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Communicating risk and uncertainty in flood warnings: a review of Defra/Environment Agency FCERM literature

Science project SC070060/SR2

Flood and Coastal Erosion Risk Management Research and Development Programme

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It's our job to make sure that air, land and water are looked after by everyone in today's society, so that tomorrow's generations inherit a cleaner, healthier world.

Our work includes tackling flooding and pollution incidents, reducing industry's impacts on the environment, cleaning up rivers, coastal waters, contaminated land and improving wildlife habitats.

This report is the result of research commissioned by the Environment Agency's Science Department and funded by the joint Environment Agency/Defra Flood and Coastal Erosion Risk Management Research and Development Programme.

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- **Delivering information, advice, tools and techniques**, by making appropriate products available to our policy and operations staff.

Steve Killeen

Head of Science

Executive summary

This report addresses Objective 2 of the Environment Agency Science project: ‘Communication and Dissemination of Probabilistic Flood Warnings’. Objective 2 is to:

Review output from parallel projects on flood warning communications to establish what personal or cultural factors require consideration for the communication of risk and uncertainty.

There are two associated tasks as part of Objective 2:

- Task 1 – collate relevant information from parallel Defra/Environment Agency Flood and Coastal Erosion Risk Management R&D projects;
- Task 2 – establish from the previous research the significance of circumstance, personal experience and culture that require consideration for the communication of risk and uncertainty.

The review starts by characterising the current flood forecasting and warning system, in order to able to understand where and how probabilistic information might be used within the flood forecasting and warning system. The review then discusses the research to date on the social aspects of probabilistic flood forecasting in general.

The remit for the review covered only Joint Defra/Environment Agency Joint Defra/Environment Agency Flood and Coastal Erosion Risk Management R&D Programme (FCERM) projects focused on flooding. The projects examined included both predominantly technical and predominantly social research projects and consider information from both types of projects alongside each other. In addition, it was felt appropriate to draw on information about the summer 2007 flooding: the Environment Agency’s report into the lessons learnt from summer 2007 floods (Environment Agency 2007a) and the Pitt Review (Pitt 2008) which collected information on flood warnings from a number of perspectives.

In examining the factors that influence response to flood warnings, the literature indicates that a range of variables together determine flood warning response either by inhibiting or enabling response by individuals and organisations. As well as the characteristics of the warning message, individual factors and social factors influence whether a response is made to a warning. All these variables are relevant to the design of any future warnings. The provision of information is only one of the variables. The way that information is understood and acted on is often influenced by other variables such as trust in the source of the information or warning. More information will not necessarily improve responses to flooding.

The review found little information about differences between different groups (members of the public, professional partners, businesses) in terms of their perception of risk and uncertainty in flood warnings:

- There is a lack of information about the way that professional partners use warning information to inform their response to flooding. However, the needs of professional partners are likely to vary according to their scientific background and how they use the information. This underlines the conclusion that a ‘one size fits all’ approach is unlikely to be effective.
- Almost no relevant information was found on businesses, for example on how they use flood warning information, their perceptions of risk and uncertainty in relation to flooding or whether there are any significant differences in response between businesses of different sizes and characteristics.

One of the potential benefits of probabilistic flood warnings perceived by Environment Agency staff and professional partners is the possibility of giving earlier warnings. These could be of particular benefit to certain groups of people and emergency responders who may need more time to make preparations for flooding.

The review has brought out a useful distinction between decision uncertainty and scientific uncertainty. The provision of probabilistic information in flood warning can be considered as making transparent one aspect of scientific uncertainty. To what extent it reduces either scientific uncertainty or decision uncertainty remains an empirical question.

List of abbreviations

ABC	Area Base Controller
AFWDO	Assistant Flood Warning Duty Officer
CFF	Coastal Flood Forecasting
EDO	Emergencies Duty Officer
EFAS	European Flood Alert System
ERA	Extreme Rainfall Alert
ES	Emergency Services
EWF	Emergency Workforce
FCERM	Flood and Coastal Erosion Risk Management
FDO	Forecasting Duty Officer
FIM	Flood Incident Management
FRMRC	Flood Risk Management Research Consortium
FWDO	Flood Warning Duty Officer
GIS	Geographical Information System
HEPEX	Hydrologic Ensemble Prediction EXperiment
HSE	Health and Safety Executive
IFRM	Incident and Flood Risk Management
JCHMER	Joint centre for Hydrometeorological Research
MDO	Monitoring Duty Officer
MIP	Major Incident Plan
MORECS	Met Office Rainfall and Evaporation Calculation System
NBC	National Base Controller
NDM	National Duty Manager
NDO	National Duty Officer
NFFS	National Flood Forecasting System
NFWDO	National Flood Warning Duty Officer
NIRS	National Incident Reporting System
ODO	Operations Duty Officer
PR	public relations
RBC	Regional Base Controller
RCC	Regional Control Centre
RDO	Regional Duty Officer
SITREP	situation report
SME	small and medium enterprise
WP	work package

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1 Aim, scope and method

1.1 Aim and tasks

This review addresses Objective 2 of the Environment Agency Science project, 'Communication and Dissemination of Probabilistic Flood Warnings'. Objective 2 is to:

Review output from parallel projects on flood warning communications to establish what personal or cultural factors require consideration for the communication of risk and uncertainty.

There are two associated tasks as part of Objective 2.

- Task 1 – collate relevant information from parallel Defra/Environment Agency Flood and Coastal Erosion Risk Management R&D projects;
- Task 2 – establish from the previous research the significance of circumstance, personal experience and culture that require consideration for the communication of risk and uncertainty.

1.2 Scope of the review and definition of key terms

It was clear once the review was underway that there was a need to widen the scope of the review to include:

- a characterisation of the current flood forecasting and warning system;
- details of research to date on the social aspects of probabilistic flood forecasting in general.

This extension was felt to be important to be able to understand where and how probabilistic information might be used within the flood forecasting and warning system.

The remit for Objective 2 covered only Joint Defra/Environment Agency Joint Defra/Environment Agency Flood and Coastal Erosion Risk Management R&D Programme (FCERM) projects focused on flooding. Details of the projects examined are given in Appendix A. This list includes both predominantly technical and predominantly social research projects, and part of this review was to consider information from both types of projects alongside each other. Furthermore, only projects relating to flood risk management were considered.

In addition, it was felt appropriate to draw on the Environment Agency's report into the lessons learnt from summer 2007 floods (Environment Agency 2007a). The Pitt Review (Pitt 2008) was also consulted as this collected information on flood warnings from a number of perspectives.

Because of the wide literature on risk and uncertainty, it was agreed that there would be specific definitions for 'risk' and 'uncertainty' for the three reviews (Objectives 1–3).

The definitions developed in Objective 1 are produced below:

- **Information about risk**. The focus of the project is on the potential inclusion of probabilistic information in flood warnings. For this reason, 'information about risk' is defined for this review as information about likelihood, chance or probability. This narrows the review to exclude research about information on consequences alone (e.g. the extent or severity of a flood), or information on what to do in an emergency situation (e.g. emergency procedures in aircraft) where likelihood is not also being conveyed. It also excludes a detailed review of research on risk perceptions per se, rather than on how information is understood and made sense of.
- **Information about uncertainty**. In the context of the provision of probabilistic information about adverse consequences, it is difficult to neatly disentangle risk from uncertainty. The two terms are often used interchangeably, or given different meanings by different groups of scientists and professionals (Faulkner et al. 2007). A statement of a probability about whether or not an event will occur is, in one sense, also a statement about the lack of certainty as to whether or not it will occur – although there are other forms of uncertainty involved such as the uncertainty of the estimation of event likelihood. For the purposes of the review therefore, a tight distinction between risk and uncertainty was not maintained – although searches specifically for studies focusing on understandings and uses of information about uncertainty were made.
- **Probabilistic information***.* It is clear that in reality the distinction between probabilistic forecasting and probabilistic warning is not clear cut, rather it can be thought of as a continuum from forecasting to warning into which probabilistic information, in different formats, might be introduced. Given this, the term 'probabilistic information' is used in this review to describe information relating to probabilities and flooding.

2 Characteristics of the flood forecasting and warning system

2.1 Current flood incident management process

This section describes the current Environment Agency forecasting and warning system, looking particularly at the interfaces between those involved in:

- forecasting (regional forecasting duty officers and monitoring duty officers) and warning (flood warning duty officers);
- warning (flood warning duty officers) and recipients of warnings:
  - internally – operational duty officers, Area base controllers;
  - externally – members of the public, professional partners.

Knowledge of the components of the current system is necessary to enable a clear understanding of where probabilistic information would (and could) be used.

2.1.1 Components of the current system

In this report, the ‘current system’ refers to the process from detection through to response. As illustrated in Figure 2.1, the current system is made up of the following activities.

- **Detection**. This involves monitoring rainfall conditions from a range of sources, e.g. rain gauges, weather radar, tide levels and wind conditions.
- **Forecasting**. The Environment Agency carries out two types of flood forecasting – river (fluvial) and coastal.
  - River flood forecasting is the conversion of measured water levels and predicted/actual rainfall gathered at the detection stage to a forecast of future water levels through time.
  - Flooding on the coast is usually a combination of high tide, storm surge and waves. Daily forecasts of surge and wave conditions from the Met Offices are used by the Environment Agency, in combination with tide levels and local knowledge, to provide coastal flood warnings.
- **Warning**. This is the process of taking a forecast of flooding in an area and disseminating a message to those affected, advising them of the likely timing and severity. Environment Agency flood warnings are given only for river and coastal flooding.
- **Response**. This covers the response by emergency services and others to provide assistance in flood events, and the response by the at-risk community to move property, valuables and themselves to safety in a flood.

In reality this is not a purely linear process: there are overlaps and iterations between the different activities.

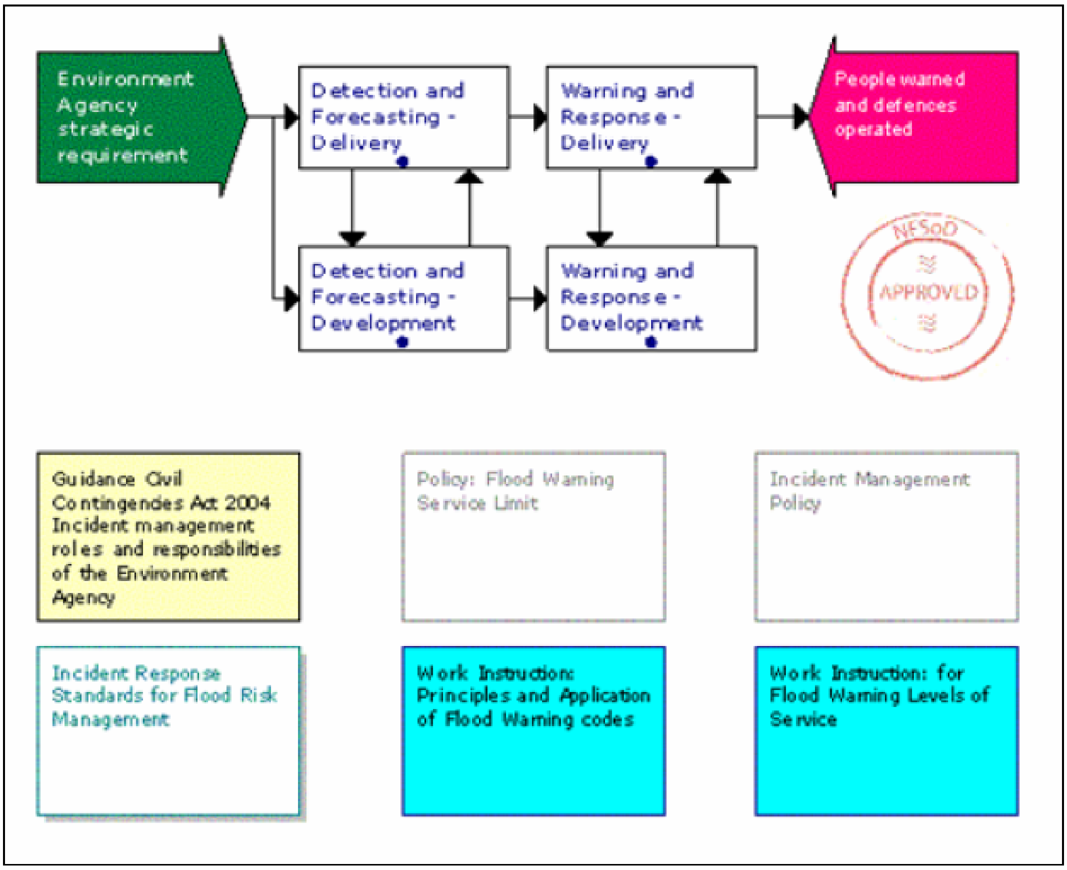


Figure 2.1 Diagram of the current flood forecasting and warning system (Environment Agency 2006a).

This project looks mainly at the interface between flood forecasting and flood warning, but with the important caveat that any warning system needs to be response-based, i.e. aiming to answer the question: 'How can effective responses to flooding be encouraged by the Environment Agency?'[1]

Any changes to the forecasting and warning system need to be examined in terms of how they contribute to answering this question.

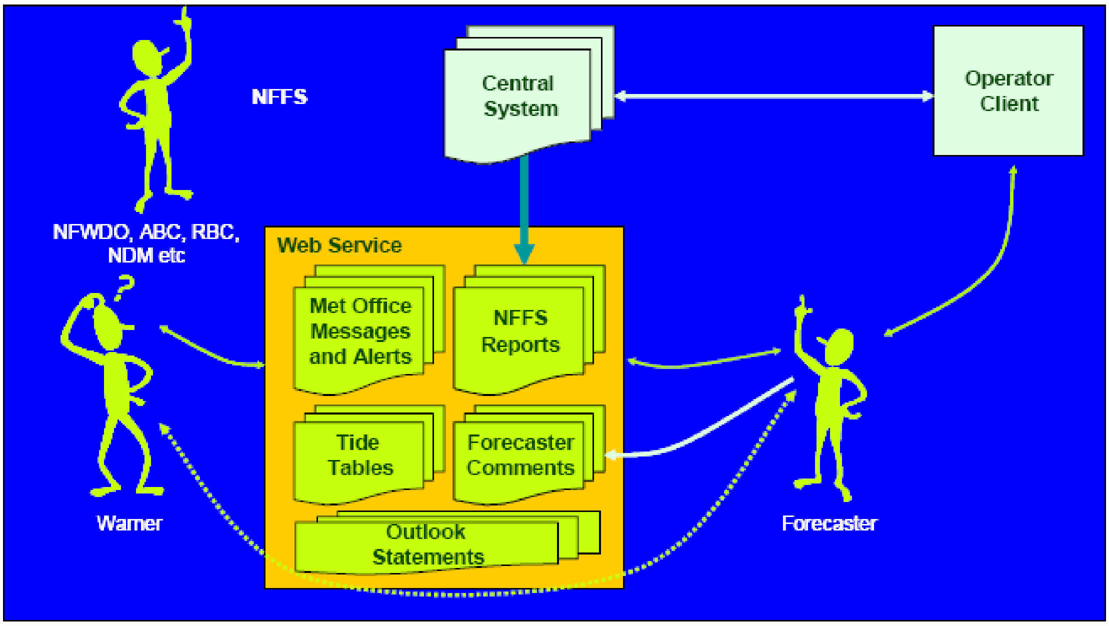
2.1.2 Main technical characteristics of the system

Figure 2.2 summarises what type of information is currently available to the regional flood forecaster and the flood warning duty officer.

