facing uncertainties can follow different approaches. They may try to suppress them, make explicit assumptions, develop different scenarios, assess the uncertainties qualitatively, or analyze them quantitatively using techniques such as Monte Carlo analysis and sensitivity analysis (cf. Refsgaard et al., 2007, Pappenberger, 2006). When developing flood risk management strategies, researchers may moreover aim for flexible and "robust" strategies that perform well in a number of potential futures and can be modified in case of unforeseen developments (cf. the concept of "adaptive management": Tompkins and Adger, 2004; Folke et al., 2005; Olsson et al., 2004). Such strategies are especially important because there are limits to reducing uncertainties: only known uncertainties can be reduced and even these not always.

Uncertainty generally refers to the situation in which there is not a unique and complete understanding of an object or a system. This can result from inherent variability or unpredictability of the system, from limited or imperfect information, or from ambiguity: the information can be interpreted in different ways (Brugnach et al., 2008). The only option in the first case is to accept and cope with uncertainty. In the second case, uncertainty can potentially be reduced by means of additional research. In the third case, uncertainty may be reduced as well, but in a different way: by organizing a dialogue between the different perspectives on the system that may result in an enrichment and convergence of the individual perspectives (Dewulf et al., 2005).

HESSD
6, 4961–4988, 2009

3.5 Risk and uncertainty communication

An important aspect of flood risk management is risk communication. Risk communication often implicitly uses the public understanding of science or PUS model, also known as the deficiency model or the scientific literacy model. This model is based on the assumption that there is a need for the stakeholders to understand particular scientific concepts and facts and that the researchers should teach them these. The concepts and facts themselves are portrayed as fixed and certain (see for an example Stamm et al., 2000). However, despite many efforts applying this model there is little evidence of an increase in public understanding of science (Logan, 2001; Kim, 2007; Weigold, 2001). This is often attributed to the inability of the experts to communicate clearly and to the limited background knowledge, intellectual capacities and willingness of the other stakeholders. Yet, there is more to it.

In flood risk communication the PUS model is reflected in the often-made distinction between objective flood risks and the subjective flood risk perceptions of the public (e.g. Raaijmakers et al., 2008, p. 311; Kaiser et al., 2004, p. 24 and 25). In this approach, the objective risks are assessed by the experts and used as a standard for judging the subjective risk perceptions of the public. There is, however, no reason why the public should uncritically accept the risk assessments made by the experts. The specific measure of risk used may not reflect the values of the public (see above). In addition, lay persons often use a different, more holistic risk concept than technical experts. Whereas technical experts usually separate risk assessment on the one hand, and risk acceptability and risk management on the other, lay persons do not (Gouldby and Samuels, 2005; cf. Jasanoff, 1999). Their assessment of risks includes factors such as their trust in crisis management, their own degree of control, vulnerability to the risk, the voluntary or involuntary character of the risk, their general attitude towards the risky activity or situation, the benefits derived from the activity or situation, and fairness of the distribution of costs and benefits (e.g. Slovic, 1999; Sjöberg, 2000; Baan and Klijn, 2004).

HESSD
6, 4961–4988, 2009

The FRD uses a "technical" risk concept and clearly distinguishes between flood risk assessment and flood risk management. However, technical risks cannot be assessed without looking at management aspects, such as the quality of crisis management. Not considering these aspects in risk assessment may reduce both the validity and public acceptance of the assessment.

A special issue concerning flood risk communication is whether or not to communicate the inherent uncertainties. Many experts believe that water managers and the public cannot cope with uncertainty, but there is growing evidence that this is not correct and that many non-experts can understand uncertainty and in fact cope with it on a daily basis (Wynne, 1992; 1996; Frewer, 2004; Pappenberger and Beven, 2006; McCarty et al., 2007). Prime examples of effective uncertainty communication are probabilistic weather forecasts that indicate bandwidths. However, uncertainty communication often suffers from highly technical, mathematical language (Faulkner et al., 2007; Wardekker et al. 2008). Moreover, there may be strategic reasons for not communicating uncertainties and overstating one's case (Wardekker et al., 2008). This strategy may, however, prove counterproductive and often reduces credibility of the risk assessment (Frewer, 2004).

