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Probabilistic flood warnings – Do eight out of ten people prefer them?

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PROBABILISTIC FLOOD WARNINGS – DO EIGHT OUT OF TEN PEOPLE PREFER THEM?

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Key Words

Flood warning; probability

Abstract

The introduction of probabilistic flood forecasts by the Environment Agency over the next few years could provide flood incident responders with better information for managing flood events. The inclusion of probability in internal and external communications of flood forecasts and warnings however, presents challenges that need to be anticipated. It is often difficult to present probabilistic data in a concise and easily comprehensible manner. To address these challenges the Environment Agency commissioned research to investigate the following:

- The current “best practices” used to communicate probability and uncertainty in warnings for a range of natural hazards worldwide;
- The extent to which professional partners and the public comprehend information about probability both generally and with respect to flood warnings;
- What Environment Agency staff, professional partners and the public require and how they would use probabilistic flood warnings to improve their response to floods.

The current practice review indicated that there is no single effective approach to communicating probabilistic and uncertainty information as communications are interpreted within personal, social or institutional contexts. The research demonstrated a high variability in the interpretation of qualitative descriptions of uncertainty and understanding of quantitative descriptions of uncertainty.

A series of workshops and focus groups were held with Environment Agency staff, professional partners and the general public to gain a better idea as to how probabilistic flood warnings could be communicated effectively to meet their respective needs. These indicated that there was general support from Environment Agency staff and professional partners for the introduction of probability-based flood warnings in principle. Certain forms of probabilistic warnings were found to be “useful” by 88% of the Environment Agency flood incident management staff who replied to a survey undertaken as part of the research.

The primary benefit of probabilistic warnings was seen as an increase in lead time which would provide the potential to prepare for a flood more effectively. Professional partners indicated that regular updating of probability estimates would enable the response to be adapted as knowledge about the impending situation developed. However, some professional partners also expressed concerns that probabilistic warnings might be misinterpreted by the public and indicated that such warnings should only be used for organisations with civil contingency responsibilities.

The research carried out will help the Environment Agency to determine what new methods for issuing warnings and disseminating flooding information will most be most useful to Environment Agency and partner organisations' staff.

1. INTRODUCTION

Whilst it is widely acknowledged that probability and uncertainty are key issues related to flood forecasting, how to communicate and disseminate probabilistic flood forecasts and warnings presents further challenges. The draft Environment Agency Strategy poses the question as to how the Environment Agency can present probabilistic forecasts and warnings and how other stakeholders can make use of them. The Pitt review of the June 2007 floods has also stated that in future probabilistic flooding warnings should be provided to professional partners (Pitt, 2008). The Environment Agency is moving towards probabilistic flood forecasting and is currently piloting both probabilistic coastal and fluvial forecasting systems.

This paper details research that was carried out to establish the requirements and mechanisms for communicating probability and uncertainty for different potential end users within flood forecasts and warnings, using information from relevant sources, consultations and other appropriate research methodologies. The specific objectives of the research included:

- Determining how public and professional partners make sense of information about probability and uncertainty from literature and other relevant sources of information.
- Understanding how information about probability and uncertainty is used and communicated internationally.
- Establishing what professional partners and the public understand about probability and uncertainty and how they would use this information if it was incorporated in flood warnings.
- Understanding what Environment Agency flood risk management teams and incident response duty officers require, and how they would use

information about probability and uncertainty within flood warnings.

- Using the results from the research to inform a policy decision on whether the Environment Agency communicates uncertainty and probabilistic information externally in the future.

In this paper it is important that the reader understands the difference between the terms “flood forecasting” and “flood warning” as these are often used interchangeably. A flood forecast is a forecast of flood levels or flows before they occur. A flood warning is designed to warn members of the public and emergency responders of the potential impact of imminent flooding.