[1] This was an important finding from Work Package 1 (WP1) Warnings of the FCERM project, 'Institutional and Social Responses to Flooding' (Twigger-Ross et al. 2008).

The National Flood Forecasting System (NFFS) is a central system. Its web service gives Flood Incident Management (FIM) staff common access to:

- NFFS forecasts;
- Met Office weather reports, alerts and warnings;[2]
- regional outlook statements;
- National Flood Warning Duty Officer (NFWDO) outlooks;
- tide tables.



Key: ABC = Area Base Controller; RBC = Regional Base Controller; NDM = National Duty Manager

Figure 2.2 Type of information currently available to forecasters and warners.

At present, weather forecasts come to the regional flood forecaster who takes a view as to whether or not the forecast should be 'promoted' (i.e. sent to the flood warning duty officer for action). The forecast joins a number reports on the web service from which the flood warning duty officer, based on available guidance (e.g. flood warning procedures), will issue a warning. When a forecast comes through that requires a warning to be issued, there is likely to be discussion between the forecaster and the 'warner' – especially if it is a flood warning or severe flood warning.[3].

Put very simply, what is currently sent through to the flood warning duty officer are deterministic flood forecasts giving a predicted level of the river. Most Environment Agency Regions have thresholds above which a specific type of warning is issued.

As noted by *Probabilistic flood forecasting: scoping study* (Sene et al. 2007), there are many areas of uncertainty at each stage within the current system. Two possible

[2] Met Office weather reports include the following formats: national five-day forecast; national tidal outlook; national monthly outlook and updates; regional weather forecast; weather charts; MORECS (Met Office Rainfall and Evaporation Calculation System); Met Office alerts; early severe weather warnings; flash severe weather warnings; heavy rainfall warnings; strong wind warnings; Storm Tide Forecasting Service alerts and Lennon Criteria Warnings for Bristol Channel (due soon).
[3] Personal communication from Andy Lane (regional forecaster North East).

uncertainty classification schemes developed in the scoping study are reproduced below (Tables 2.1 and 2.2); these provide an indication of the different types of what might be called 'scientific uncertainty'. It is clear that there are many sources of scientific uncertainty and the scoping study suggests that:

> 'Probabilistic flood forecasting techniques could in principle be applied to most forecasting problems within the Environment Agency' (Sene et al. 2007:59).

Table 2.1 A possible uncertainty classification scheme for fluvial flood forecasting using the Lettenmaier and Wood (1993) classification scheme.

Type	Primary Sources of Uncertainty	Secondary Sources of Uncertainty
1	- High Flow Ratings - Hydraulic/Routing Model Parameters - River channel/floodplain survey	Likely - Abstractions/discharges - Runoff from lateral catchments (Type 3 or 4) Depends on catchment/flood risk area - Tidal Boundary - Washland operations - Tidal Barrier operations - River control structures - Flood defence geometry and condition
2	- A combination of Types 1 and 3	- A combination of Types 1 and 3
3	- Rainfall Actuals - Rainfall Runoff Model Parameters - Antecedent Conditions	Likely - River Levels (if updating) - High Flow Ratings (if updating) Depends on catchment/flood risk area - Snowmelt - Reservoir operations - Flood defence geometry and condition
4	- Rainfall Forecasts - Rainfall Runoff Model Parameters - Antecedent Conditions	Likely - River Levels (if updating) - High Flow Ratings (if updating) Depends on catchment/flood risk area - Snowmelt - Reservoir operations/state - Flood defence geometry and condition

Source: Sene et al. (2007)

Table 2.2 A possible uncertainty classification scheme for coastal flood forecasting.

Dominant response	Primary Sources of Uncertainty	Secondary Sources of Uncertainty
Tidal Range	- Tidal level measurement - Astronomical tide estimates	- Wind speed and direction - Flood defence geometry - Bathymetry/morphology - Wave overtopping models - Wave measurements
Surge	- Wind speed and direction - Sub-grid scale (secondary) depressions - Surge propagation	- Tidal level measurement - Astronomical tide estimates - Flood defence geometry - Bathymetry/morphology - Wave overtopping models - Wave measurements
Wave	- Wind speed and direction - Flood defence geometry - Bathymetry/morphology - Shallow water effects - Wave overtopping models - Wave measurements - Wave-wave interactions - Wave breaking	- Tidal level measurement - Astronomical tide estimates

Source: Sene et al. (2007)

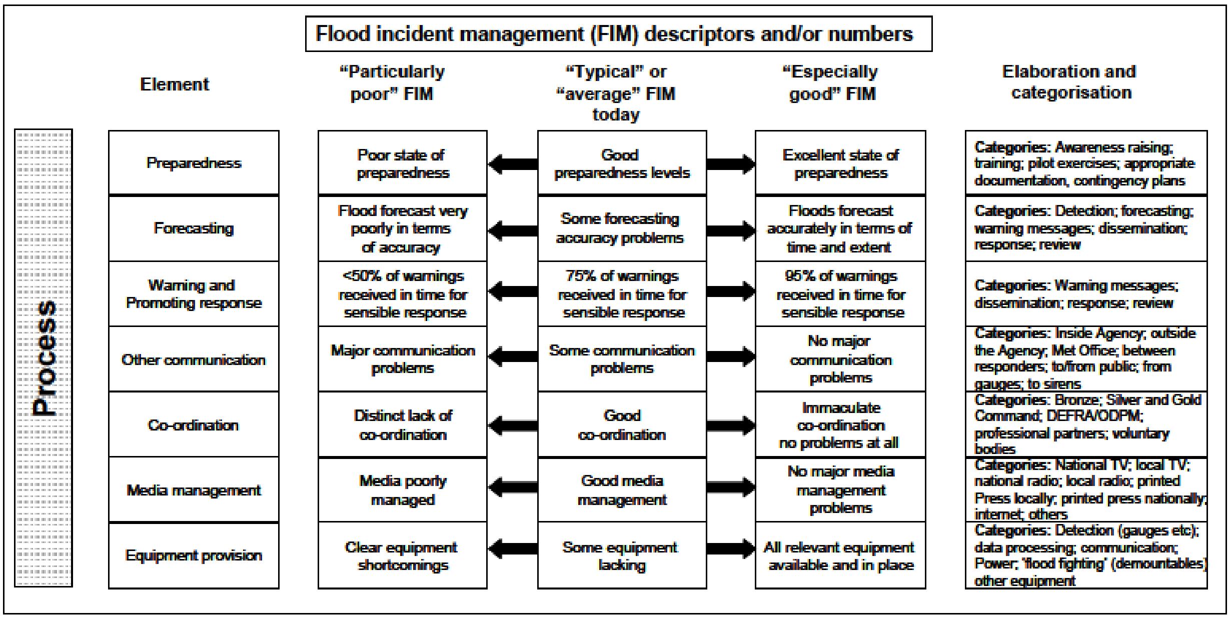
Details of the areas that flood forecasters felt would benefit most from useful probabilistic information are discussed in Section 2.2. The piloted products examined in Section 2.2 look at specific aspects of scientific uncertainty. However, it is important to be clear that:

- probabilistic forecasting is a general term covering a range of techniques to address scientific uncertainty;
- the different products being developed address only specific aspects of that uncertainty – albeit major ones such as rainfall prediction.

In terms of warning and response, Sene et al. (2007) suggested that approaches to uncertainty are less well developed. Figure 2.3, which is reproduced from an Environment Agency report of risk assessment for flood incident management, shows a simplified set of descriptors for the FIM process and provides some insight into what the key ‘failure’ points might be within the system. Essentially, the elements listed in the first column of Figure 2.3 are those that are crucial to the functioning of the process. The next three columns provide an indication of what ‘poor’, ‘good’ and ‘especially good’ flood incident management would look like.

Faulkner et al. (2007) make a useful distinction between scientific and decision uncertainty; the findings of this review suggest that much of the ‘forecasting uncertainty’ is best described as ‘scientific uncertainty’, while the type of uncertainty experienced within warning and response is largely ‘decision uncertainty’. The question is in what ways and to what extent can the implementation of probabilistic flood warning help to reduce that decision uncertainty. This is discussed further in Section 3.

Figure 2.3 A simplified set of descriptors for the flood incident management process.

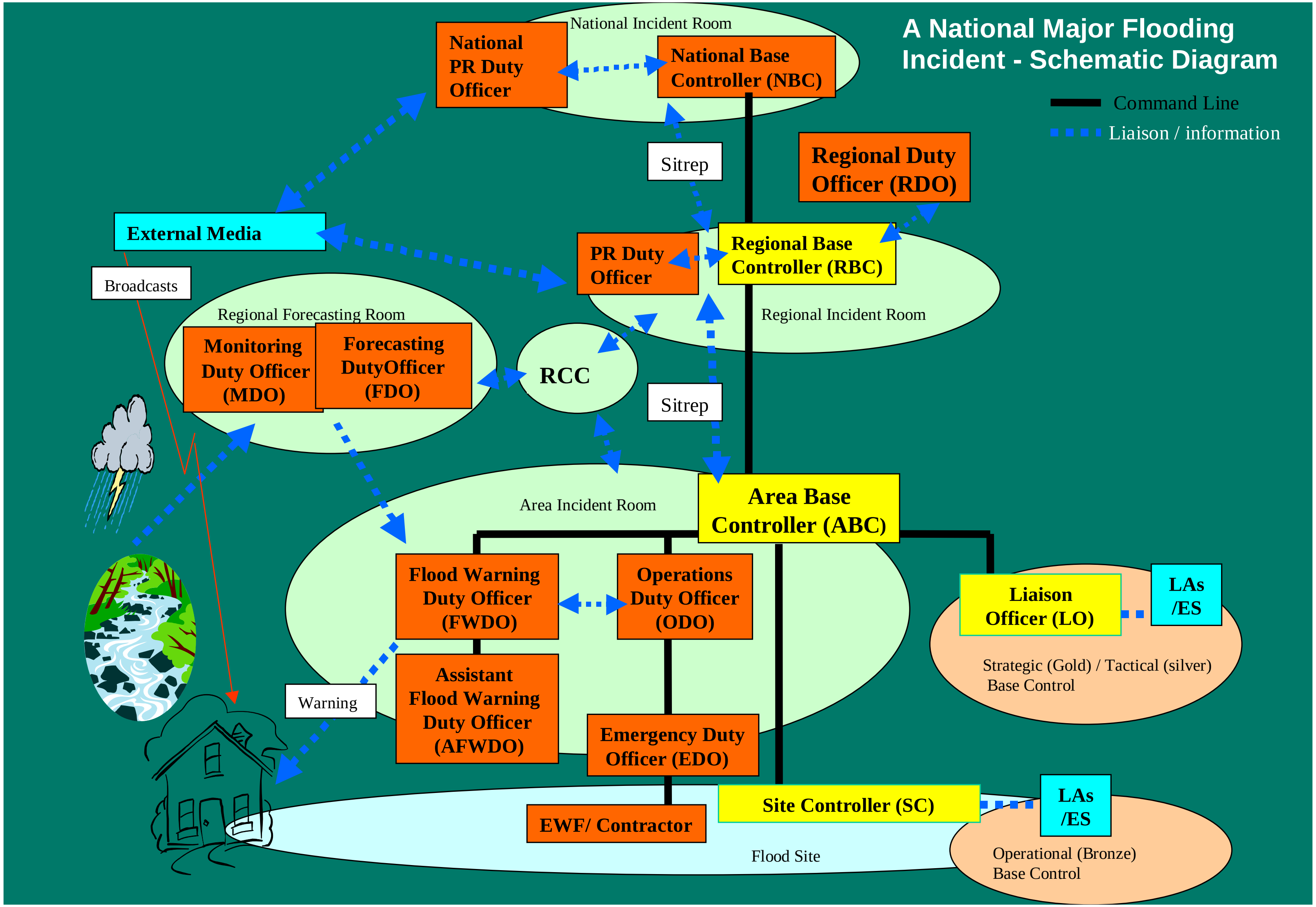


Source: Environment Agency (2007b)

2.1.3 Staffing characteristics

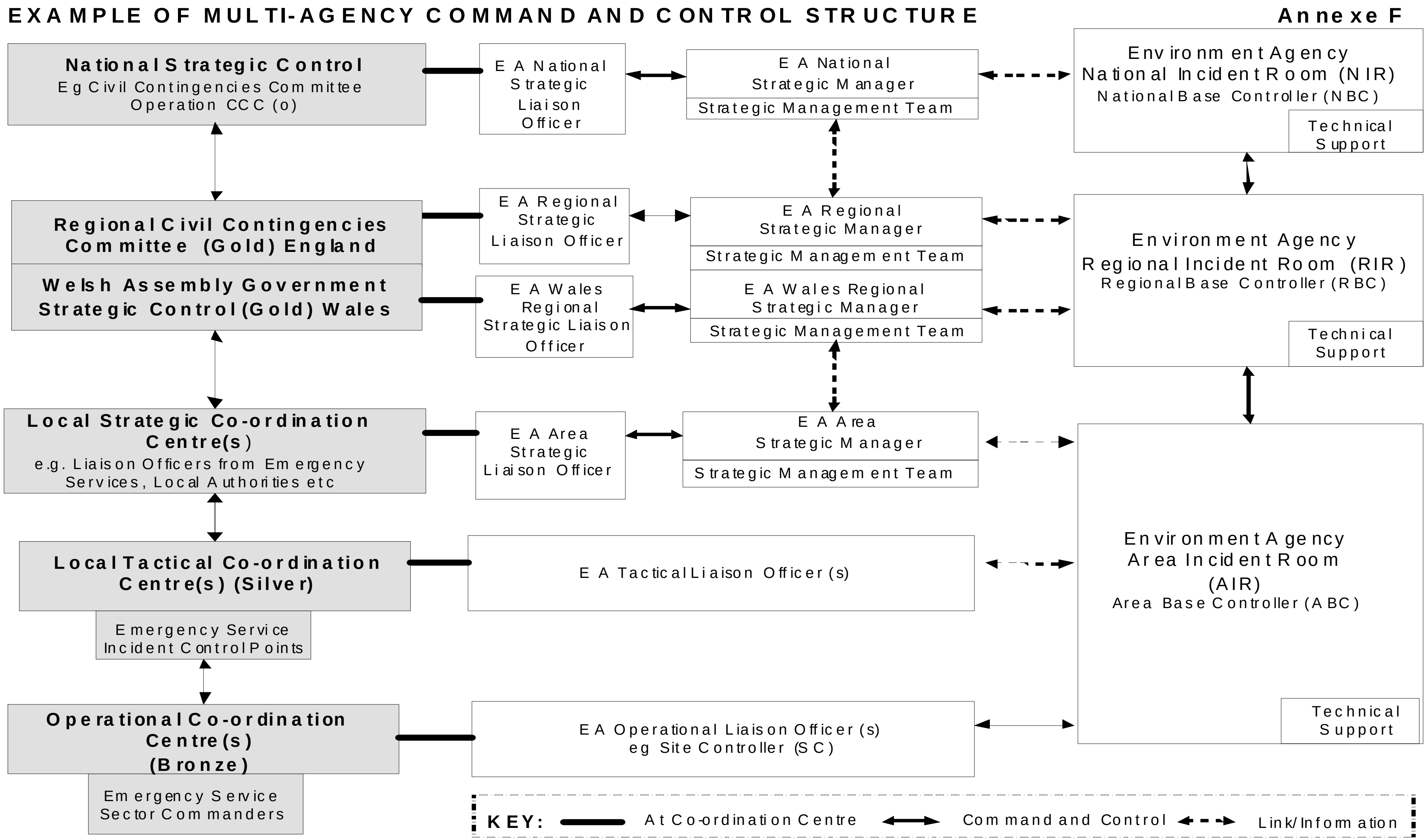
The forecasting and warning system in place at present for flood incident management involves the people shown in Figure 2.4 (within the Environment Agency) and Figure 2.5 (external partners). The roles and responsibilities of the various Environment Agency staff are summarised in Appendix B.