3.6 Trust

Another reason why public acceptance of risks assessment may be low is lack of trust in the research and the researchers (e.g. Slovic, 1999; Twigger-Ross et al., 2009). Trust or lack thereof is, however, not a static characteristic of the public. As Brian Wynne (1992; 1996) pointed out, it results from the interactions between the researchers and their public and from the social and institutional context. Factors influencing trust include the track record of the researchers (have they been proven wrong in the past?), their consideration of the information and views from the public, their openness to criticism, their institutional affiliation and the "recognizability" of their research, which depends not only on the language that is used, but also on the concepts that are used and the values that are reflected in the research (see also Kramer, 1999; Bachman,

2001; Vangen and Huxham, 2003).

Technical flood risk experts usually approach flood risk management as a technical issue. Against this background, trust can easily be regarded as an extra or "nice to have", as well as expensive and time consuming. Yet, when the public does not trust information on flood risks, they may not take precautions and the damage in case of a flood may be much larger than necessary (Twigger-Ross et al., 2009).

3.7 Collaboration

As shown in the Appendix, most of the current research on flood risk management is from a technical or natural science background. However, the FRD poses challenges for the social sciences as well. Implementing the FRD requires collaboration at the river basin level between many parties, such as upstream and downstream water managers, land-use planning authorities, organizations involved in crisis management, different sections of the public and different types of experts. This raises a number of issues that social science research can help to address. These include differences in problem perception and risk perception (Gray, 2004; see also above), the sometimes lacking motivation to collaborate (e.g. Huxham and Vangen, 2005; Gray, 1989), strategies to be used for reaching agreement (Fisher and Ury, 1981), arrangements for implementing agreements (Gray, 1989), and the broader institutional and social environment that may be conducive to collaboration or not.

Technical and natural science research may promote collaboration too (Craps, 2003). It may support collective decision-making by all stakeholders concerned by providing a common focus for the discussions and by informing or even structuring them. A crucial issue is the identification and selection of the stakeholders to be involved. Important stakeholders for implementing flood risk management should not be left out, but the number involved should be manageable (cf. Ridder et al., 2005).

3.8 Interdisciplinary research

In addition to different types of monodisciplinary research, there is a large role for interdisciplinary research in flood risk management. As the preceding sections have shown, it is impossible to strictly separate the technical and social aspects of flood risk management and research. Monodisciplinary research can be appropriate for studying specific aspects, but not flood risk management as a whole. This requires interdisciplinary research.

Interdisciplinary research is difficult. It questions the taken-for-granted assumptions of the different disciplines and requires that researchers leave, at least temporarily, the familiar territory of their own discipline, from which they derive their professional status and identity. They need to be willing to learn new things and familiarize themselves with concepts and approaches that are often fundamentally different from the ones that they are used to. In addition, there are institutional constraints for interdisciplinary research. The career opportunities of individual academics and the budget of many research groups depend on the number of publications in high-ranking journals. These are usually monodisciplinary journals reporting on fundamental research (Jacobson et al., 2004; Boer et al., 2006; Oughton and Bracken, 2006; Bracken and Oughton, 2009).

3.9 Participatory research

Finally, a strong case can be made for participatory research that involves the key governmental and non-governmental stakeholders (cf. Jasanoff, 1999, p. 137). Participation in setting up and conducting research can promote the recognizability of the concepts used, increase trust in the results and enhance their uptake. Most researchers, however, do not have much experience with participatory research. It requires a lot of flexibility and creativity since the wishes of the stakeholders differ and may change. Moreover, participation does not fit well in traditional academic research.

The FRD requires public participation in the "production, review and updating of the

HESSD
6, 4961–4988, 2009

flood risk management plans" (art. 10.2). Although the FRD is not explicit about this, "production (...) of the flood risk management plan" may be interpreted as including the preparation of the maps, which form a basis for the plans (art. 7.1), the preliminary flood risk assessments, and all other research that plays a role in producing the plans. Participation can, however, be resource intensive for both the organizers and the participants, and badly-organized participation can actually reduce trust. Hence, participatory processes should be designed very carefully (see for suggestions for instance Mostert, 2003; Ridder et al., 2005; Mostert et al., 2007).