2. REVIEW OF THE CURRENT LITERATURE

As part of the research three literature reviews were undertaken covering:

- How the public and professional partners make sense of information about probability and uncertainty and methods that are used to communicate probability in areas such as health care and medicine.
- Defra/Environment Agency flood and coastal erosion risk management literature relevant to communicating probability and uncertainty in flood warnings.
- A review of methods used internationally in the fields of natural hazards, climate change and weather forecasting to communicate and disseminate probability and uncertainty in warnings.

Interestingly it was found that although there are examples of probabilistic flood forecasting systems that have been implemented outside the UK (e.g. in the USA and Finland) there are no examples of probabilistic flood warnings that have been

developed to communicate these forecasts (Environment Agency, 2008c). Limited end user surveys of different examples of communicating probabilistic information (e.g. in some weather forecasts) suggest that end users prefer probabilistic information displayed graphically, as symbols or in the form of a map together with text (WMO, 2007 and 2008). However, such conclusions may be dependent on the context in which surveys were undertaken and related to what type of information is being conveyed.

With respect to aiding the understanding of a probabilistic warning there is research that indicates that qualitative expressions of probability (e.g. “very likely”, “possibly”) are interpreted in different ways by different people and that quantitative probabilities expressed in percentage terms are more readily understood than other formats. There is limited research on how the public and professional partners understand probabilistic information related

to imminent natural hazards; what is available suggests that the public often has a greater understanding of probabilistic information than they are given credit for.

3. APPROACH TO THE RESEARCH

The research was carried out via a series of focus groups, workshops and surveys. Four focus groups each comprising eight people were held in Fleetwood, Oxford, Kinnel Bay and Purley near Reading. These were used to gain an insight into the public’s understanding of probabilistic warning information and its communication. Two workshops were held with professional partners in London and Leeds to obtain their views on probabilistic flood warnings. The Environment Agency staff’s understanding of probabilistic information, its communication and their requirements was gained via a series of workshops and a survey of flood incident management staff that mainly comprised Flood Warning Duty Officers.

Likelihood of a “Severe Flood Warning”

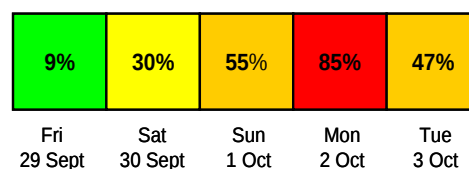
Fri 29 Sept	Very unlikely
Sat 30 Sept	Unlikely
Sun 1 Oct	Probable
Mon 2 Oct	Very likely
Tue 3 Oct	Probable

Meaning of severe flood warning:

Act now! Severe flooding is expected with extreme danger to life and property.

View 1 Example of a flood warning including qualitative probabilistic information

Probability of a “Severe Flood Warning”



Meaning of warning:

Act now! Severe flooding is expected with extreme danger to life and property.

View 2 Example of a flood warning including quantitative probabilistic information

(Source: Environment Agency, 2009)

Figure 1 Examples of mock up probabilistic flood warnings used in the research

It was not the purpose of this research to develop new flood warning codes. However, it was necessary to produce warnings incorporating probability in different ways to use in the research, in order to answer the question “what could a probabilistic flood warning look like?” Mock up flood warnings were produced that incorporated probabilistic information in different formats, so that these could act as a focus for the research. Examples of some of the mock ups used are shown in Figure 1.

4. RESEARCH INTO THE PUBLIC’S UNDERSTANDING OF PROBABILISTIC WARNING INFORMATION AND ITS COMMUNICATION

4.1 Background to the focus groups

The research team chose to use focus groups as a method to enable dialogue with members of the public regarding probability and uncertainty. Focus groups enable the type of two-way dialogue and interaction which is necessary to explore carefully and sensitively what may be rather involved and unfamiliar ideas for participants. Enabling discussion between participants was also designed to reveal the type of debate and deliberation that would be generated by the introduction of probabilistic information into hazard warnings and the processes through which different formats and delivery methods would be evaluated.