Figure 2.4 Schematic diagram of roles and relationships during a major flooding incident (Environment Agency internal).



Key: ES = emergency services; EWF = emergency workforce; RCC = Regional Control Centre; Sitrep = situation report; LA = Local Authority

Figure 2.5 Schematic diagram of roles and relationships during a major flooding incident (external partners).



2.1.4 Drivers for change

Environment Agency targets

The main driver within the Environment Agency for changes in the flood forecasting and warning service is its Flood Warning Investment Strategy. This defines the areas where improvement should be focused and sets annual targets for improvement for a ten-year period. The targets relate to the following measures:

- damage reduction;
- coverage;
- service effectiveness;
- availability;
- ability;
- effective action.

Appendix C gives definitions of these measures and a summary of the targets set for England and Wales for 2003/2004 to 2012/2013.

The measures are expressed as a proportion of 'serviced' properties (i.e. homes and businesses within the Flood Warning Service limit) and therefore do not consider the extension of the service to a wider population. The extension of the lead time for warnings is part of the 'damage reduction' target (Sene et al. 2007).

Probabilistic flood warnings are seen as a way of improving performance across a number of these targets; for example, by extending lead times for warnings and facilitating effective action on the part of emergency responders, businesses and the public.

Recent studies

A number of recent studies have highlighted the need to improve and extend the cover of flood forecasting and warnings. In particular, there are concerns about the lack of cover for rapid response catchments and urban areas which are protected by flood defences but where the consequence of a low probability event such as breaching or overtopping of defences could have high consequences in terms of loss of life, injuries and damage to property (Shaw et al. 2005, Cave et al. 2008).

The flooding at Boscastle in south-west England in 2004 underlined the vulnerability of flashy catchments: it was felt that only a combination of fortuitous conditions had prevented a major loss of life. Because the Environment Agency is unable to ensure that warnings are given with a minimum of two hours lead time, there is no warning service for this kind of catchment.

Research on flash flooding commissioned earlier this year (Cave et al. 2008) is contributing to a better understanding of the feasibility and value of providing a warning service for severe flash flooding. Among the aspects being explored are:

- the level of tolerance of false alarms among members of the public and professional partners;

- the impact of increasing lead times.

As well as working towards its own performance targets for flood warnings, the Environment Agency has also come under pressure to further improve flood warnings in the wake of recent flood events. While the flooding in Boscastle highlighted the vulnerability of rapid response catchments, the flooding in Carlisle in 2005 revealed a different set of problems such as the limitations of warnings covering only fluvial flooding.

Summer 2007 floods

The urgent need to find ways of incorporating rainfall predictions into flood forecasting and warning was brought home by the flooding in summer 2007.

The findings of the review carried out by the Environment Agency and the independent review undertaken by Sir Michael Pitt both added impetus to the development of better flood warnings.

Environment Agency's lessons learnt report

The 'lessons learnt' report (Environment Agency 2007a) looked at the performance of the flood forecasting and warning system during the flooding.

It found that, while most forecasts were accurate, professional partners may not have fully understood them or known how best to use them. This was partly because the Environment Agency's warnings were expressed in deterministic terms (e.g. 'it will/won't flood') in contrast to the Met Office's probabilistic forecasts (e.g. 'there is a 60 per cent chance of heavy rain'). The professional partners were also unclear about the relationship between the information they were given (triggers) and the responses required (e.g. evacuation, distribution of resources).

The report also found that forecasting staff were overwhelmed by requests to provide advice or to help emergency responders to understand the forecasts and their implications.

As a result, the report recommended a review of:

- the flood forecasting development programme to assess the scope for improving accuracy, timeliness and reliability;
- ways of using rainfall forecasts in the flood forecasting system to provide more timely warnings in fast-responding catchments;
- the specific needs of professional partners, alongside collaboration with the Met Office, to look at the best way of presenting and explaining weather forecasts and flood warnings so that professional partners and the public better understand them and can easily take action;
- the resilience of flood forecasting teams;
- flood forecasting models and threshold levels where flooding was not forecast sufficiently in advance.

The report highlights the need to achieve a balance between:

- the amount of warning time professional partners need to take action;
- their willingness to accept that longer lead-in times will lead to a higher level of false alarms and increased costs.

Sir Michael Pitt's review

The independent review led by Sir Michael Pitt (Pitt 2008) called for 'urgent and fundamental changes in the way the country is adapting to the likelihood of more frequent and intense periods of heavy rainfall' including:

> '... a step change in the quality of flood warnings. This can be achieved through closer cooperation between the Environment Agency and the Met Office and improved modelling of all forms of flooding. The public and emergency responders must be able to rely on this information with greater certainty than last year' (Pitt 2008:vii).

The Pitt Review recognises the Met Office as a world leader in weather prediction and argues that closer working with the Environment Agency should:

> '... deliver real changes in technical capability … [and] improve the usefulness and reliability of extreme rainfall forecasts and warnings, which are essential for providing effective warnings for rapid response catchments and surface water flooding' (Pitt 2008:xiii)

The Pitt Review also points out that there will need to be engagement with emergency responders in Local and Regional Resilience Forums so that any changes in forecasting and warnings are designed they meet their requirements (within the constraints of feasibility and costs).

The review was critical of the way that information was translated into warnings and communicated with emergency responders:

> 'During the floods, people experienced the effects of the lack of joined-up communication across these agencies. There was no single authoritative voice, no proper forecasting and warning system for surface water flooding, and a general need for more accurate, targeted and earlier warnings … too much information was given to people without clear explanation or pre-determined triggers for action' (Pitt 2008:xiii).

Among the Pitt Review's recommendations are:

- The Environment Agency should further develop its tools and techniques for predicting and modelling river flooding, taking account of extreme and multiple events and depths and velocity of water (Recommendation 4, p. 414).
- The Environment Agency should work with partners to urgently take forward work to develop tools and techniques to model surface water flooding (Recommendation 5, p. 414).
- The Environment Agency should provide a specialised site-specific flood warning service for infrastructure operators, offering longer lead times and greater levels of detail about the velocity and depth of flooding (Recommendation 33, p. 416).
- The Met Office and the Environment Agency should issue warnings against a lower threshold of probability to increase preparation lead times for emergency responders (Recommendation 34, p. 416).
- The Met Office and Environment Agency should issue joint warnings and impact information on severe weather and flooding emergencies to responder organisations and the public (Recommendation 35, p. 416).

2.2 Current probabilistic flood forecasting and flood warning products being piloted to stakeholders

2.2.1 Probabilistic forecasting pilot study in two Environment Agency Regions

This project is piloting probabilistic forecasting products with forecasting staff in the Environment Agency's North East and Midlands Regions.

Ensemble rainfall forecasts are being modelled to produce ensemble flood forecasts which include the following:

- '**Spaghetti' plots** which show results for 24 different forecasts in a single plot and provide support for decision-making by allowing an estimate of the probability by visual inspection (see Figure 2.6).
- **Plume plots** in which a statistics module computes percentiles (e.g. 25, 33, 66 and 75 per cent) and produces four lines, envelope and deterministic. This allows the quantification of probabilities (e.g. spread around deterministic) and has a potential use for risk based decision-making (see Figure 2.7).

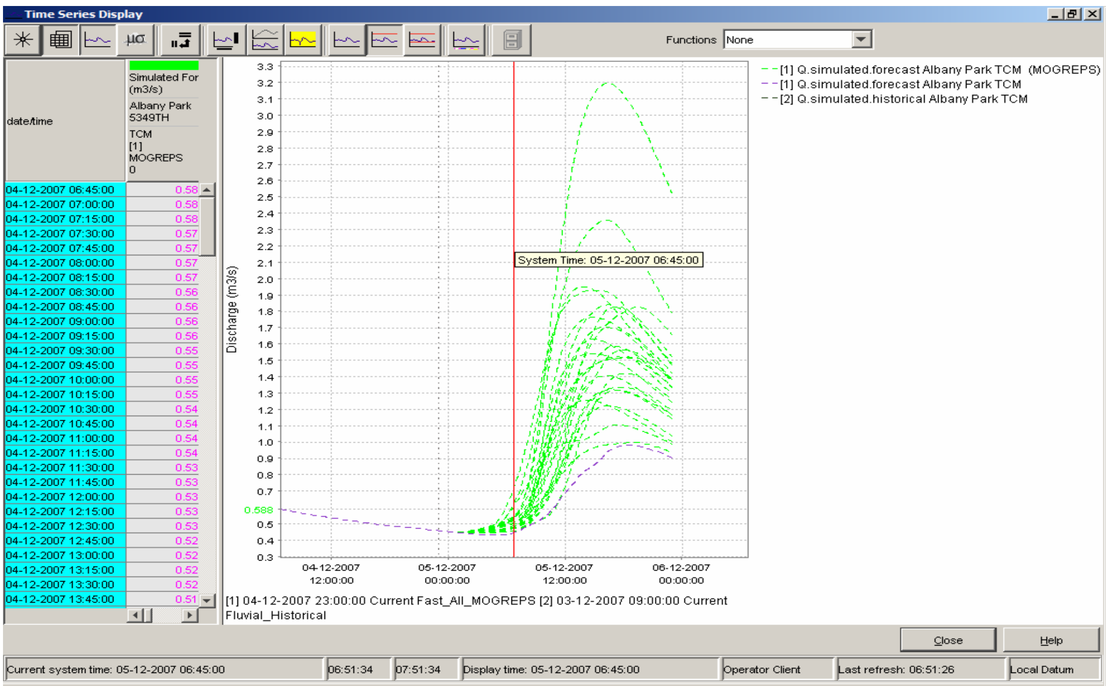


Figure 2.6 Spaghetti plot produced using 24 ensemble Met Office rainfall forecasts.

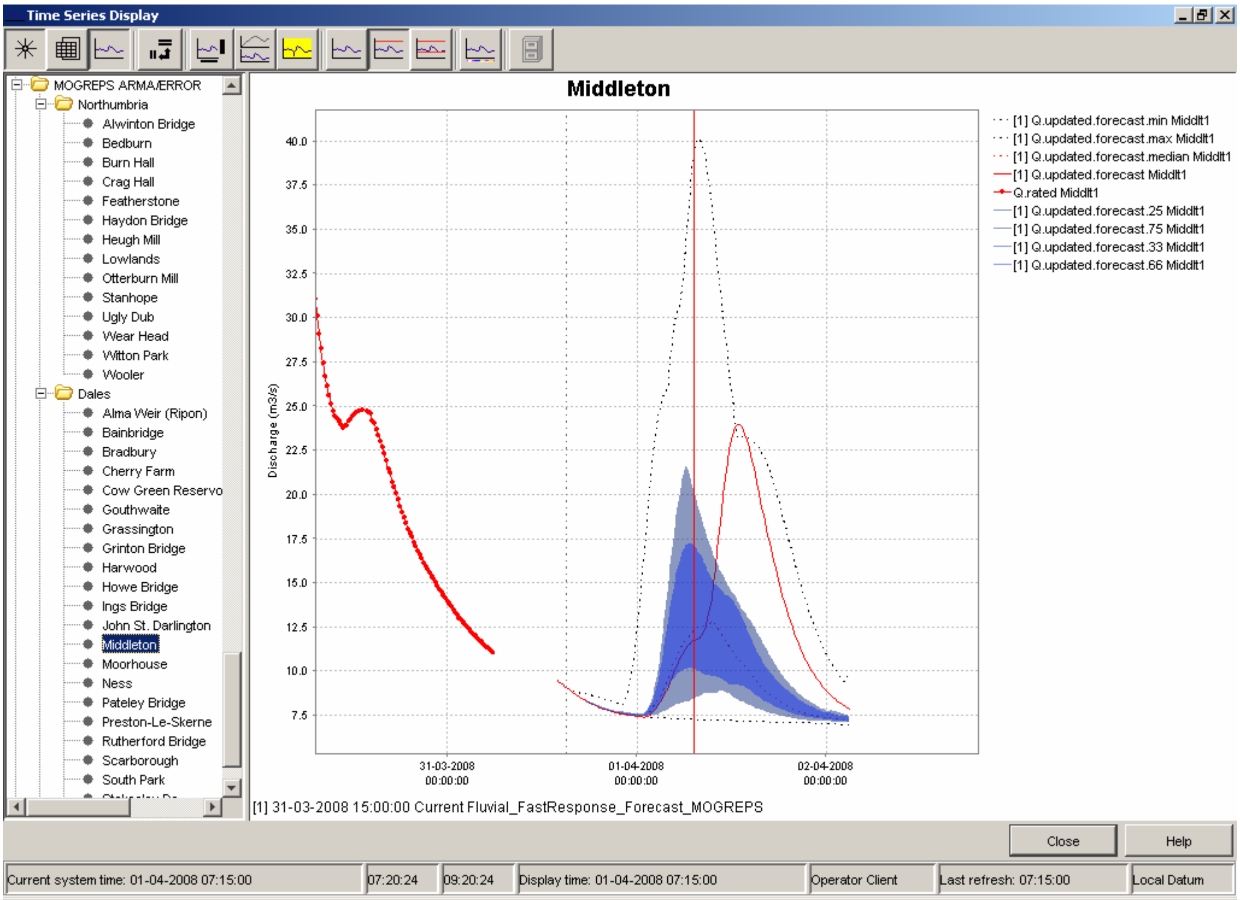


Figure 2.7 Example plume plot.

Phase 1 (Hydrological Modelling using Convective Scale Rainfall Modelling) of the project examined models that could be used. Environment Agency staff are trialling the products during the second stage. So far only Environment Agency forecasting staff have been working with these products, which have been issued to work alongside existing deterministic models. An evaluation has not yet been finalised.

2.2.2 Coastal flood forecasting: model development and evaluation

The purpose of the coastal flood forecasting project is to develop, demonstrate and evaluate improved probabilistic methods for surge, near shore-wave and coastal flood forecasting (CFF) in England and Wales.

There are four aspects to this project:

- model development;
- model evaluation;
- forecast demonstration;
- forecast evaluation.

This project produced a first report in November 2007 and will be reporting the final results of the evaluation shortly.

This project looks mainly at the scientific uncertainty issues that are part of the coastal flood forecasting system and is evaluating the extent to which probabilistic inputs would improve flood forecasting. The potential interface between forecasting and warning is not being explored.

The outputs from this project are being trialled via a website and include the following:

- forecast overview;
- UK surge ensemble forecast;
- area ensemble;
- probability of exceedence (see Figure 2.8).