4 Discussion

The FRD is less complex than for instance the Water Framework Directive, but it is still complex. It requires EU Member States to undertake a preliminary assessment of flood risks (or use art. 13.1), to prepare flood hazard maps and flood risk maps for the areas with a potential significant flood risk, and to prepare flood risk management plans for these areas. The plans have to contain "appropriate objectives" for the management of flood risks, but these do not seem to be binding. Moreover, Member States have to consider many different types of measures and all aspects of flood risk management, but the FRD does not set any priorities: it is up to the Member States what measures they include in their flood risk management plans. To complicate matters, Member States have to organize public participation and coordinate the implementation of the FRD internationally and with the implementation of the WFD.

Member States could approach the implementation of the FRD in two fundamentally different ways: as a procedural requirement that has to be met in order to prevent problems with the European Commission and the European Court of Justice, or as an opportunity to introduce or improve flood risk management. In the first case the FRD just means extra work without resulting in any additional benefits. In the second case even more work will be needed, but the potential benefits are significant.

The FRD poses several challenges for research. Some derive directly from the text of

the FRD, such as the preparation of flood hazard and flood risk maps, while others are related to flood risk management more generally, such as the definition of "flood risk", the issue of uncertainty, the selection of alternatives, and risk communication. The research challenges are at the same time management challenges, and it is therefore impossible to separate flood risk research and management completely. Moreover, it is impossible to separate the technical and social aspects of flood risk management completely because the performance of many technical measures depends on how humans and institutions perform.

The overall conclusion of this paper is that there is a big need for interdisciplinary and participatory research on flood risk management. This is the most difficult challenge of all because most of the research world and many individual researchers are not geared towards this type of research. Yet, interdisciplinary and participatory research also offers possibilities for scientific innovation.

To help meet the challenges identified in this paper, more empirical research is needed. First, detailed case studies could be conducted on flood risk research processes and the interlinkages with the management process. These should include cases of interdisciplinary and participatory research where they can be found. Secondly, action research projects can be set up in which researchers become engaged in management practice and reflect and report about their experiences.

Appendix A

Scanning current research on flood risk management

A good starting point for assessing the current state of affairs in flood risk management research is the collection of 206 papers that were presented at the European conference *Flood risk management; research into practice*, held in Oxford, UK, from 30 September to 2 October 2008 (Samuels et al., 2009). Despite the title of the confer-

ence, more than half of the papers (112) deal exclusively with the occurrence of floods and not with their consequences. Thirty-nine explicitly consider the consequences of flooding from a technical or natural science background. Forty-nine pay some attention to the social aspects of flood risk management or have these as a central topic. These papers discuss for instance differences in vulnerability to floods, the potentials and limitations of flood insurance, the effects of recovery operations on the (psychological) health of the flood victims, and issues of risk perception.

The Oxford conference was an initiative of the European Floodsite project (Integrated Flood Risk Analysis and Management Methodologies, www.floodsite.net), funded by the European Commission. More research projects have, however, been funded by the European Commission. Many of these projects focus on flood forecasting and flood modelling (e.g. ACTIF (www.actif-ec.net/), FLOODMAN (projects.itek.norut.no/floodman), EFFS (de Roo and Beven, 2003), FLOODRELIEF (projects.dhi.dk/floodrelief), IMPACT (www.impact-project.net/), MANTISSA (prswww.essex.ac.uk/mantissa) and MUSIC (www.geomin.unibo.it/hydro/music)). Far fewer deal with the impacts of floods (e.g. MICE, http://www.cru.uea.ac.uk/projects/mice) or with specific measures (e.g. ECOFLOOD, http://levis.sggw.waw.pl/ecoflood; see for older European research also Ashton et al., 2003). In addition to these research projects, a number of projects related to floods have been funded in the European Interreg programme, such as ComCoast (www.essex-estuaries.co.uk/comcoast.htm), ComRisk (comrisk.hosted-by-kfki.baw.de/) and FLAPP (www.flapp.org). The Interreg project involve flood managers and usually study specific flood risk management or flood protection measures.