Four focus groups were carried out in Oxford, Purley near Reading, Fleetwood and Kinnel Bay in Wales. These locations were chosen using guidance from the Environment Agency regional staff and the project steering group. Oxford and Purley in Reading have experienced fluvial flooding from the River Thames in the past three years and Fleetwood and Kinnel Bay are coastal areas that had experienced flooding at some point in the past. The research team drew up a recruitment profile for each of the four areas, taking note of discussions with Environment Agency

regional staff and the project steering group. This profile was then given to a professional recruiter who visited each area and recruited as closely to the profile as far as practicable. Factors specified in the profile were a balance of male/female participants, balance of ages, type of housing (e.g. such as detached/terraced housing, rented accommodation/owner occupier), balance of socio-economic status, and flood experience.

Thirteen of the 16 participants in Oxford and Purley near Reading had experienced fluvial and groundwater flooding. All of the 16 participants in Fleetwood and Kinnel Bay had been flooded through seawater, groundwater and water contaminated with sewage. The last occurrence of flooding in Fleetwood and Kinnel Bay occurred in 1977 and 1990 respectively compared to 2007 in Purley and 2008 in Oxford, both of which flood frequently (Environment Agency, 2009).

4.2 Findings from the focus groups

Participants in the focus groups generally welcomed the possibility of receiving probabilistic warnings if it would enable them to receive advance warning and, therefore, make more informed choices. Advance warning was seen to be of particular benefit for vulnerable people in the community, such as those needing regular medicine, those with babies or young children. Being provided with simple probability information was thought to be a useful means of communicating uncertainty. Since uncertainty is inferred anyway, being informed of the levels of uncertainty and forecasted probabilities was seen as potentially useful additional information (Environment Agency, 2009).

There was much discussion of what information would be most useful to have in probabilistic warnings, the scale of area that such information should relate to, in what format they should be and how they should be communicated to or made accessible to the public. These are key factors to take into account in any future development of probabilistic warnings for

the public, and it is crucial to remember that not all people have the same information needs.

Most participants felt that it would be useful to be alerted to the threat of flooding through present means (e.g. the media, Floodline Warnings Direct, door knocking), and have probabilistic information provided on the Environment Agency's website for those who wished to seek further information. There was no clear consensus as to how probability information should best be conveyed but some general patterns in the groups' discussions were identified. Simple qualitative terms alone (such as 'likely', or 'probable') were not generally welcomed as they were seen to be too open to interpretation, but when combined with percentage indicators this was seen as more convincing (Environment Agency, 2009).

There would appear to be a tension between warning people early enough so that they can take appropriate action, but not so early that the forecasts keep changing, because then, future forecasts might be perceived as not being accurate or reliable. However, it is a feature of probabilistic forecasts and indeed flood forecasts in general that they will often change on a day-to-day, or an hour-to-hour basis depending on the size of the catchment. It is possible that engaging in dialogue about levels of uncertainty in forecasts may provide better public understanding and acceptance of what may otherwise be perceived as forecasting errors rather than uncertainty. It is important to note that participants felt that too many "false alarms" could eventually mean a loss of trust in the accuracy of the forecasts. However, it is unclear how the participants perceive false alarms. For example, if a "Severe Flood Warning" was issued with a 75% probability attached to it and then a flood did not occur would the participants classify this as a "false alarm"?

5. RESEARCH INTO PROFESSIONAL PARTNERS' UNDERSTANDING OF PROBABILISTIC WARNING INFORMATION AND ITS COMMUNICATION

5.1 Background

Under the Civil Contingencies Act 2004, emergency responders are categorised into Category 1 and 2 responders. Category 1 (core) responders are those organisations at the core of emergency response. For flooding the key Category 1 responders are: Ambulance services; Environment Agency; Fire and rescue services; Local authorities; National Health Service and Health Protection Agency; Police forces.

Category 2 responders are "co-operating" bodies who, while less likely to be involved in the heart of planning work, will be heavily involved in incidents that affect their sector. They include utility companies, telecommunications companies and the Highways Agency.