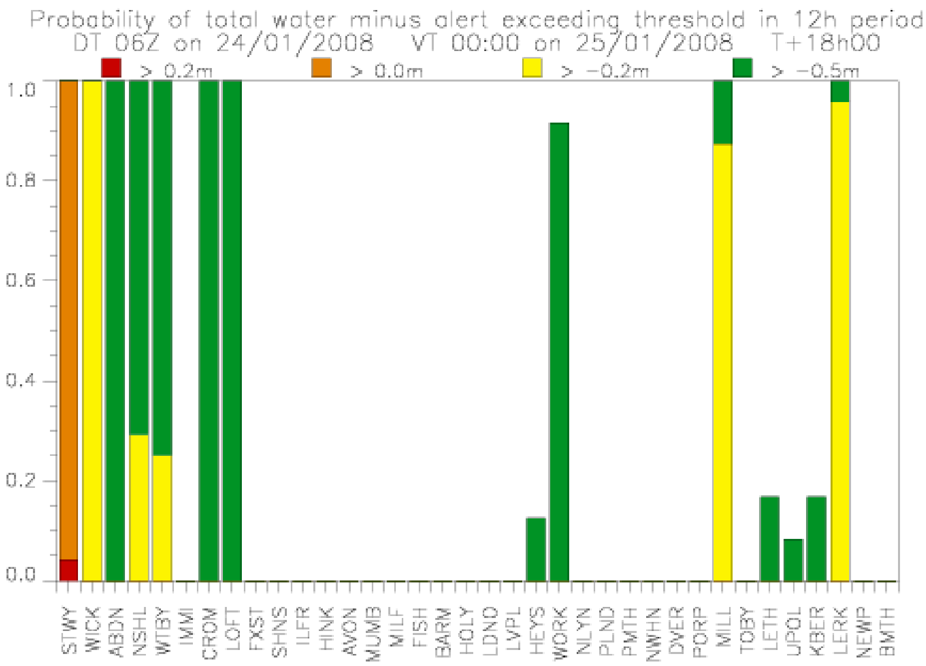


Figure 2.8 Graph showing probability of exceedence.

2.2.3 Use of probability forecasts

The ‘Use of Probability Forecasts’ project is managed by the Met Office and the Joint Centre for Hydrometeorological Research (JCHMR). It aims to:

- prepare a list of uncertainty based (rainfall) forecast products for demonstration purposes;
- establish an initial user requirement for uncertainty-based forecast products (via a questionnaire and workshop);
- develop an implementation plan for any products identified in the user requirement, including a consideration of training and IT requirements;
- implement any products identified as likely to deliver a ‘quick win’;
- provide recommendations for follow-on projects to support the further integration of forecast uncertainty into fluvial flood forecasting and warning procedures.

The project is envisaged as the first of a series of developmental steps towards the integration of rainfall forecasting uncertainty into fluvial forecasting models and flood warning procedures.

During Stage 1, which began in June 2006, the project:

- developed a draft user requirement document, based on consultations and a questionnaire;
- held a workshop in Wallingford on 15 November 2006 for key Environment Agency national and regional staff;
- identified several potential ‘quick win’ products for routine automated delivery to the Environment Agency (e.g. hourly).

Box 1 from the questionnaire used to develop the draft user requirement document was reproduced in the probabilistic scoping study (Sene et al. 2007:21) as a good introduction to some of the reasons for using probability forecasts. Box 1 is reproduced on the next page of this report.

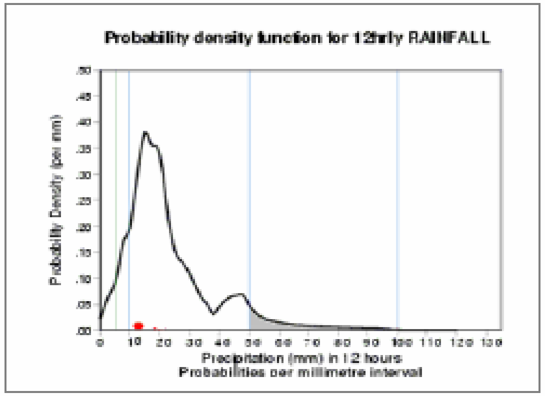
BOX 1 - Introduction: why use probability forecasts ? *Source: the Met Office "Use of Probability Forecasts" questionnaire (© Met Office)*

Typically, a weather forecast will present the user with an estimate of whether or not an event will occur (e.g. will catchment rain accumulation exceed 50mm in 12 hours or not?), or with a particular forecast quantity (e.g. 75mm rainfall accumulation in 12 hours). This is referred to as a deterministic forecast.

Unfortunately, such is the nature of atmospheric predictability that there is frequently significant uncertainty associated with weather forecasts. This can have implications for the decisions made on the basis of these weather predictions. Consequently, it is desirable to have an objective measure of the uncertainty associated with a weather forecast to help in the decision making process.

Consider a river catchment for which a flood warning will be issued if rainfall accumulations are forecast to exceed 50mm in 12 hours. Currently, the decision whether or not to issue a warning is usually based upon a deterministic forecast of the accumulation, without access to quantitative information on the associated forecast uncertainty.

Our deterministic forecast of rain accumulation for the catchment discussed above is subject to significant uncertainty, as shown in the figure below. The red circle represents our deterministic estimate of the forecast accumulation; in this case 12mm in 12 hours. The black line represents the probability density function, which represents the range of uncertainty associated with the forecast. The area under this line, to the right of a specified accumulation, gives the probability that this accumulation will be exceeded. Clearly, it is possible for the 12 hour rainfall accumulation to exceed 50mm as shown by the grey shading (a 5% probability).



The costs and potential losses associated with such an event (50 mm in 12 h) are summarised in the 2×2 event contingency table below:

		Event Forecast	
		Yes – *User protects*	No – *No protective action*
Event Observed	Yes	Hit Mitigated Loss, L_m	Miss Loss, L
	No	False alarm Cost, C	Correct rejection No cost or loss

Example costs and losses

For a forecast of the event to have value it is necessary that C < Lm < L. In words, the cost of protective action (i.e. flood forecasting, warning and actions taken as a result) must be less than the loss incurred (loss of property, life) if no action is taken. Furthermore, the mitigated loss incurred when protective action is taken and an event occurs should be less than the loss incurred without that action (i.e. the protective action must serve to reduce the loss). In the case of heavy rain induced flooding, the cost of protective action, C (flood forecasting, warning and resultant actions) is typically less than the loss, L, if a flood occurs and no warning is issued, so it is preferable to take protective action if there is a significant chance that flooding may occur.

To illustrate, in simple terms, how such cost-loss information can be used in conjunction with probability forecasts to improve decision making, we will assume the following arbitrary costs and losses:

- the loss incurred if the event occurs and no protective action is taken is £44m;
- the cost of protective action is £2m;
- there is perfect protection against flooding so no extra loss is incurred if protective action is taken and the event occurs (i.e. the mitigated loss is equal to the cost of protection).

If the decision maker only has access to the deterministic forecast of rain accumulation, no protective action will be taken. However, if 50 mm of rain or more falls, a substantial loss (£44m) is likely to be incurred.

Alternatively, if the decision whether or not to take protective action is based upon the forecast probability distribution, the 5% chance of the event occurring can be used in conjunction with a knowledge of the costs and potential losses to make a more cost effective decision. In this example, the best strategy will be to issue a warning and take protective action because the probability of the event exceeds the ratio C/L (2/44 = 0.045 or 4.5%). If adhered to, the strategy of taking protective action whenever the forecast probability exceeds 4.5% would ensure the most cost effective response, i.e. the minimum overall economic impact, in this case.

For more extreme events (e.g. 200 mm in 12 h), the probability threshold above which protective action should be taken is likely to be lower because the consequences of such events in terms of potential loss of life and property are much greater. Alternatively, in cases where the cost of protective action is small and the potential losses are substantial the best course of action is always to protect.In reality, the above example is over simplified. It is highly likely that some losses will be incurred even when protective action is taken. In these circumstances choosing the best strategy becomes a little more complicated.

2.2.4 Extreme Rainfall Alert (ERA) service pilot

Since July 2008, the Environment Agency and the Met Office have been jointly piloting a service to alert emergency responders to the probability of heavy rainfall which could cause surface water flooding. All Category 1 and 2 emergency responders have been invited to register to receive the alerts, which will be trialled for six months.

To provide the alerts, the Met Office and the Environment Agency are combining forecasts of heavy rainfall with information about the areas that are naturally vulnerable to surface water flooding. This indicates the probability of flooding. When the probability is over 10 per cent, it triggers one of three alerts (Table 2.3).

Table 2.3 Extreme Rainfall Alerts.[1]

	Advisory	Early Alert	Imminent Alert
Probability of thresholds being exceeded: 30 mm per hour; or 40 mm in 3 hours; or 50 mm in 6 hours.	Very low: ≥10%	Low: ≥20% to <40%	Moderate: ≥40%
Guidance to responders on receipt of an ERA	Extreme rainfall may lead to surface water flooding. **Be prepared should the situation worsen.**	Extreme rainfall may lead to surface water flooding. **Consider activating your emergency procedures**	Extreme rainfall may lead to surface water flooding. **Activate your emergency procedures**
Timing of alert	Issued at 14:00 local time valid for the 24-hour period starting from the next midnight.	Issued with a lead time of 8–11 hours.	Issued with a lead-time of 1–3 hours.
Coverage	All opted-in responders in affected counties in England and Wales	All opted-in responders in the affected county only	All opted-in responders in the affected county only

Notes [1] Adapted from Environment Agency and Met Office (2008).

The information is available by email, auto-voicemail, Short Message Service (SMS) and fax. Corrections and cancellations to Early Alerts and Imminent Alerts are issued as required.

The alerts make transparent the associated probabilities and are accompanied by instructions on the appropriate response. This meets the needs of professional partners as highlighted in the literature (see Section 3.2) and as identified in the reviews of the flooding in summer 2007 (see Section 2.1.4).

2.2.5 Feedback from Environment Agency staff on issues arising from probabilistic forecasting and duty officer concerns

The probabilistic flood forecasting scoping study (Sene et al. 2007) included consultation with Environment Agency staff. One of the main areas investigated was what Environment Agency staff thought would need to be in place for probabilistic warnings to be implemented. The findings are summarised below.

- **Guidance on use of probabilistic flood forecasts.** The consultation process identified a strong need for guidance on interpretation and best practice use of probabilistic forecast information, and in particular the criteria for issuing flood warnings. This could be through guideline documents, AMS Work Instructions, training and other approaches.

- **Floodline Warnings Direct.**[4] As noted earlier, one implication of the availability of probabilistic flood forecasts is that recipients (particularly professional partners) might have the option to be warned at a pre-defined level of risk (where risk is defined as the multiple of probability and consequence) or probability (if the consequence is known and constant). This new system should allow targeting of individual customers, although the methods for setting thresholds and calculating risk would probably be independent of the system and remain to be determined. However, it was noted that there is no direct link at present from NFFS to Floodline Warnings Direct; for example, the facility to transfer probabilistic flood inundation maps for real-time generation of property at risk counts could be useful.

- **Extended lead times.** Like meteorology, where forecasters routinely use ensemble forecasts to make judgements on weather several days ahead, several flood forecasting and warning staff noted that they see these extended lead times as one of the main potential benefits of probabilistic flood forecasts.

- **Fluvial forecasting issues: emergency planning and operational response.** The potential to extend forecast lead times to provide an indication of probability several hours or even days in advance was seen as potentially of great interest to Operations staff. For example, for health and safety reasons, some activities (e.g. working in or near fast flowing water) are better performed during daylight hours and some operations (e.g. manual operation of barriers, canal gates, etc.) can require long lead times to put in place – particularly when staff resources are stretched in a major event. In addition, costs and risks are better defined and managed at these timescales, reducing the impact of false alarms. At least one Region has been asked by local authorities to provide assessments of the likelihood of a pre-MIP alert (pre Major Incident Plan alert) being upgraded to a MIP-warning.

- **Risk-based warnings.** With information on probability, some recipients may choose to be warned at a lower probability than would otherwise occur than with the present deterministic approach. Examples mentioned during this project include:
    - commercial organisations with a high consequence if flooding occurs (e.g. some types of shops or business);
    - operators of temporary/demountable defences;
    - property owners where property is of high value but easily moved (e.g. car dealerships).

- **Guidance on setting probability thresholds.** A point made widely during the consultation was that guidance would be required on setting probabilities for warning and on the statistical characteristics of hydrological

[4] See http://www.environment-agency.gov.uk/homeandleisure/floods/38289.aspx for details of this service.

(flow) ensembles. Ideally, all thresholds would be linked to cost/loss ratios or similar measures of risk, although it was noted that not all warning decisions can be expressed in monetary terms and that appropriate cost–loss information may not always be available. Some simple pilot studies would help to establish some of the concepts and further research required. Ongoing studies in the Environment Agency (e.g. on threshold crossing approaches) should also be considered.

- **Roles and responsibilities for probabilistic forecasting and warning.** Regarding this general question, the consultation produced a range of views including the opinions that:

    - probabilistic forecasts should be used primarily by regional forecasting teams who would continue to provide single 'best estimate' forecasts to flood warning teams (and hence to professional partners and the public);
    - Flood Warning and Operations staff would find this information useful and it could assist in their decision-making (e.g. if flood warning moves to a more risk-based approach), but that external recipients would not want imprecise or qualified warnings (e.g. Gold Commanders, local authorities, etc.);
    - professional partners may also require information on risk and uncertainty in forecasts. The extent would depend on their roles and expertise; for example, for mobilising in advance of possible flooding or to assist in reservoir, gate or barrier operations. Some professional partners might also require the full ensemble of flow forecasts; for example to input into their own decision support systems (e.g. hydropower or reservoir operators).

  There was also the general question of whether probabilistic forecasts are seen as a complement to existing approaches or an eventual replacement. Taking this approach one step further is the view that the most open and honest approach is to acknowledge the uncertainty, and to routinely include an assessment with all forecasts presented in the media, on Floodline, etc. The private sector may also see opportunities to add value to the probabilistic discharge forecast.

- **Communication of probabilistic forecasts.** The consultation generated much debate about ways of presenting and communicating information on uncertainty, noting that several alternative ways of viewing information may be useful and that different users may require different types of information. There are also some concerns about overloading users with information (particularly less experienced users) and, where this is likely to occur, the requirement for simple, intuitive displays. For Environment Agency forecasters and warners, many favoured a display based on an interactive geographical information system (GIS) for operational use. Additional research and pilot tests were suggested to evaluate alternative ways of presenting information. Experience from meteorological forecasting suggests that systems should be able to evolve as users become more familiar with using the products and start to demand a higher level of sophistication. Much can also be learnt from existing operational and pilot tests overseas (e.g. HEPEX[5] and EFAS[6]) and ongoing research programmes on risk communication, e.g. Flood Risk Management Research Consortium (FRMRC)[7] Work Package 7.

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[5] Hydrologic Ensemble Prediction EXperiment (http://hydis8.eng.uci.edu/hepex/)
[6] European Commission's EFAS (European Flood Alert System) programme (http://efas.jrc.ec.europa.eu/)
[7] See http://www.floodrisk.org.uk

3 Understanding of risk and uncertainty in flooding

This section summarises information from Defra/Environment Agency FCERM reports specific to the following two questions:

- What insights do the research projects provide on understandings of flood risk and uncertainty on the part of members of the public, professional partners and businesses?
- What information is there on differentiation between different groups/types?