The picture that emerges from Europe can be confirmed by a simple search in the Scopus (www.scopus.com, search date 12 March 2009). Of all the papers included in this database and published after 1999, 554 mention “flood protection” in the title, abstract or keywords and only 175 “flood risk management”. Of the latter, less than one-third (54) have been published in social science journals. If we search for “flood mitigation”, we find an additional 174 articles and papers, including some that discuss

flood prevention rather than managing the consequences of flooding. Only 29 of these have been published in social science journals.

Without being exhaustive, this analysis amply shows that in most parts of the worlds there is still more attention to the occurrence of floods than to managing flood risks. Moreover, most research on flood risk management is from a technical or natural science background. More information on some of the literature consulted can be found in section three of this paper.

References

Ashton, V., Aziz, H., Keith, S., and Smith, T.: Review of EU Flood R&D Projects, Report prepared as a part of the group management project on the M.Sc. Water Resources Technology and Management Course, University of Birmingham, Department of Civil Engineering, Birmingham, http://www.actif-ec.net/library/review_EU_flood_projects.pdf, 2003.

Baan, P. J. A. and Klijn, F.: Flood risk perception and implications for flood risk management in the Netherlands, Int. J. River Basin Manage., 2, 113–122, 2004.

Bachman, R.: Trust, power and control in trans-organizational relations, Organ. Stud., 22, 337–365, 2001.

Bell, H. M. and Tobin, G. A.: Efficient and effective? The 100-year flood in the communication and perception of flood risk, Environ. Hazards, 7, 302–311, 2007.

Boer, Y. d, Gier, A. d., Verschuur, M., and Wit, B. d.: Building Bridges, Researchers on their experiences with interdisciplinary research in the Netherlands, RMNO, KNAW, NWO, COS, 2006.

Bracken, L. J. and Oughton, E. A.: "What do you mean?" The importance of language in developing interdisciplinary research, T. I. Brit. Geogr., 31, 371–382, 2006.

Brugnach, M., Dewulf, A., Pahl-Wostl, C., and Taillieu, T.: Towards a relational concept of uncertainty: about knowing too little, knowing differently, and accepting not to know, Ecol. Soc., 13(2), 30, 2008.

Bruijn, K. M. d., Mens, M. J. P., and Klijn, F.: A Method for Developing Long-Term Strategies for Flood Risk Management, in: Flood Risk Management: Research and Practice, Proceedings of the European Conference On Flood Risk Management Research Into Practice (Flood-

risk), Oxford, UK, 30 September – 2 October 2008, edited by: Samuels, P., Huntington, S., Allsop, W., and Harrop, J., CRC Press/Balkema, Leiden, 793–801, 2009.
CIS: Guidance on Public Participation in Relation to the Water Framework Directive, Active Involvement, Consultation, and Public Access to Information, Prepared in the Framework of the Common Implementation Strategy of the European Commission and the EU Member States, Office for Official Publications of the European Communities, Luxemburg, 2002.
Commission of the European Communities: Communication from the Commission to the Council, the European Pariament, the European Economic and Social Committee and the Committee of the Regions, Flood risk management, Flood Prevention, Protection and Mitigation; COM(2004)472 final, 2004.
Council of the European Union: Common Position Adopted by the Council with a View to the Adoption of a Directive of the European Parliament and of the Council On the Assessment and Management of Flood Risks (Interinstituional File: 2006/0005 (COD), 12131/06), 2006a.
Council of the European Union: Statement of the Council's Reasons (Interinstituional File: 2006/0005 (COD), 121316//06), 2006b.
Dawson, R. J., Roche, N., Ford, A. C., Barr, S. L., Hall, J. W., Werrity, J., Ball, T., Werrity, A., Raschke, M., and Thurmer, K.: Quantifying the Benefits of Non-Structural Flood Risk Management Measures, in: Flood Risk Management: Research and Practice, Proceedings of the European Conference On Flood Risk Management Research Into Practice (Floodrisk), Oxford, UK, 30 September – 2 October 2008, edited by: Samuels, P., Huntington, S., Allsop, W., and Harrop, J., CRC Press/Balkema, Leiden, 715–721, 2009.
Dewulf, A., Craps, M., Bouwen, R., Taillieu, T., and Pahl-Wostl, C.: Integrated management of natural resources: dealing with ambiguous issues, multiple actors and diverging frames, Water Sci. Technol., 52, 115–124, 2005.
Douglas, H.: Inserting the Public Into Science, in: Democratization of Expertise? Exploring Novel Forms of Scientific Advice in Political Decision-Making, edited by: Maasen, S. and Weingart, P., Sociology of the Sciences 24, Springer, Dordrecht, 153–169, 2005.
Dworak, T. and Görlach, B.: Flood risk management in Europe – the development of a common EU policy, Int. J. Water Resour. D., 3, 97–103, 2005.
European Commission: Proposal for a Directive of the European Parliament and of the Council On the Assessment and Management of Floods [SEC(2006) 66], COM(2006) 15 final, 18.01.2006, Brussels, 2006.
European Parliament: European Parliament Legislative Resolution on the Proposal for a Direc-