As part of the research two workshops were held with professional partners in autumn 2008, one in London and one in Leeds. The purpose of these workshops was to determine the most appropriate and effective way that the Environment Agency can use information on probability and uncertainty within its flood warning communications with its professional partners. The specific objectives of the workshops were to:

- Provide emergency responders with information about the Environment Agency's thinking so far in relation to probabilistic flood warnings.
- Explore with representatives of the Environment Agency's partner organisations.
- How they currently use probabilistic information in analogous situations.

- How they currently apply their understanding of probabilistic information to flood situations.
- How they might respond to changes in probabilistic information and warnings that the Environment Agency might propose.
- Gather views about how the Environment Agency might take this idea forward.
- The findings of the research are discussed below.

5.2 Findings from the professional partners

The research found that professional partners seem to use the current “Flood Watch” and “Flood Warning” codes as a trigger to seek extra information, rather than a trigger for action. The research suggested that often the Environment Agency Areas where professional partners have taken the most notice of flood warnings is where they have strong working relationships with the Flood Warning Duty Officers. The Environment Agency needs to generate and maintain trust with professional partners if probabilistic warnings are to lead to effective responses. This means ensuring that if key members of staff change, there are other members of the team who also have a relationship with the professional partners.

Professional partners and other end users would like the Environment Agency’s flood warning service to be better tailored to the needs of users as well as responding to the Environment Agency’s own priorities. Making qualitative and/or quantitative assessments of probability and uncertainty is part of the every day work of emergency responders. This research indicates that professional partners would be very interested in being involved in developing a “fit for purpose” probabilistic warning system. There is a clear opportunity for the Environment Agency to use partners’ experience and goodwill to develop probabilistic warnings collaboratively.

One source of difficulty in relation to probabilistic information is that there appear to be inconsistencies in the way terminology is used by the Environment Agency, the Met Office and different professional partners. Agreement on the terminology to be used for probabilistic flood warnings will lead to greater consistency in the way that information about uncertainty is communicated to professional partners and members of the public, and will help to avoid situations where inconsistencies lead to confusion and lack of or ineffective response.

6. ENVIRONMENT AGENCY STAFF’S UNDERSTANDING OF PROBABILISTIC INFORMATION, ITS COMMUNICATION AND THEIR REQUIREMENTS

6.1 Background

The Environment Agency staff’s understanding of probabilistic information, its communication and their requirements was gained via the following:

(i) Telephone Interviews with two senior Environment Agency staff: A regional flood forecaster and an Area Manager recently responsible for leading the Environment Agency’s review of the 2007 floods.

(ii) An initial workshop with eight Environment Agency flood forecasting and warning staff, focussing on the current management of risk and uncertainty within flood warnings, the role of information and the opportunities and risks associated with the use of probabilistic forecasting and warning information.

(iii) A self-completion questionnaire sent to Environment Agency flood forecasting and warning staff. Seventy-one completed questionnaires were received and analysed.

(iv) A final workshop held with 23 Environment Agency flood forecasting and warning staff. The purpose of the workshop was to provide an opportunity for

staff to develop ideas about what the Environment Agency could do to realise the potential benefits of using probabilistic information in flood warnings, and how it could address some concerns raised.

(v) Follow up interviews. In order to clarify some of the issues raised during the research, interviews were held with four members of the Environment Agency's forecasting and warning staff.

6.2 Findings from the Environment Agency

Over 80% of staff responding to the questionnaire said that they took probability and uncertainty into account, at least to some extent. The research found that currently Environment Agency staff take into account the uncertainty in flood forecasts in the following ways:

(i) Using different forecasting techniques and tools to confirm results

– It was recognised that individual pieces of information cannot give a complete picture of either the causes or consequences of flooding, and where possible staff use different sources of information to check results.

(ii) Using local knowledge and experience e.g. knowledge of the catchment and how it behaves and of where the vulnerable locations are located.