The three categories of stakeholder are examined in turn:

- members of the public (see Section 3.1);
- professional partners (see Section 3.2);
- businesses (see Section 3.3).

For each stakeholder category, there is an examination of the evidence on:

- their general understanding of flood risk and uncertainty;
- their responses to flood risk and uncertainty;
- their differentiation between groups (personal, cultural, organisational circumstances).

3.1 Members of the public

3.1.1 General perceptions of flood risk and uncertainty

Over the last decade, a number of Defra/Environment Agency publications have investigated the general perceptions of flood risk and uncertainty. Two areas can be distinguished:

- **perception of flood risk and uncertainty** expressed in general discussions about flooding, unprompted by any formal definitions of risk and uncertainty;
- **perception of terminology expressing flood risk and uncertainty**. This includes:
    - flood warning codes, i.e. all clear, flood watch, flood warning, severe flooding;
    - expressions of risk of flooding, i.e. 1 in 100 chance of flooding.

Perception of flood risk and uncertainty

Walker et al. (2008) provide a comprehensive summary of the literature on the perception of risk, including the perception of flood risk and uncertainty. From that review a number of key conclusions that are relevant to flood warnings emerge (Table 3.1):

Table 3.1 Implications of risk communication context for flood warning.

Characteristic of risk communication context	Implication for flood warning
Risk communications are not 'passively' received; they are filtered, actively interpreted and evaluated in a social context.	Need to work with communities to develop flood warning systems jointly so they are part of the social context, e.g. Hambledon Parish Council developed a Flood Warning System which it ran itself.[1]
Trust in the source of communication and the credibility of the communication medium are crucial in influencing how risk communications are received.	Understand that all contacts people have with the Environment Agency will have a bearing on whether it is a trusted source or not. Work on developing trust with local communities. Trust is built up over time and needs attention to all three aspects – competency, compassion and consistency.
Risk communication takes place between different publics or parts of the community in an informal way, beyond the formal instigation or control of risk managers.	Work with informal networks (e.g. community groups) to get people talking about flooding. Give talks to clubs for older people, supporting events that discuss local flood history, etc.

Notes [1] *Managing flood risks in parishes: a best practice guide*, Hampshire Flood Steering Group.

Perception of terminology expressing flood risk and uncertainty

In 1999, changes were made to the warning codes[8] then in operation following considerable research that found there was much confusion about what the colour-coded warnings meant (BMRB International 1998, 1999).

Furthermore, the research indicated that what the public wanted from flood warnings messages was not matched by what was in the messages. The pieces of information in flood warning messages requested by more than 10 per cent of the 'at risk' public surveyed (BMRB International 1998, 1999) were:

- time of flooding/when to expect it;
- instructions on what to do;
- how severe the flooding will be;
- which areas are likely to be flooded;
- height of the flood.

New warning codes (Table 3.2) were designed in response to the research findings.

[8] Until 2000, the Environment Agency and predecessor bodies used three colours to warn people:
Yellow – a warning of flooding of some low lying farmland and roads near rivers and the sea;
Amber – a warning of flooding to isolated properties, roads and large areas of farmland near rivers and seas;
Red – a warning of serious flooding affecting many properties roads and large areas of farmland.

Table 3.2 Current Environment Agency flood warning codes.[1]

Code	What it means
Flood Watch	Flooding is possible. Be aware. Be prepared. Watch out.
Flood Warning	Flooding is expected affecting homes, businesses and main roads. Act now.
Severe Flood Warning	Severe flooding is expected. Imminent danger to life and property. Act now.
All clear	Flood watches or warnings are no longer in place.

Notes [1] See http://www.environment-agency.gov.uk/homeandleisure/floods/31620.aspx for full details of Environment Agency flood warning codes

Research carried out after the summer floods 2007 (Environment Agency 2007a) collected, amongst other things, information on the understanding of flood warning codes. Not surprisingly those who were aware they are at risk of flooding were more likely to be aware of and understand the flood warning codes and to listen for them on radio and TV. Those people who were not aware they are at risk did not see any reason to attend to the codes in any media.

In terms of understanding the flood warning codes, research in 2006 (Environment Agency 2006b) found that when respondents from the 'at risk' population were shown only the four warning names and asked to explain their understanding of these codes, understanding was good. For example, 81 per cent identified at least one correct response for Flood Watch (i.e. some element of the content of the warning). For Flood Warning, 70 per cent of respondents said 'flooding of homes and business is expected' and overall 89 per cent identified at least one correct response. As this evidence suggests, the names of the codes are clear and easy to interpret without prior understanding. However, it was felt the similar understandings given for flood warning and severe flood warning could indicate that respondents were failing to appreciate the increased danger signified by a Severe Flood Warning.

Similar patterns were found in the 2005/6 post-flood awareness campaign survey. Fielding et al. (2007) carried out qualitative work to find out what the levels of awareness and understanding of the flood warning codes was among at risk respondents, both flooded and not flooded. Participants in focus groups were asked if they could say, unprompted by visual aids, what the codes were. There was a clear difference between those who had been flooded and those who had not, with the former having a clear awareness and understanding of the flood warning codes, and where to go for information, whereas the 'not flooded' group had little or no awareness of the flood warning codes or where to go for information.

This work highlights some of the issues around the flood warning message and what is understood. Haggart (1994) provides a useful summary of the attributes of an effective flood warning message, which is reproduced in Table 3.3.

Table 3.3 Attributes of effective flood warnings.

Attribute	Details
Factual information	The hazard should be described and how it poses danger to people. The message should say what is happening, what is expected to happen and when it will occur – the effects of a flood should be predicted if possible. The location of the risk should be described in a way that is readily understood by the public. Information should be given about the time available for recipients to act. Messages should contain estimates of probable damage. Information should be specific, accurate and relevant to the individual. Messages should related to an be reinforced by local conditions. Reference to benchmark floods can enhance comprehension. Messages will not be believed if recipients think they are not receiving the whole truth.
Action advice	Information on what people should do to preserve their safety. Information on what people should do to protect their property. Messages should be persuasive to convince people to take action. The warning must convey what is appropriate response.
Source of message	The source of the message should be indentified. Messages that come from credible sources are more likely to be believed. Those issuing a warning message should convey authority.
Consistency	A message should be consistent within itself and across different messages. Messages are more likely to be believed if they are consistent.
Clarity	The warning must be clear concise, and 'user friendly'. The warning must be easily understood by the target audience. Warnings should be worded in simple non-technical and jargon free language. Message content should be attention grabbing and ordered with the most important information first.
Tone	Messages should be positive rather than negative. Messages should suggest action rather than inaction. Messages should encourage social interaction rather than isolation. Messages should be vivid, around emotional interest and relate to local situations.
Alerting function	Warning messages should convey a sense of urgency and arouse some emotion and feeling. Signal words and colours can be used to emphasise the level of risk. The use of appropriate icons can enhance the alerting function. Messages should contain wording which is designed to motivate and arouse.

Target audience	Different recipient groups will need different information and for it to be presented in different ways. Acquisition of knowledge on the make up of at-risk communities in important.
Message construction	Media messages should be brief and to the point. Templates should be produced prior to flooding to save time. By adopting appropriate language, messages should be used to convey uncertain information.
Professional skills	Construction of messages requires specialist communication skills. Media/public relations specialists should be involved with improving message quality.

Source: Haggart (1994)

It is useful to note the specific recommendation made by Fielding et al. (2007) relating to any change to warning messages and methods:

> 'If the content or dissemination of flood warnings is altered in any way, it is vital that steps are taken to ensure the following: warning content must be clear, sufficiently differentiated and convey a suitable sense of urgency; methods of dissemination are clearly and widely understood by the at-risk public' (Fielding et al. 2007:vi).

In terms of terminology used to indicate the probability of flood risk and the standard of flood defence, work carried out for the Defra/Environment Agency FCERM programme (Defra and Environment Agency 2003) found evidence that the use of 'return rates' is confusing in the descriptions of risk:

> 'It must be remembered that return periods have generated a lot of confusion and may even exacerbate the perception amongst sections of the public that the experts cannot be trusted to be correct. If return periods are to be used they should be one of many techniques and certainly not the first one that is presented to the public. Furthermore, it is not helpful to separate out the understanding of flood and coastal defence terminology from recommendations for improving knowledge awareness and expectations. Enhancing the understanding of flood and coastal defence needs to address not only the message (terminology) but also the medium used to communicate and the characteristics of the target population' (Defra and Environment Agency 2003:18).

The same report concluded that

> '… much communication on risk is characterised as one way, overly technical, unsympathetic to the concerns of the public, and proffered by unaccountable and closed expert committees (Health and Safety Executive (HSE), 1998). This study has confirmed that despite improvements, much of the public still perceive these criticisms as characteristic of risk communication and consultation in flood and coastal management' (Defra and Environment Agency 2003:15).

It is clear from the work commissioned by Defra/Environment Agency on flood warning messages that:

- introducing probabilistic information will need to be done with the awareness that ‘expert’ expressions of that information are unlikely to be the way in which members of the public engage with probabilistic information;
- any extra information that is provided needs to be considered in terms of what actions it may then enable members of the public to carry out which will be protective in terms of flood risk (there are many influences on why and how a flood warning is responded to with effective action).

3.1.2 Responses to flood risk and uncertainty

Defra/Environment Agency research has looked in general at the responses to flood risk by members of the public and more specifically at their responses to flood warnings.

Responses to flooding

A review by Fernandez-Bilbao and Twigger-Ross (2008) on literature on the responses to flooding showed that the most common actions undertaken during and before a flood can be grouped according to the following categories:

- moving people and pets to safety (often the first response);
- moving valued possessions and cars;
- trying to stop water entering the property;
- trying to confirm the warning (often the first response), seek advice and help others

The review also found that people often prioritise actions designed to alleviate psychological discomfort and do not just focus on moving material property. These actions include the first point above (i.e. moving people and pets to safety) and also helping vulnerable neighbours. In terms of saving possessions, people tend to concentrate more on items of sentimental value.

A further issue impacting response is that of the perception of a ‘typical’ flood. Research in Carlisle showed that many of the participants had a pre-determined idea that a flood would be a slow-onset event signalled by rising surface water. In Carlisle, the flood had neither of these two characteristics. The speed of onset and the fact that the flood waters rose up through the floors of most buildings meant that residents and business operators in general did not react quickly; as a consequence, avoidable damage to property occurred. Understanding people’s constructions and expectations of flooding and, specifically its consequences, is a gap in the current knowledge (Twigger-Ross et al, 2008).

The findings also indicate that different types of preparedness actions or responses may be appropriate for different types of people and flood risk situations, e.g. between owner-occupiers and renters, rural and urban areas.

Responses to flood warnings

Receiving a timely, informative and credible flood warning is a crucial factor in aiding response to flooding and recovery. However, receiving a warning does not necessarily lead to action.

Fielding et al. (2007:6-8) summarised the variables shown to affect response to a warning as follows:

- **Characteristics of the warning message**. Providing specific and locally relevant information and the consistency and frequency of the information received are the key factors that lead to responding to a warning. The source of the message is also a critical factor; importantly, face-to-face communication seems to increase public response. Environmental factors such as heavy rainfall can themselves provide a warning and increase the likelihood of response.

- **Individual factors**. These include factors such as age and ethnicity and other predictors of 'vulnerability'. On the other hand, however, people's perceptions of risk and their own vulnerability have a clear effect on response; for example, a belief that one's home is at risk or a feeling of vulnerability has been reported to heighten response;

- **Social factors**. Warning response is a complex social process that often occurs in groups. Factors that increase response include having strong social networks, being responsible for children, having an illness, and being in the same place as the rest of the family members.

In addition to these factors, the German case study from the FLOODsite project (see Tapsell 2008) illustrates that different warning methods may be appropriate for different segments of the population; for instance during the event, no-one over 59 had consulted the internet to receive information about the flood. There is also evidence in the UK that elderly people use the internet less than other ages (Office of National Statistics (ONS) 2008), yet there is a growing emphasis on electronic warning methods.

The diagram shown in Figure 3.1 summarises the many different factors that facilitate or inhibit an effective response to flooding.

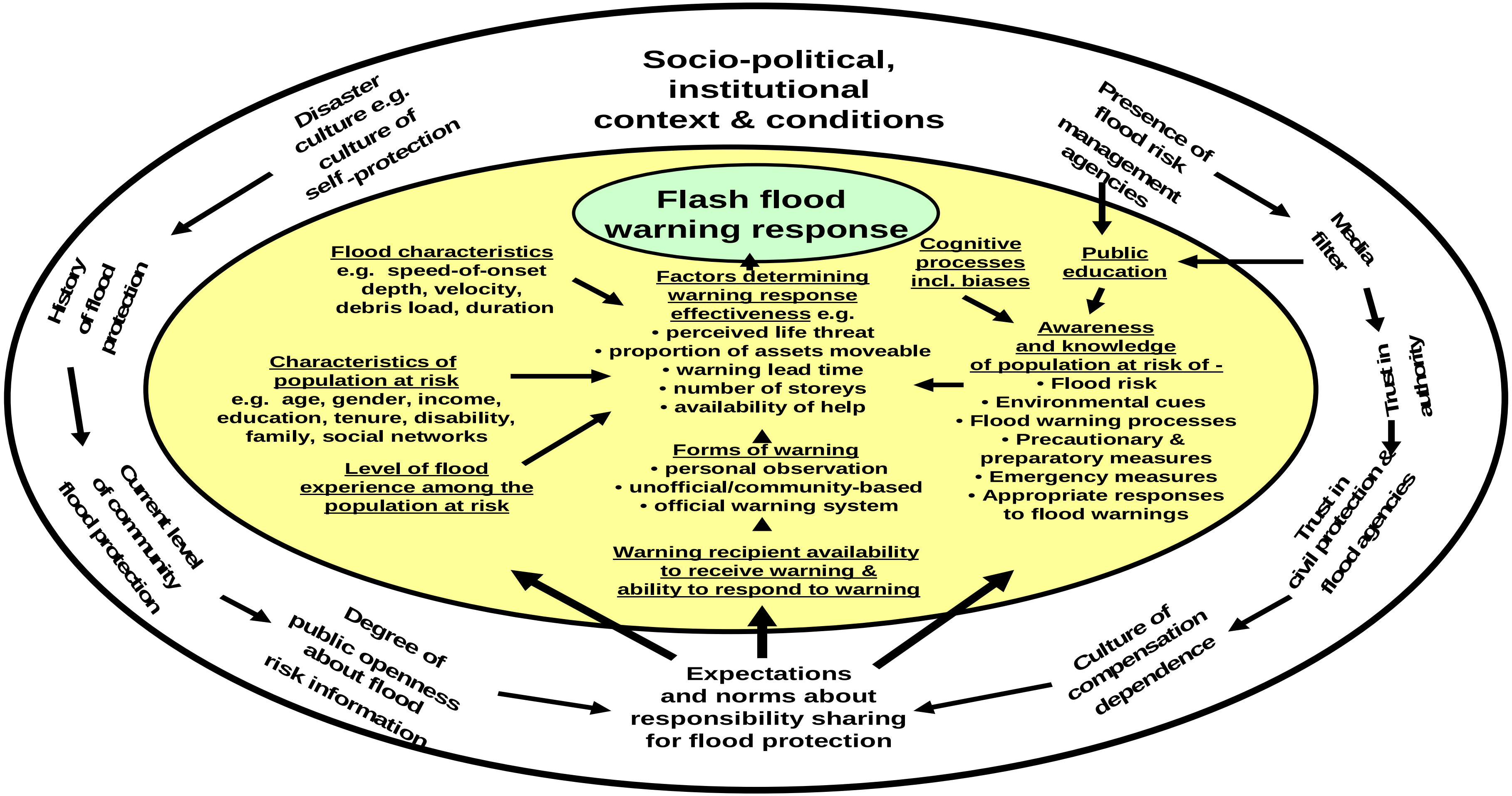


Figure 3.1 The variables which determine flood warning response either by inhibiting or enabling response by individuals occupying flood prone locations (Parker et al. 2007:94).