tive of the European Parliament and of the Council on the Assessment and Management of Floods (COM(2006)0015 - C6-0020/2006 - 2006/0005(COD)) (Codecision procedure: first reading), 2006.
European Parliament: European Parliament Legislative Resolution on the Proposal for a Directive of the European Parliament and of the Council On the Assessment and Management of Flood Risks (12131/6/2006 - C6-0038/2007 - 2006/0005(COD)) (Codecision procedure: second reading), 2007.
Faulkner, H., Parker, D., Green, C., and Beven, K.: Developing a translational discourse to communicate uncertainty in flood risk between science and the practitioner, AMBIO, 36, 692–704, 2007.
Fischhoff, B., Watson, S., and Hope, C.: Defining risk, Policy Sci., 17, 123–139, 1984.
Fisher, R. and Ury, W.: Getting to yes: negotiating agreement without giving in, Houghton Mifflin, Boston, xiii, 163 pp., 1981.
Folke, K., Hahn, T., Olsson, P., and Norberg, J.: Adaptive governance of social-ecological systems, Annu. Rev. Env. Resour., 30, 441–473, 2005.
Frewer, L.: The public and effective risk communication, Toxicol. Lett., 149, 391–397, 2004.
Fuchs, S., Dorner, W., Spachinger, K., Rochman, J., and Serrhini, K.: Flood Risk Map Perception Through Experimental Graphic Semiology, in: Flood Risk Management: Research and Practice, Proceedings of the European Conference On Flood Risk Management Research Into Practice (Floodrisk), Oxford, UK, 30 September – 2 October 2008, edited by: Samuels, P., Huntington, S., Allsop, W., and Harrop, J., CRC Press/Balkema, Leiden, 705–714, 2009.
Gautam, K. P. and Van Der Hoek, E. E.: Literature Study On Environmental Impact of Floods, Delft Cluster-Publication DC1-233-13, Delft, The Netherlands, 2003.
Gouldby, B. and Samuels, P.: Language of Risk, online available: http://www.floodsite.net/html/partner_area/project_docs/T32_04_01_FLOODsite_Language_of_Risk_D32_2_v5_2_P1.pdf., 2005.
Gray, B.: Collaborating: Finding Common Ground for Multiparty Problems, 1st edn., Jossey-Bass Management Series, Jossey-Bass, San Francisco, xxv, 329 pp., 1989.
Gray, B.: Strong opposition: frame-based resistance to collaboration, J. Community Appl. Soc., 14, 166–176, 2004.
Hall, J. W., Meadowcroft, I. C., Sayers, P. B., and Bramley, M. E.: Integrated flood risk management in England and Wales, Nat. Hazards Rev., 4, 126, 2003.