(iii) Assessing the confidence in the information that is being passed on, which could either be an assessment of the information itself or an assessment of the confidence of the person who is passing on the information.

(iv) Issues of time, having to take into account for example: how long is needed to take action, how long to wait before the forecasts are accurate.

It is worth noting that despite this evidence of the way that Environment Agency staff take uncertainty into account, there was some discrepancy between practitioners about how much uncertainty is currently communicated, both within the Environment Agency itself and to professional partners. It may be that this reflects differences in practices between regions, or that it is more

about differences between individuals' understanding of uncertainty or readiness to communicate it.

The survey of Environment Agency staff found that certain forms of probabilistic warnings were found to be "useful" by 88% of the Environment Agency flood incident management staff. When questioned about the benefits of probabilistic flood warnings, of the nine options provided in the survey the top three benefits were identified as follows:

1. Show the user the degree of uncertainty related to the meteorological inputs in the flood forecast.
2. Increased lead times helping professional partners to plan the resources they need to address an incident more effectively.
3. Provide extra information which could help to make the decision to issue a flood warning.

When surveyed regarding their concerns about probabilistic flood warnings, the top three concerns identified were as follows:

1. Members of the public will not understand probabilistic warning information.
2. The Environment Agency's computer systems will not be able to cope with the increased data and model run times.
3. There will be more false alarms.

The research indicated that there is still a debate within the Environment Agency about what kind of "probabilistic warnings" are being proposed and how they would be used. As a result staff in different roles tend to make different interpretations. Flood Warning Duty Officers and Operations staff tend to be less clear than flood forecasting staff about how probabilistic information would be used and the potential impact on their work.

Most staff recognise that probabilistic information could provide greater certainty about when flooding might happen. However, they feel that probabilistic information is only one way of improving the flood warning system. Some staff were

concerned that the implementation of probabilistic flood warnings could divert resources away from other investments such as improving the monitoring, hydrological and hydraulic models that support the flood forecasting systems.

Staff expressed concerns that the Environment Agency's computing systems, hydraulic models and communication systems might not be able to cope with the additional information generated by probabilistic forecasts and warnings.

Given the variable coverage of forecasting models, staff felt that introducing probabilistic forecasting and warnings in parts but not all of England and Wales could have negative consequences such as different services generating conflicting warnings, difficulties in joining up warning information for professional partners or businesses who operate in different Environment Agency Areas and ultimately, loss of trust.

Environment Agency Area Offices take different approaches in deciding whether to issue warnings and interact with the end users (e.g. professional partners). While these are sometimes influenced by the use of telemetry and the forecasting data available, they often reflect the application of professional judgment, knowledge and experience to the interpretation of uncertainty in different geographical and social contexts.

Some staff felt that it would be unhelpful to expose the level of uncertainty in the current forecasts externally and that the Environment Agency could be seen as not being able to meet its responsibilities or to be trying to offload these responsibilities on others.

7. CONCLUSIONS AND RECOMMENDATIONS

The 'public' and the 'professional partners' and Environment Agency staff are not homogenous groups. A "one size fits all" approach to probabilistic warnings will not be successful. From the research it was

clear that all three groups wanted to have more certainty about flooding in terms of when, where and how it was going to happen, something which they hoped could be delivered by a probabilistic flood warning. There is an appetite amongst professional partners and the public to receive probabilistic flood warnings if an improvement in warning lead times and accuracy can be achieved.

The research recommends the following:

- Further work is required to establish:
 - What people think a probabilistic warning is going to deliver (e.g. longer lead times).
 - What is the most appropriate way of warning those people to give them improved certainty.
 - What role could probabilistic information of the sort that the Environment Agency is developing play in providing flood warnings that meet the needs of the Environment Agency customers (i.e. professional partners and members of the public)?
- The information content of the "Flood Watch" and "Flood Warning" codes should be revisited and possibly redefined if probabilistic flood warnings are to be introduced.
- The Environment Agency should address concerns about how their staff will cope effectively with the additional information that will be generated by probabilistic flood forecasts and warnings.
- The introduction of probabilistic flood forecasts should complement ongoing improvements to the hydrometric and flood forecasting networks.
- The Environment Agency should encourage staff to be open about the uncertainties inherent in flood forecasting and warning in their engagement with professional partners, businesses and members of the community.
- The Environment Agency should work with staff to ensure there is understanding and clarity around the potential use of probabilistic

information in order to build internal “buy in” to probabilistic forecasts and warnings.