3.1.3 Differentiation between groups in terms of understanding, response and perceptions of flood risk and uncertainty

There is a growing understanding that, because communities and vulnerable[9] groups are not homogeneous (e.g. Shaw et al. 2005, Tapsell et al. 2005, Thrush et al. 2005), different groups understand, respond and perceive flood risk and uncertainty in different ways.

Different groups of people may need different warnings, and different types of warnings may be needed for different catchments or flood types. The combinations are many: the type of area (e.g. rural or urban) is another factor as it may determine the type of catchment and flood (Balmforth et al. 2006) but also the socio-economic composition of the population (Twigger-Ross 2005). Different events, catchments and social groups form different flood scenarios, which may render some communication channels unsuitable (Briscombe et al. 2005). For instance, some ethnic groups show a dislike of telephones mainly due to their lack of fluency in English (Robertson 2005).

These and other factors have been identified the literature as 'barriers' to the success of flood warnings, both in terms of communication but also in terms of actions undertaken by those who receive the warning. To summarise:

- **Barriers to communication** include (Tapsell et al. 2005):
  - composition and density of the resident population;
  - local structures of governance;
  - existence of local agents of change or opinion leaders (e.g. community leaders);
  - level of provision of information technologies.
- **Barriers to action** may include (Fielding et al. 2007):
  - individual characteristics such as old age, disability or physical frailty;
  - characteristics of the home, e.g. single storey houses;
  - characteristics of the flood and/or flood warning.

> 'Individual differences were observed in actions taken on receipt of warning, for example: single pensioners were the most likely category to take no action at Flood Watch and home owners were significantly more likely than tenants to attempt to minimise water entry into their property' (Fielding et al. 2007:v)

Shaw et al. (2005) identified **other factors** as key in developing flood awareness which may also be relevant to targeting flood warnings. These include:

- how recently flooding had occurred – if there has not been a recent event, the likelihood is that there will be lower awareness of flood risk;
- visibility of flood defences – they may eliminate the perception of flood risk;
- population characteristics;
- flood source.

Finally, in terms of **risk perception** Fielding et al. (2007) summarised by saying:

[9] Twigger-Ross and Scrase (2006) summarise various definitions of vulnerability as 'a function of susceptibility to loss and capacity to recover (resilience)'. In addition, the term is used here to refer to those who are less likely to receive/understand and/or act on a flood warning.

> ‘What does seem clear, however, is that perceptions of risk and vulnerability have an effect upon warning response. People who perceive their resources to be insufficient are less likely to respond whereas a belief that one’s home is at risk increases response as does a feeling of vulnerability with regard to the hazard in question.’ (Fielding et al. 2007:7).

Although there are likely to be differences in risk perception of flooding between different groups of people, this is not something that has been systematically studied in Defra/Environment Agency research to date. Based on the findings of Fielding et al. (2007) and Burningham et al. (2005), what is important to consider is that categories ascribed to people (e.g. age and a person’s subjective assessment of their vulnerability) will both have impacts on perceptions of risk and uncertainty.

3.2 Professional partners

The Environment Agency’s professional partners for flood incident management are the emergency responders as defined by the Civil Contingencies Act 2004.[10] Category 1 responders are local authorities, emergency services (police and fire and rescue services) and health services. Category 2 responders are utility companies (including communications), transport services, and the HSE.

There may be a case for also considering voluntary sector organisations that regularly play a role in emergency response as emergency responders and providing them with warnings, even though they are not formally named as responders. Such organisations include the British Red Cross, the Women’s Royal Voluntary Service (WRVS) and others with regional or local relevance.

3.3.1 General perceptions of flood risk and uncertainty

Emergency responders need to be able to make preparations for and manage flood incidents. The differences in their responsibilities and the nature of their response mean that they can have very different requirements and potentially understandings of warnings.

There has been little investigation of how professional partners perceive flood risk and uncertainty, or how they understand and respond to flood risk in relation to other risks that they are dealing with.

The Environment Agency does not appear to have information at a national level about who it is within professional partner organisations that receives warnings. Region and Area staff generally have links with counterparts in emergency response organisations, although this varies from place to place. It has been suggested that, in many places, these relationships are weak and sometimes bureaucratic, hampering effective information sharing (Colborne 2008).

Faulkner et al. (2007) distinguish between two different kinds of uncertainty in flood risk management – scientific uncertainty and decision uncertainty. These are discussed in turn below.

[10] http://www.opsi.gov.uk/Acts/acts2004/ukpga_20040036_en_1

Scientific uncertainty

The sources of scientific uncertainty in Environment Agency flood forecasts include:

- unreliability of data collection;
- use of models (assumptions, structures, boundary conditions).

The uncertainties present in individual models are compounded when these are combined.

> ‘For example tide, wave and weather forecasts can be used as input to models of flood size, timing frequency, routing, and inundation pattern. Those then provide the input to models of flood defence failure; or become part of damage and economic and social assessments of flood impact. Uncertainties become cascaded in ways that can be only partially constrained (Pappenberger et al. 2005)’ (Faulkner et al. 2007:693).

At present, the scientific uncertainty in Environment Agency models is not shared with its professional partners who receive the same single deterministic forecast as members of the public.

A number of studies (Faulkner et al. 2007, Sene et al. 2007) have pointed out that it is likely that some professional partners involved in emergency response will be familiar with the concepts of risk and uncertainty, and the ways in which uncertainty or probability are commonly described. However, both individual expertise and training as well as organisational characteristics may affect perceptions of the usefulness or otherwise of including probabilistic information in flood (or other kinds of) warnings and of the associated risks and benefits.

Anecdotal evidence suggests that organisations that use modelling as part of their day-to-day procedures will find it easier to understand and take account of probabilistic information (Sene et al. 2007). Utility companies, for example, are likely to use forecasting and modelling on a regular basis, and have specialised departments or staff. This will not be the case for most local authorities.

However, these observations do not come from the emergency responders themselves. Further work is needed to understand the extent and sources of difference in professional partners’ understandings of risk and uncertainty.

Moreover, it is suggested that more complex aspects of probabilities are likely to be less well understood and that professional partners will initially need help in making sense of scientific uncertainty:

> ‘... a professional emergency manager working at the public interface may initially struggle to comprehend probabilistic and/or ensemble forecasts without further translation of the science’ (Faulkner et al. 2007:692).

One of the major factors contributing to confusion between professional partners over current flood warnings is the difference in the language used by the Environment Agency and the Met Office to describe flood and severe weather risks (Environment Agency 2007a, Pitt 2008). The Pitt Review suggests that probabilistic information would be well-received by professional partners because of the potential benefits in terms of ‘better forecasting and more accurate prediction of where and when flooding will occur’ (Pitt 2008:xiii), i.e. the usefulness of the information.

Decision uncertainty

Decision uncertainty includes a wider range of factors including the financial and social costs or benefits of taking a particular course of action (e.g. moving evacuation equipment or closing roads). Environment Agency duty officers have to take account of these wider social and economic consequences (and uncertainties) when deciding whether to issue a warning or whether to put certain flood defence structures into operation (e.g. demountable defences or the Thames Barrier) (McCarthy et al. 2007).

Given the significance of this kind of uncertainty, which may be harder to make explicit – and possibly to control – than scientific uncertainty, decision-makers may not welcome the increased visibility of scientific uncertainty (Faulkner et al. 2007).

The Environment Agency is not a naturally collaborative organisation. The professional background of the majority of its staff (e.g. in engineering or environmental sciences) and the types of issues it deals with mean that its way of seeing the world tends to emphasise the physical and engineering sciences (Colbourne 2008). As a result, past research has not looked primarily at the context in which emergency responders receive information or the factors they take into account in deciding their response. Information is lacking on elements such as the decision systems of professional partners and the degree of uncertainty in estimates of the consequences of flooding, including in the extent and location of damages.

It is likely that there is a relationship between partners' understanding of – and ability to manage – decision uncertainty and their willingness to accept scientific uncertainty (particularly outside their field of expertise). Effective use of probabilistic information should be based on an understanding of the degree of probability or uncertainty that partners collectively are willing to accept.[11]

This kind of debate seems to have taken place in the Netherlands in recent years with the result that:

> '... a broader understanding of the errors and biases which permeate human perception of risk information has emerged, and new "postnormal" communication tools [have been] debated' (Faulkner et al. 2007:692).

3.2.2 Professional partner response to flood warnings

This section examines the reception of flood warning information by professional partners and their response in conditions where responders are working from their own premises rather than a central command location. The Civil Contingencies Act requires responders to share information and co-ordinate, so this should be seen as part of all preparation and response activities.

The degree of co-ordination on flood incident response is illustrated in the diagram of communications links in multi-agency response to flooding in Lancashire (Figure 3.2). In this case, the police – along with the Environment Agency and Lancashire County Council – play a central role in co-ordinating the efforts of the emergency response partners.

[11] Personal communication, Craig Woolhouse, Environment Agency

However, further research is needed to find out:

- whether the relationships shown are similar to those found in other parts of the country;
- how communications operate in practice.

Although professional partners may have an understanding that the warnings they receive from the Environment Agency (and other sources) include a degree of uncertainty which is inherent to the science of forecasting, they need to know how they can use this information to take the best decisions about how to respond to the forecast emergency situation (e.g. by putting staff on alert, making stores available, etc.).

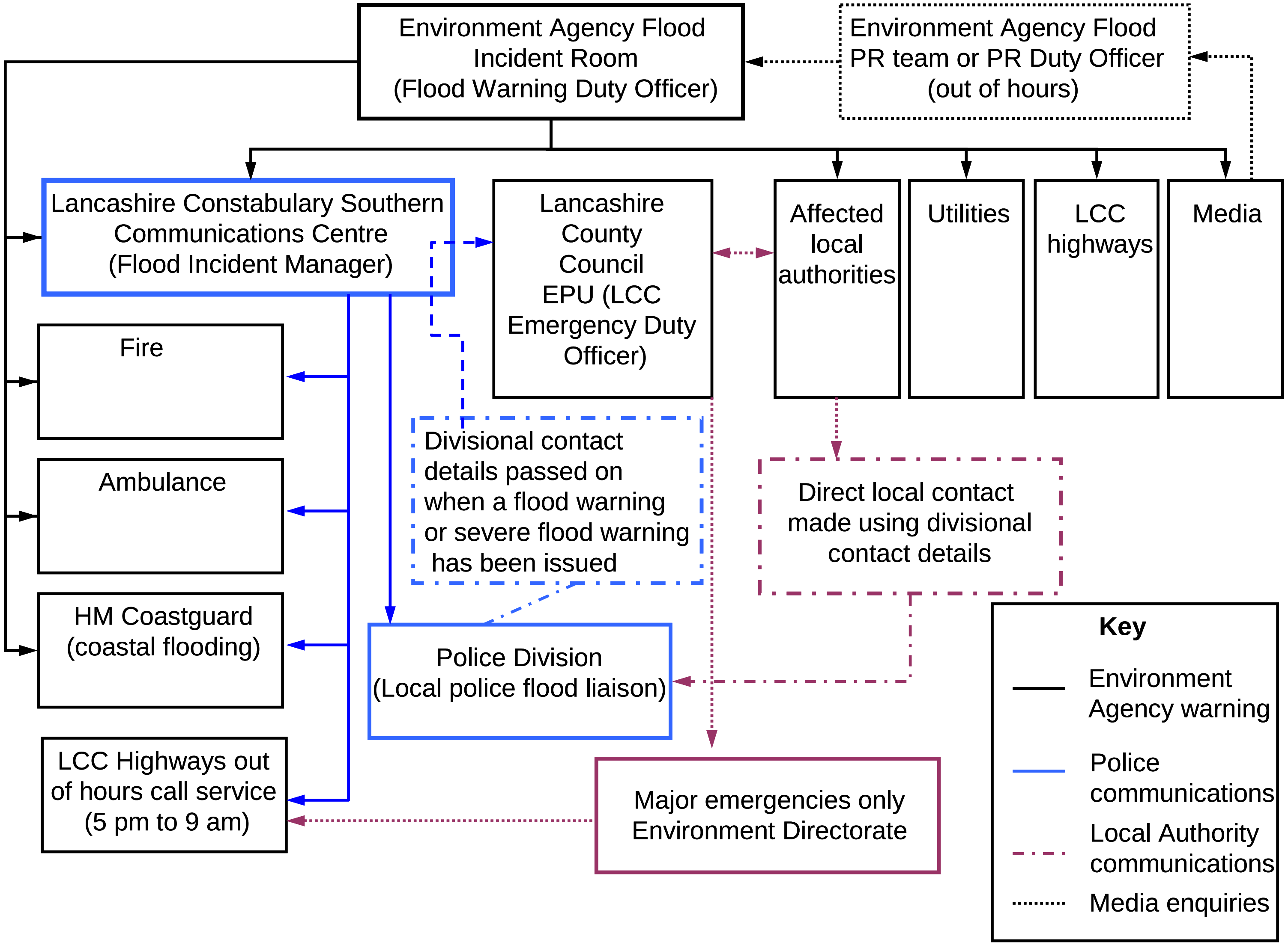
In a recent study of risk communication between professional partners in the context of a flood incident, local authority and police service professionals said that, while scientific data inputs were of interest, their primary concern was the protection of life (McCarthy et al. 2007). Management decisions are centred on the availability of staff and resources alongside provisions for the health and safety of staff and members of the public.

The two professional partners participating in the study did not feel that probabilistic ensemble forecasts would be useful for their work. They were more interested in receiving information about the likely extent and depth of flooding, the chances of flooding recurring and how long floodwater might remain. However, they did think that the probabilistic information tools (particularly the visual presentation of risk) could be useful communications tools for 'making people really sit up and take notice' (McCarthy et al. 2007).

The lack of enthusiasm for probabilistic information as a tool to support emergency response shown by the participants in this study is not necessarily shared by all emergency responders, many of whom feel that earlier warning could significantly improve their response. However, the Environment Agency is concerned that these partners may not fully recognise the trade-off between earlier warnings and the increased likelihood of false alarms.[12]

[12] Personal communication, Craig Woolhouse, Environment Agency

Figure 3.2 Lancashire County Council: services involved in flood incidents and routes of communication (taken from multi-agency response plan).



3.2.3 Differentiation between professional partners

Professional partners use warnings for different purposes (McCarthy et al. 2007). For example, local authorities need to make provisions for sheltering those unable to stay in their homes and for maintaining services for vulnerable people. They are likely to need lead times of around 24 hours to ensure that staff and stores are available and locations that can offer emergency shelters are on standby. Police services can carry out actions such as closing roads with a much shorter lead time. At the other extreme, water companies have indicated that they would need 48 hours' notice to put in place equipment to deal with the kind of flooding seen in the Midlands in 2007.[13]

Following the simulation exercise reported by McCarthy et al. (2007), both the local authority and the police professionals involved argued for the importance of accuracy in the Environment Agency's flood warnings. However, the professionals had slightly different understandings of what 'accuracy' would mean in practice.