Hankin, B., Waller, S., Astle, G., and Kellagher, R.: Mapping space for water: screening for urban flash flooding, J. Flood Risk Manage., 1, 13–22, 2008.
Hecker, E. J., Zepp, L. J., and Olsen, J. R.: Improving Public Safety in the United States – From Federal Protection to Shared Flood Risk Reduction, in: Flood Risk Management: Research and Practice, Proceedings of the European Conference On Flood Risk Management Research Into Practice (Floodrisk), Oxford, UK, 30 September – 2 October 2008, edited by: Samuels, P., Huntington, S., Allsop, W., and Harrop, J., CRC Press/Balkema, Leiden, 973–978, 2009.
Hendy, P.: Analysis of the Human and Social Impacts of Flooding in Carlisle 2005 and Hull 2007, in: Flood Risk Management: Research and Practice, Proceedings of the European Conference On Flood Risk Management Research Into Practice (Floodrisk), Oxford, UK, 30 September – 2 October 2008, edited by: Samuels, P., Huntington, S., Allsop, W., and Harrop, J., CRC Press/Balkema, Leiden, 905–910, 2009.
Hoes, O. and Schuurmans, W.: Flood standards or risk analyses for polder management in the Netherlands, Irrig. Drain., 55, 113–119, 2006.
Holzwarth, F.: The EU Water Framework Directive – a key to catchment-based governance, Water Sci. Technol., 45, 105–112, 2002.
Huber, N. P., Bachman, D., Schüttrumpf, H., Köngeter, J., Petry, U., Pahlow, M., Schumann, A. H., Bless, J., Lennartz, G., Arranz-Becker, O., Manfred, R., and Fries, J.: An Integrated Risk-Based Multi Criteria Decision-Support System for Flood Protection Measures in Riversheds – REISE, in: Flood Risk Management: Research and Practice, Proceedings of the European Conference On Flood Risk Management Research Into Practice (Floodrisk), Oxford, UK, 30 September – 2 October 2008, edited by: Samuels, P., Huntington, S., Allsop, W., and Harrop, J., CRC Press/Balkema, Leiden, 829–835, 2009.
Huxham, C. and Vangen, S.: Managing to Collaborate: The Theory and Practice of Collaborative Advantage, Routledge, London, New York, 2005.
Istomina, M. N., Kocharyan, A. G., and Lebedeva, I. P.: Floods: genesis, socioeconomic and environmental impacts, Water Resour., 32, 349–358, 2005.
Jacobson, N., Butterill, D., and Goering, P.: Organizational factors that influence university-based researchers' engagement in knowledge transfer activities, Sci. Commun., 25, 246–259, 2004.
Jasanoff, S.: The songlines of risk, Environ. Value., 8, 135–152, 1999.
Jongejan, R. B.: How safe is safe enough? The government's response to industrial and flood

risks, s.n., s.l., 2008.
Jonkman, S. N., van Gelder, P., and Vrijling, J. K.: An overview of quantitative risk measures for loss of life and economic damage, J. Hazard. Mater., 99, 1–30, 2003.
Kaika, M. and Page, B.: The EU Water Framework Directive: Part 1. European policy-making and the changing topography of lobbying, Eur. Environ., 13, 314–327, 2003.
Kaiser, G., Reese, S., Sterr, H., and Markau, H.-J.: COMRISK – Common strategies to reduce the risk of storm floods in coastal lowlands, Subproject 3, Public perception of coastal flood defence and participation in coastal flood defence planning, Department of Geography, University of Kiel, Kiel, 101–108, 2004.
Kaiser, G., Hofmann, Sterr, H., and Kortenhaus, A.: Micro-Scale Analysis of Flood Risk at the German Bight Coast, in: Flood Risk Management: Research and Practice, Proceedings of the European Conference On Flood Risk Management Research Into Practice (Floodrisk), Oxford, UK, 30 September – 2 October 2008, edited by: Samuels, P., Huntington, S., Allsop, W., and Harrop, J., CRC Press/Balkema, Leiden, 363–373, 2009.
Kim, H.: PEP/IS: A new model for communicative effectiveness of science, Sci. Commun., 28, 287–313, 2007.
Klijn, F., Samuels, P., and Os, A. v.: Towards flood risk management in the EU: state of affairs with examples from various European countries, Int. J. River Basin Manage., 6, 307–321, 2008.
Kramer, R. M.: Trust and distrust in organizations: emerging perspectives, enduring questions, Annu. Rev. Psychol., 50, 569–598, 1999.
Logan, R.: Science Mass Communication: Its Conceptual History, Sci. Commun., 23, 135–163, 2001.
Manojlovic, N. and Pasche, E.: Integration of resiliency measures into flood risk management concepts of communities, WIT T. Ecol. Environ., 118, 2008.
McCarthy, S., Tunstall, S., Parker, D., Faulkner, H., and Howe, J.: Risk communication in emergency response to a simulated extreme flood, Environ. Hazards, 7, 179–192, 2007.
Merz, B., Thieken, A. H., and Gocht, M.: Flood Risk Mapping at the Local Scale: Concepts and Challenges, in: Advances in Natural and Technological Hazards Research, edited by: Beguim, S., Stive, M., and Hall, J. W., Springer, Dordrecht, 231–251, 2007.
Meyer, V., Haase, D., and Scheuer, S.: A Multicriteria Flood Risk Assessment and Mapping Approach, in: Flood Risk Management: Research and Practice, Proceedings of the European Conference On Flood Risk Management Research Into Practice (Floodrisk), Oxford,