- The Environment Agency should provide further professional development to enable their staff to make better sense of probabilistic forecasts, in terms of what they mean and the way in which they can be communicated.
- There is a clear opportunity for the Environment Agency to use professional partners’ experience and goodwill to develop probabilistic warnings collaboratively. A forum should be set up with professional partners to work together on further developing probabilistic flood warnings.
- The lessons learnt from Environment Area Offices that have a close working relationship with professional partners are shared nationally as this will greatly assist the successful uptake of probabilistic warnings by professional partners.
- Different forms of probabilistic warnings should be developed by experts in communication and graphic design, in conjunction with the Environment Agency and the public. Comprehensive research will need to be carried out with the public to gain an understanding of their interpretation of these warnings.
- The research indicates that there is an appetite for probabilistic warnings amongst members of the public who have experience flooding. However, the Environment Agency should carry out further research with a broad range of the public to test probabilistic flood warning materials once these have been developed. The research should include both people who have experienced flooding and others who have not, in order to see how their responses differ.
- Further work needs to be carried out with the public to assess the most effective media via which probabilistic flood warnings can be disseminated to them.
- Further work needs to be carried out to understand how the public perceive “false” warnings in probabilistic terms and what effect this may have on their response.
- The Environment Agency should consider the technical and operational impacts of providing a more localised probabilistic flood warning service than is currently technically possible to make available to the public.

8. ACKNOWLEDGEMENTS

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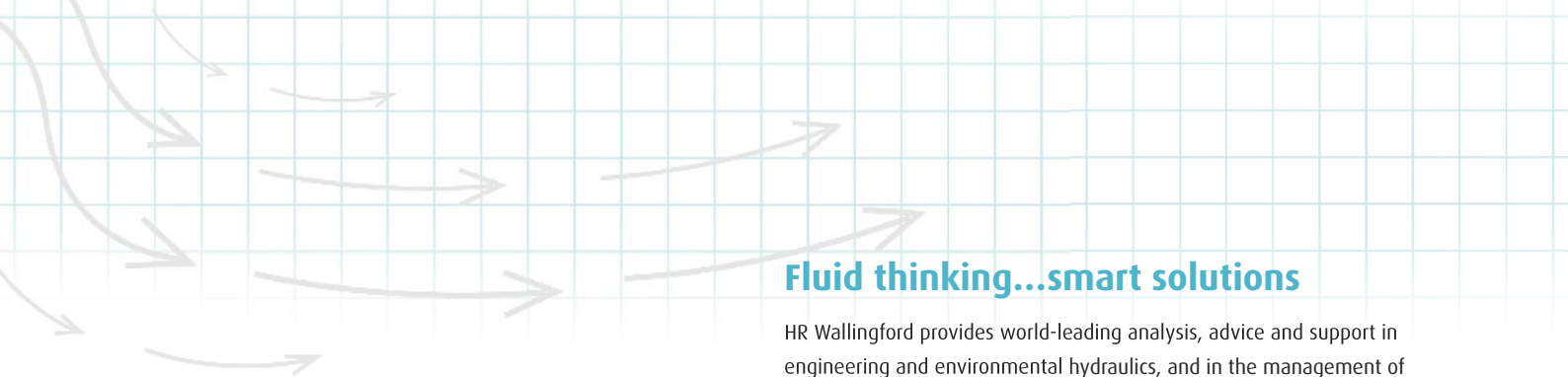
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