For emergency services taking decisions affecting people and places, accuracy was important in relation to geographical detail:

> 'With their need to make tactical decisions on the ground, the professionals felt that the greater the local detail (e.g. the locations of large pumps) the better' (McCarthy et al. 2007).

However, this could lead to over-confidence in information providing this level of detail:

> 'Of some concern was the local authority professional's view that the finer detail implicit in the two-dimensional hydrodynamic inundation models, the greater is the certainty in the predictions suggesting some higher level of 'accuracy' or even 'certainty'. However, if the two-dimensional model is the final output from a complex modelling cascade as trialled at the workshop, inevitably the inundation model is almost entirely dependent on the effectiveness of the models that precede it. This means that the degree of confidence of this apparent detail needs further unpicking to be useful to these professionals' (McCarthy et al. 2007).

3.4 Businesses

Little information is available in Defra/Environment Agency research on the responses of businesses to flood warnings. This is a significant gap in knowledge, considering the potential economic damages to business as a result of flooding[14]. Damage to businesses can also have knock-on effects on the wider community if workers have to be laid off or because of the health and environmental impacts of hazardous substances leaking and dispersing in the flood water.

One of the main problems in describing business response to flood warnings is the huge variety in size, type and location.

[13] Personal communication, Craig Woolhouse, Environment Agency
[14] These damages are well-documented in the flood risk management appraisal handbook developed by the Flood Hazard Resource Centre at Middlesex University (FHRC 2006).

3.4.1 Business size

Whereas large companies often have professional risk managers or members of staff with some understanding of scientific uncertainties and the tools for presenting probabilistic information, it seems less likely that small and medium enterprises (SMEs) will have a clear understanding of the science uncertainties that characterise flood warnings or of the kinds of models used for forecasting.

Nevertheless, small businesses can have valuable assets that need to be protected from flooding. Small size means that they may be better able to move assets (vehicles, equipment, etc.) out of the flood risk area if given sufficient warning.

Complicated or apparently contradictory information about the probability of flooding is likely to be a barrier to effective response on the part of small businesses. As one Barnsley business explained to the Pitt Review team:

> 'You look on the internet and you look on three different internet browsers. Three different programmes for weather and all have three different reports but same area and you are like which one, I will look out of window. Do you know what I mean?' (Pitt 2008:xxiii)

3.4.2 Business sector

The sector to which the business belongs will affect understanding of, and response to, flood warnings in general and specifically to probabilistic information in flood warnings.

For example, farmers and small rural businesses are likely to have:

- a good practical understanding of weather and changes in river catchments;
- experience in comparing forecasts (principally weather forecasts) with evidence in the real world.

They will also be keen to receive warnings with longer lead times to ensure they have time to move livestock and equipment (Environment Agency 2007a).

The Environment Agency now has a number of flood risk staff working to recruit businesses to the Floodline Warnings Direct service and to provide advice on resilience measures. These people may be a good source of information about businesses in their area and their responses to flood warnings.

4 Implications

The review of Defra/Environment Agency FCERM research relevant to the use of probabilistic information in flood warnings has highlighted a number of issues that will be explored in the next stages of the research.

- There is little available information about differences within the groups examined in this review (members of the public, professional partners, businesses) in terms of their perception of risk and uncertainty in flood warnings. Although understanding differences in perceptions of risk and uncertainty was one of the objectives of this work, differences in perception are likely to be less important than differences in the response to flooding. For example, the use of probabilistic information to provide an early alert to disabled or elderly people and their carers may greatly increase their ability to take action.
- One of the potential benefits of probabilistic flood warnings perceived by Environment Agency staff and professional partners is the possibility of giving earlier warnings. This could be of particular benefit to certain groups of people who may need more time to make preparations for flooding (e.g. the elderly or disabled people) or to emergency responders that need a longer lead in period to put systems into operation (e.g. water companies).
- There are a range of variables which together determine flood warning response either by inhibiting or enabling response by individuals and organisations. As well as the characteristics of the warning message, individual factors such as age and ethnicity and other predictors of 'vulnerability' and social factors such as social networks all influence whether a response is made to a warning. All these variables will be relevant to the design of any future warnings.
- The provision of information is only one of these variables. The way that information is understood and acted on is often influenced by other variables such as trust in the source of the information or warning. More information will not necessarily improve responses to flooding.
- Previous work for the Environment Agency has looked at probabilistic flood forecasting products. As yet, probabilistic flood warning products have not been specifically developed.
- Previous research highlighting the use of 'expert expressions' and return periods as unhelpful in communicating risk to members of the public needs to be taken into account in the design of probabilistic information products (forecasts or warnings).
- There is a lack of information about the way that professional partners use warning information to inform their response to flooding. It will be necessary to understand how this works in order to assess the potential impact of using probabilistic information. The needs of professional partners are likely to vary according to their scientific background and how they use the information: this underlines the fact that a 'one size fits all' approach is unlikely to be effective.
- Almost no relevant information was found on how businesses use flood warning information, their perceptions of risk and uncertainty in relation to flooding, or the significant differences in response between businesses of different sizes and characteristics.

- The review has brought out a useful distinction between decision uncertainty and scientific uncertainty. The provision of probabilistic information in flood warning can be considered as making transparent one aspect of scientific uncertainty. To what extent it reduces either scientific uncertainty or decision uncertainty remains an empirical question.

References

BALMFORTH, D., DIGMAN, C.J., BUTLER, D. and SHAFFER, P., 2006. *Defra integrated urban drainage pilots: scoping study.* London: Defra. Available from: http://www.defra.gov.uk/environ/fcd/policy/strategy/scoperev.pdf [Accessed 19 February 2009].

BMRB INTERNATIONAL, 1998. *Flood warning dissemination – report on 1998 and 1997 public awareness surveys*. Prepared for the Environment Agency, May 1998.

BMRB INTERNATIONAL ,1999. *Floods – at-risk survey report*. Prepared for the Environment Agency, May 1999.

BRISCOMBE, N., GOILLAU, P., SHEPPARD, T., WATSON, G. and CALLADENE, T., 2005. *Move to safety – the role of human and technology factors in future flood warning systems.* In Proceedings of IEE and MOD HFI DTC Symposium, People and Systems – Who Are We Designing For (16–17 November 2005), 61-67. London: IEEE. [This work was funded by DEFRA through the Joint Environment Agency/DEFRA Flood and Coastal Erosion Risk Management R&D Programme as Projects FD2202 and FD2209 (Improving Dissemination of Flood Warnings – Phases 1 and 2).]

BURNINGHAM, K., FIELDING, J., THRUSH, D., AND GRAY, K., 2005. *Flood warning for vulnerable groups*. Science Summary SC990007/SS. Joint Defra/Environment Agency Flood and Coastal Erosion Risk Management R&D Programme. Bristol: Environment Agency Bristol: Environment Agency. Available from: http://publications.environment-agency.gov.uk/pdf/SCHO0505BJBS-e-e.pdf [Accessed 19 February 2009].

CAVE, B., CRAGG, L., GRAY, J., PARKER, D.J., PYGOTT, K and TAPSELL, S., 2008. *Understanding of and response to severe flash flooding.* Draft. Environment Agency Science Report SC070021.

COLBOURNE, L., 2008. *Collaboration with civil contingency partners and communities for improved FCERM outcomes. Improving institutional and social responses to flooding*. Science Report SC060019. Report to the Environment Agency.

DEFRA/ENVIRONMENT AGENCY, 2003 *Community and public participation: risk communication and improving decision-making in flood and coastal defence*. R&D Technical Report FD2007/TR. Joint Defra/Environment Agency Flood and Coastal Erosion Risk Management R&D Programme. Bristol: Environment Agency. Available from: http://sciencesearch.defra.gov.uk/Document.aspx?Document=FD2007_2085_TRP.pdf [Accessed 19 February 2009].

ENVIRONMENT AGENCY, 2006a. *Flood warning levels of service*. AMS Work Instruction 137_05 Version 2. Bristol: Environment Agency.

ENVIRONMENT AGENCY, 2006b. *2006–2007 Pre flood awareness campaign full report.* Bristol: Environment Agency.

ENVIRONMENT AGENCY, 2007a. *Review of 2007 summer floods*. Bristol: Environment Agency. Available from: http://www.environment-agency.gov.uk/research/library/publications/33891.aspx [Accessed 19 February 2009].

ENVIRONMENT AGENCY, 2007b. *Risk assessment for flood incident management: management and tools*. R&D Technical Report SC050028/SR1. Joint Defra/Environment Agency Flood and Coastal Erosion Risk Management R&D Programme. Bristol: Environment Agency. Available from: http://publications.environment-agency.gov.uk/pdf/SCHO0307BMIK-e-e.pdf [Accessed 19 February 2009].

ENVIRONMENT AGENCY and MET OFFICE, 2008 *Extreme Rainfall Alert (ERA) service pilot – user guide*. Unpublished.

FAULKNER, H., GREEN, C., PARKER, D.J. and BEVEN, K., 2007. Developing a translational discourse to communicate uncertainty in flood risk between science and the practitioner. *Ambio*, 36(8), 692-704. Available from: http://ambio.allenpress.com/archive/0044-7447/36/8/pdf/i0044-7447-36-8-692.pdf [Accessed 19 February 2009].

FERNANDEZ-BILBAO, A and TWIGGER-ROSS, C (eds) (2008) *Improving response, recovery and resilience. Improving Institutional and Social Responses to Flooding Science Report (SC060019) - Work Package 2.* EA/Defra Science Report.

FIELDING, J, BURNINGHAM, K, THRUSH, D and CATT, R., 2007. *Public responses to flood warnings*. Science Report SC020116. Joint Defra/Environment Agency Flood and Coastal Erosion Risk Management R&D Programme. Bristol: Environment Agency. Available from: http://sciencesearch.defra.gov.uk/Document.aspx?Document=Public_Resp__10528.PDF [Accessed 19 February 2009].

FLOOD HAZARD RESOURCE CENTRE (FHRC), 2006. *Benefits of flood and coastal risk management: a handbook of assessment techniques*. Joint Defra/Environment Agency R&D Programme. Hendon: Middlesex University Press.

HAGGART, Kelly (ed) 1994. *Rivers of Life*. PANOS – Bangladesh Centre for Advanced Studies, Dhaka.

LETTENMAIER, D.P. and WOOD, E.F., 1993. *Hydrologic forecasting*. In Handbook of Hydrology (ed. R.D. Maidment), pp. 26.1-26.30. New York: McGraw-Hill.

OFFICE FOR NATIONAL STATISTICS (ONS), 2006. Internet Access: Households and Individuals. Available from: http://www.statistics.gov.uk/statbase/Product.asp?vlnk=5672 [Accessed 19 February 2009].

MCCARTHY, S., TUNSTALL, S., PARKER, D., FAULKNER, H. and HOWE, J., 2007 Risk communication in emergency response to a simulated extreme flood. *Environmental Hazards*, 7, 179-192.

PAPPENBERGER, F., BEVEN, K.J., HUNTER, N., GOULWELEEUW, B., BATES, P., DE ROO, A. and THIELEN, J. 2005. Cascading model uncertainty from medium range weather forecasts (10 days) through a rainfall-runoff model to flood inundation predictions within the European Flood Forecasting System (EFFS). *Hydrology and Earth System Sciences*, 9, 381-393.

PARKER, D.J., PRIEST, S., SCHILDT, A., and HANDMER, J., 2008. *Modelling the damage reducing effects of flood warnings*. Final report. FLOODsite Report No. T10-07-12. Available from: http://www.floodsite.net [Accessed 19 February 2009].

PITT, M., 2008. *The Pitt Review: lessons learned from the 2007 floods*. London: Cabinet Office. Available from: http://archive.cabinetoffice.gov.uk/pittreview/thepittreview/final_report.html [Accessed 19 February 2009].

ROBERTSON, C, 2005. Unpublished MSc dissertation on flood warning and ethnic communities.

SENE, K., HUBAND, M., CHEN, Y. and DARCH, G., 2007. *Probabilistic flood forecasting: scoping study*. R&D Technical Report FD2901. Joint Defra/Environment Agency Flood and Coastal Erosion Risk Management R&D Programme. Bristol: Environment Agency. Available from: http://sciencesearch.defra.gov.uk/Document.aspx?Document=FD2901_6230_TRP.pdf [Accessed 19 February 2009].

SHAW, J., CUDMORE, S., COLLIER, D., REED, D.W., ANTONELLI, A. and BERMAN, J., 2005. *Improving flood warning awareness in low probability and medium-high consequence flood zones*. R&D Technical Report W5-024. Joint Defra/Environment Agency Flood and Coastal Erosion Risk Management R&D Programme. Bristol: Environment Agency. Available from: http://publications.environment-agency.gov.uk/pdf/SCHO0505BJDT-e-e.pdf [Accessed 19 February 2009].

Tapsell, S. *FLOODsite case study*. In Fernández-Bilbao, A and Twigger-Ross, C (eds) (2008) *Improving response, recovery and resilience. Improving Institutional and Social Responses to Flooding Science Report (SC060019) - Work Package 2.* EA/Defra Science Report.

TAPSELL, S, BURTON, R, OAKES, S and PARKER, D., 2005. *The social performance of flood warning communications technologies*. Technical Report W5C-016. Joint Defra/Environment Agency Flood and Coastal Erosion Risk Management R&D Programme. Bristol: Environment Agency. Available from: http://publications.environment-agency.gov.uk/pdf/SCHO0505BJDY-e-e.pdf [Accessed 19 February 2009].

THRUSH D., BURNINGHAM, K and FIELDING J., 2005. *Flood warning for vulnerable groups: a qualitative study.* Science Report SC990007/SR3. Joint Defra/Environment Agency Flood and Coastal Erosion Risk Management R&D Programme. Bristol: Environment Agency. Available from: http://publications.environment-agency.gov.uk/pdf/SCHO0505BJBU-e-e.pdf [Accessed 19 February 2009]

TWIGGER-ROSS, C., 2005. *The impact on flooding on urban and rural communities*. R&D Technical Report SC040033/SR1. Joint Defra/Environment Agency Flood and Coastal Erosion Risk Management R&D Programme. Bristol: Environment Agency. Available from: http://publications.environment-agency.gov.uk/pdf/SCHO1005BJTG-e-e.pdf [Accessed 19 February 2009].

TWIGGER-ROSS, C and SCRASE, I., 2006. *Development of an Environment Agency policy on flooding and vulnerability.* Bristol: Environment Agency

TWIGGER-ROSS, C., FERNANDEZ-BILBAO, A., TAPSELL, S., WALKER, G., WATSON, N., DEEMING, H., and KASHEFI, E., 2008. *Improving flood warnings*. Final report. Science Report SC060019. Joint Defra/Environment Agency Flood and Coastal Erosion Risk Management R&D Programme Bristol: Environment Agency. [Project: Improving Institutional and Social Responses to Flooding].