UK, 30 September – 2 October 2008, edited by: Samuels, P., Huntington, S., Allsop, W., and Harrop, J., CRC Press/Balkema, Leiden, 1687–1693, 2009.
Morita, M.: Risk Analysis and Decision-Making for Optimal Flood Protection, in: Flood Risk Management: Research and Practice, Proceedings of the European Conference On Flood Risk Management Research Into Practice (Floodrisk), Oxford, UK, 30 September – 2 October 2008, edited by: Samuels, P., Huntington, S., Allsop, W., and Harrop, J., CRC Press/Balkema, Leiden, 817–827, 2009.
Mostert, E.: The challenge of public participation, Water Policy, 5, 179–197, 2003.
Mostert, E., Pahl-Wostl, C., Rees, Y., Searle, B., Tàbara, D., and Tippett, J.: Social learning in European river basin management, Barriers and supportive mechanisms from 10 river basins, Ecol. Soc., 12, Art. 19, 2007.
Mostert, E. and Raadgever, G. T.: Seven rules for researchers to increase their impact on the policy process, Hydrol. Earth Syst. Sci., 12, 1087–1096, 2008, http://www.hydrol-earth-syst-sci.net/12/1087/2008/.
Nieuwenhuizen, W.: Standaardmethode schade aan LNC-waarden als gevolg van overstromingen: methode voor het bepalen van de gevolgen van overstromingen voor de aspecten opgaande begroeiing, vegetatie, aquatische ecosystemen en historische bouwkunde, Alterra rapport 709, Alterra, Wageningen, 2003.
Olsson, P., Folke, K., and Berkes, F.: Adaptive comanagement for building resilience in social–ecological systems, Environ. Manage., 34, 75–90, 2004.
Oughton, E. and Bracken, L.: Interdisciplinary research: framing and reframing, Area, 1–10, 2009.
Page, B. and Kaika, M.: The EU Water Framework Directive: Part 2, Policy innovation and the shifting choreography of governance, Eur. Environ., 13, 328–343, 2003.
Pappenberger, F. and Beven, K. J.: Ignorance is bliss: or seven reasons not to use uncertainty analysis, Water Resour. Res., 42, W05302, 2006.
Pappenberger, F., Harvey, H., Beven, K., Hall, J., and Meadowcroft, I.: Decision tree for choosing an uncertainty analysis methodology: a wiki experiment, http://www.floodrisknet.org.uk/methods; http://www.floodrisk.net, Hydrol. Process., 20, 3793–3798, 2006.
Raaijmakers, R., Krywkow, J., and van der Veen, A.: Flood risk perceptions and spatial multi-criteria analysis: an exploratory research for hazard mitigation, Nat. Hazards, 46, 307–322, 2008.

Refsgaard, J. C., van der Sluijs, J. P., Højberg, A. L., and Vanrolleghem, P. A.: Uncertainty in the environmental modelling process – a framework and guidance, Environ. Model. Softw., 22, 1543–1556, 2007.
Roo, A. P. J. d. and Beven, K. J.: Development of a European flood forecasting system, Int. J. River Basin Manage., 1, 49–59, 2003.
Sauer, A., Schanze, J., and Walz, U.: A GIS-Based Risk Assessment Methodology for Flood Pollutants, in: Flood Risk Management: Research and Practice, Proceedings of the European Conference On Flood Risk Management Research Into Practice (Floodrisk), Oxford, UK, 30 September – 2 October 2008, edited by: Samuels, P., Huntington, S., Allsop, W., and Harrop, J., CRC Press/Balkema, Leiden, 1429–1438, 2009.
Sjöberg, L.: Factors in risk perception, Risk Anal., 20, 1–11, 2000.
Sjöberg, L.: The allegedly simple structure of experts' risk perception: an urban legend in risk research, Sci. Technol. Hum. Val., 27, 443–459, 2002.
Slovic, P.: Trust, emotion, sex, politics, and science: surveying the risk-assessment battlefield, Risk Anal., 19, 689–701, 1999.
Stamm, K., Clark, F., and Eblacas, P.: Mass communication and public understanding of environmental problems: the case of global warming, Public Underst. Sci., 9, 219–237, 2000.
Stuyt, L., Reinders, J. E. A., Hoek, E. E. v. d., Hermans, E. G. M., Muinck Keizer, M. d., and Icke, J.: The Environmental Impact of Flooding of the Dutch Delta-Metropole, in: Advances in Natural and Technological Hazards Research, edited by: Beguim, S., Stive, M., and Hall, J. W., Springer, Dordrecht, 107–129, 2007.
Tapsell, S. M., Priest, S. J., Wilson, T., Viavattene, C., and Penning-Rowsell, E. C.: A New Model to Estimate Risk to Life for European Flood Events, in: Flood Risk Management: Research and Practice, Proceedings of the European Conference On Flood Risk Management Research Into Practice (Floodrisk), Oxford, UK, 30 September – 2 October 2008, edited by: Samuels, P., Huntington, S., Allsop, W., and Harrop, J., CRC Press/Balkema, Leiden, 933–943, 2009.
Tompkins, E. L. and Adger, W. N.: Does Adaptive Management of Natural Resources Enhance Resilience to Climate Change?, Ecol. Soc., 9, 10, 2004.
Twigger-Ross, C., Fernandez-Bilbao, A., Colbourne, L., Tapsell, S., Watson, N., Kashefi, E., Walker, G., and Medd, W.: Putting People and Places at the Centre: Improving Institutional and Social Response to Flooding, in: Flood Risk Management: Research and practice, Proceedings of the European Conference On Flood Risk Management Research Into Practice

(Floodrisk), Oxford, UK, 30 September – 2 October 2008, edited by: Samuels, P., Huntington, S., Allsop, W., and Harrop, J., CRC Press/Balkema, Leiden, 849–854, 2009.
Vangen, S. and Huxham, C.: Nurturing collaborative relations, Building trust in interorganizational collaboration, J. Appl. Behav. Sci., 39, 5–31, 2003.
Vinet, F.: From hazard reduction to integrated risk management: toward adaptive flood prevention in Europe, WIT T. Ecol. Environ., 118, 113–122, 2008.
Wardekker, J. A., van der Sluijs, J. P., Janssen, P. H. M., Kloprogge, P., and Petersen, A. C.: Uncertainty communication in environmental assessments: views from the Dutch science-policy interface, Environ. Sci. Policy, 11, 627–641, 2008.
Weigold, M. F.: Communicating science: a review of the literature, Sci. Commun., 23, 164–193, 2001.
Wynne, B.: Misunderstood misunderstanding: social identities and public uptake of science, Public Underst. Sci., 1, 281–304, 1992.
Wynne, B.: Misunderstood Misunderstandings: Social Identities and Public Uptake of Science, in: Misunderstanding Science? The Public Reconstruction Of Science And Technology, edited by: Irwin, A., and Wynne, B., Cambridge University Press, Cambridge, New York, 19–46, 1996.