WALKER, G. and Kashefi, E., 2008. How the public and professional partners make sense of information about risk and uncertainty: Literature Review. Science Report SC070060/SR. Joint Defra/Environment Agency Flood and Coastal Erosion Risk Management R&D Programme Bristol: Environment Agency. [Project: Communicating and Disseminating Probabilistic flood Warnings]

WATSON, A., HARVATT, J. and PICKERING, R., 2007. *National Duty Officer support assessment*. Science Report SC07007/SR. Bristol: Environment Agency.

Appendix A – FCERM projects examined in the review

Theme	Name of project	Project code	Research contractor	Finish date
Strategy and policy development (SPD)	Who benefits from flood management policies	FD2606	HR Wallingford	2008
	Supporting the development of a social science strategy for the FCERM R&D Programme	FD2604	Collingwood Environmental Planning	2008
	Risk assessment and risk management in small urban catchment areas	FD2603	University of Manchester	2008
	Community participation and risk perception	FD2007	Scott Wilson	2004
Incident management and community engagement (IMCE)	Coastal flood forecasting	SC050069	HR Wallingford	2009
	Improving institutional and social responses to flooding (IISRF)	SC060019	Collingwood Environmental Planning	2008
	Understanding the responses to flash flooding	SC070021	Halcrow Group Ltd	2008
	Flood Warning Dissemination Demonstration	SC040034	QinetiQ Ltd	2007
	Probabilistic flood forecasting scoping study	FD2901	Atkins	2006
	Use of probability forecasts		Joint project Environment Agency and Met Office	2008
	Hydrological modelling with convective scale rainfall	FDK(06)03	WL/Delft Hydraulics and CEH	2007
	Flood warnings for vulnerable groups	W5C-018	University of Surrey	2005
	Public response to flood warning	SC020116	University of Surrey	2007
	Improving flood warning awareness in low probability and medium-high consequence flood zones	W5-024	Greenstreet Berman	2005
	Community engagement with flood history		University of Gloucester	
	National Duty Officer support assessment	SC07007	JBA	2007

Appendix B – Roles and duties of Environment Agency staff

a) Regional Base Controller (RBC)

Role Co-ordinate and direct the Regions response to a major flood.

Duties

- Activate and staff the Regional Incident Room.
- Declare the flood event a Regional Major Incident if the criteria in CICS are met.
- Provide Strategic Liaison Officers from the Regional Office to support Areas when requested by Area Base Controllers.
- Assist the effectiveness of the response to the flood event.
    - Take a strategic overview of risks and the level of response.
    - Make strategic decisions in conjunction with the Area Base Controllers, Liaison Officers (who in turn will liaise with emergency services), Public Relations Duty Officer and the Regional Duty Officer.
    - Agree remedial action when necessary.
    - Make and/or approve realistic and justifiable proposals to secure or reallocate resources.
- Ensure that the long-term resource availability and requirements of the Region are identified, co-ordinated and allocated in accordance with risk and return. Prioritise requirements within the Region when there is a shortage of resource.
- Liaise with Head Office and other regions as defined by the HELP procedures.
- Initiate the Inter Regional Aid procedures when required.
- Identify the need and initiate the Military Aid procedures when agreed with Area Base Controllers. Maintain contact with the NE Brigade Commander regarding military assistance.
- Liaise with adjacent Regions where an event overlaps the Regions. Ensure the response is co-ordinated.
- Obtain authorisation for emergency expenditure when required.
- Provide timely and accurate information to the National Duty Officer (NDO), Regional Director, Regional Duty Officer (RDO), Defra/National Assembly of Wales, Regional Management Team (RMT) members when required, and other officers in accordance with Environment Agency HELP and RBC procedures.
- Specify the information and data that you require from Area Base Controllers.
- Provide accurate and up-to-date information to the PR Duty Officer.

- Ensure a log of all actions and decisions is taken.
- Provide feedback on the effectiveness of the Regional Incident Procedures and recommend, where necessary, changes to national policy/procedures to the Regional Flood Defence Manager.
- Responsible for the production of Regional SITREPs.
- Attend and undertake all relevant training requirements.

b) Area Base Controller (ABC)

Role Manage the Area's response to a flood event

Duties

- Take command of the Area's response to the flood incident.
- Decide and communicate the command structure in place for all elements of the response.
- Lead and co-ordinate the activities of the Flood Warning Duty Officer (FWDO), Operations Duty Officer (ODO), Liaison Officers, Site Controllers and support staff not reporting to one of the above.
- Brief senior managers and the Regional Base Controller.
- Pro actively examine the incident to see what has happened, what will happen and what could happen.
- Take a strategic and tactical overview of risks and the level of response and make decisions in conjunction with:
    - the Strategic (Gold) Liaison Officers (who will in turn liaise with emergency services);
    - the Regional Base Controller (where there are limited regional resources);
    - the Tactical (Silver) Liaison Officers (who in turn will liaise with emergency services);
    - the Public Relations Duty Officer;
    - your staff.

  And agree remedial action when necessary.
- Brief Area staff regularly on the incident.
- Anticipate resource needs and actions which need to be taken. Prioritise actions and resources.
- Ensure that public relations are properly dealt with in conjunction with the Public Relations Duty Officer and Regional Base Controller. Ensure that an appropriate officer takes responsibility for VIP visits to the Area.
- Ensure welfare provisions are in place to include rotas, shift patterns, facilities, provisions and health and safety equipment.
- Establish regular liaison with local authorities, the emergency services and, if necessary, the military. NB Military liaison will normally be via Liaison Officers and the RBC who will maintain an overview.

  - Set up Strategic, Tactical and Operational Commands together with local authorities and the emergency services when they are agreed to be necessary.
  - Obtain Strategic Liaison Officers from Regional Office via the Regional Base Controller when needed.
- Ensure an event management system is in place and is working effectively.
- Liaise with Head Office and Defra as defined by the Environment Agency's HELP procedures.
- Be responsible for the production of Area SITREPs.
- Be responsible for the production of the Flood Event and document hand-over to FIM team leader.
- Instigate and co-ordinate post-event data collection.
- Attend and undertake all relevant training requirements.

c) Monitoring Duty Officer (MDO)

Role Monitor weather forecasts, radar, actual rainfall, fluvial and coastal water levels

Duties

- Be aware of catchment and weather conditions across the Region.
- Monitor as defined by the Regional Monitoring Procedures.
- Provide accurate and timely information to the appropriate duty officer.
- Check full datasets are received.
- Quality assure the data for validity.
- Identify unusual trends in valid data.
- Interpret the monitoring data and information accurately, and draw valid conclusions.
- Know the procedures for instigating remedial action.
- Maintain an accurate log of events and actions.
- Attend and undertake all relevant training requirements.

d) Forecasting Duty Officer (FDO)

Role Forecast likely water conditions

Duties

- Prepare forecasts as set down in the Regional Forecasting Procedures.
- Select and agree with Areas the appropriate frequency of forecast and data requirements for the event.
- Liaise with the weather and tidal services provider to obtain appropriate weather forecasts and warnings.

- Proactively prepare additional forecasts which may be required.
- Quality assure forecasts produced (both inputs and outputs).
- If appropriate, use alternative forecasting approaches in consultation with Areas.
- Regularly update Areas to ensure the information they require is provided when they require it.
- Fully and accurately record information received and given and decisions made in the duty log.
- Monitor tides as defined by the Regional Monitoring Procedures.
- Responsible for setting up an MDO and FDO rota.
- Attend and undertake all relevant training requirements.

e) Flood Warning Duty Officer (FWDO)

Role Issue flood warnings.

Duties

- Confirm current and predicted catchment and coastal conditions with the Forecasting Duty Officer and Operations Duty Officer.
- Fully and accurately record information received, given and the decisions made in the duty log.
- Determine correctly the scale of the event and initiate the Area Flood Warning Manual procedures.
- Accurately identify the flood risk and issue flood warnings by appropriate method as defined by the Area Flood Warning Manual.
- Provide accurate and timely information to the Area Base Controller and PR Duty Officers in accordance with Area Flood Warning Manual Procedures.
- Brief local authorities and the emergency services in accordance with the Area Flood Warning Manual Procedures.
- Deal with external telephone calls.
- Give press interviews when requested by the Area Base Controller.
- Downgrade the flood warnings when required by the Area Flood Warning Manual procedures.
- Check that the flood warning systems are operating effectively.
- Implement alternative flood warning communication procedures promptly in the event of the automatic systems failing.
- Identify improvements to service delivery and the operation of procedures and make clear and justifiable recommendations.
- Direct the work of the Assistant Flood Warning Duty Officer (AFWDO).

- Check that health & safety and risk assessments requirements are carried out for staff on-site under direct control of incident management.
- Attend and undertake all relevant training requirements.

f) Operations Duty Officer (ODO)

Role Organise the implementation of emergency operations.

Duties

- Ensure that the line of command for all works to Environment Agency defences during the flood event is agreed and known by all those who need to know. This particularly applies when external organisations are involved (e.g. the military, contractors or local authorities).
- Confirm catchment, coastal or tidal conditions with the Forecasting Duty Officer and Flood Warning Duty Officer.
- Initiate and maintain effective communications with the Emergency Duty Officer and Flood Warning Duty Officer.
- Issue Operational Instructions in accordance with the Area Operational Procedures and check they have been carried out successfully.
- Check that health & safety and risk assessments requirements are carried out for staff on-site under direct control of incident management.
- Assess and monitor the event response to confirm that it is appropriate. Promptly implement contingency plans when the event response is not working and scale down the response if it is excessive.
- When necessary assess the need for additional resources with the Emergency Duty Officer and Area Base Controller.
- When additional resources are secured ensure, with the Emergency Duty Officer as appropriate, that they are obtained when required and deployed effectively. It should be noted that the Emergency Duty Officer will not assume responsibility for the supervision of external resources.
- Ensure a log of all Operational Instructions issued and the deployment of all operational resources is kept.
- Give press interviews when requested by the Area Base Controller.
- Accurately identify improvements to service delivery and the operation of procedures, and make clear and justifiable recommendations.
- Be responsible for receiving Area National Incident Reporting System (NIRS) incidents and allocating incident requirements to appropriate staff.
- Be responsible for out-of-hours reservoir safety incidents.
- Be responsible as the out-of-hours competent Incident and Flood Risk Management (IFRM) duty officer.
- Attend and undertake all relevant training requirements.

g) Emergencies Duty Officer (EDO)

Role Implement emergency operations.

Duties

- Confirm with the Operations Duty Officer the line of command for all works carried out by the Environment Agency and to its defences during the flood event. This particularly applies when external organisations are involved (e.g. the military, contractors or local authorities). NB It is possible that some of the operational work **will not** be under the command of the Emergency Duty Officer.
- Receive and act upon Operational Instructions issued by the Operations Duty Officer.
- Ensure that the Operations Delivery are fully briefed on risk assessments and the health & safety requirements of implementing the procedures.
- Check that a suitable level of response is in place to deliver the Operational Instructions, including preparing in advance and using a contingency plan for when Operations Delivery resources are used up.
- Report promptly and accurately on the implementation of the Operational Instructions.
- Effectively manage the people and plant resource requirement.
- Identify the need for implementing contingency plans to support the incident response in conjunction with the Operations Duty Officer. If requested by and agreed with the Operations Duty Officer, manage the additional resource.
- Review the operation of procedures following events and accurately identify improvements to service delivery.
- Manage and implement emergency works where possible.
- Attend and undertake all relevant training requirements.

h) **National Flood Warning Duty Officer (NFWDO) –** assists in the national co-ordination of flood events

i) **Press officers** – provide out-of-hours support for media communications

Roles and responsibilities of strategic managers in major incidents

The role of a strategic manager in a Major Incident – whether at National, Regional or Area level – is to manage the impact of the incident on the Environment Agency's reputation, operations and liabilities. This includes managing the expectations of professional partners, key stakeholders, the public and the media.

In undertaking this role, the Strategic Manager works closely with the Base Controller to ensure that the incident response is managed in an effective and efficient manner, including issues such as the re-prioritisation of normal activities, moderation of standards of service and the effective and safe use of staff.

The Strategic Manager will normally be:

- at National Level, the Director of Operations or nominated deputy;
- at a Regional level, the Regional Director or nominated deputy;
- at an Area level, the Area Manager or nominated deputy.

The Strategic Manager is responsible for:

- ensuring the reputation of the Environment Agency is protected, with regard to the management of the incident, and the impact on the rest of the business;
- advising on and support the team on any major media briefings, visits of VIPs;
- ensuring that the Environment Agency's long-term strategic goals (e.g. preventing development of the floodplain and industrial regulation) are promoted as appropriate;
- setting boundaries and goals for the Base Controller to ensure that the response is managed in an effective and efficient manner; including issues such re-prioritisation of normal activities and moderation of standards of service during an incident;
- ensuring people are being utilised effectively and safely;
- providing strategic direction on policy issues, and support to Base Controllers, for the management of the incident: such as provision of adequate resources, representation at any Strategic or Tactical Control Centres;
- ensuring liaison with key stakeholders/individuals (e.g. government/MPs) is achieved, either by them or nominated representatives, but ensuring in close liaison with Base Controllers.

Like Base Controllers, Strategic Managers will require support during a Major Incident, to ensure that all aspects of their role are actively managed. They should consider whether to set up a Strategic Management Team, including other Management Team members. This team should assist in dealing with media, policy, personnel and finance issues. The team should meet at frequent, predetermined intervals, whether in person or by telephone/video conference.

Incident management requires officers to assume roles such as Base Controller, Strategic Manager and Liaison Officer. Some of these roles may on occasions be undertaken by the same person (although all the activities remain the same). For example, the Base Controller (tactical) will need to consider strategic decisions in the absence of a strategic manager or the Strategic Manager and Strategic Liaison Officer roles may be undertaken by the same person.

Appendix C – Flood warning investment strategy targets

As part of its National Flood Warning Service Strategy, the Environment Agency sets performance targets for the Flood Warning System. These targets relate to the measures defined in Table A1.

Table A1 Definition of flood warning investment strategy measures.

Measure	Definition
Damage reduction	The amount of pre-flooding action that can be taken to reduce the cost of the flooding event expressed as a percentage factor, taking into consideration the lead time of the warning (i.e. the length of time between when a warning was issued and when flooding occurred) that allows the pre-flooding action to be carried out.
Coverage	The proportion of properties (homes and businesses) within the Flood Warning Service Limit that have been offered an 'appropriate' flood warning service.
Effectiveness	The proportion of flooded serviced properties that were sent a flood warning.
Availability	The proportion of flooded serviced properties that received a flood warning.
Ability	The proportion of residents who are able to receive, understand and respond to warnings.
Effective action	The proportion of residents who take action on receipt of a flood warning.

Figure A1 Flood warning investment strategy targets.

English Regions					
	Year 03/04	Year 06/07	Year 07/08	Year 09/10	Year 12/13
Damage Reduction	30%	35%	37%	40%	40%
Coverage	70%	78%	78%	80%	80%
Service Effectiveness	65%	75%	77%	80%	80%
Availability	63%	75%	77%	80%	80%
Ability	80%	85%	85%	85%	85%
Effective Action	50%	75%	78%	85%	85%
EA Wales					
	Year 03/04	Year 06/07	Year 07/08	Year 09/10	Year 12/13
Damage Reduction	30%	35%	37%	40%	40%
Coverage	50%	68%	72%	80%	80%
Service Effectiveness	49%	61%	65%	80%	80%
Availability	61%	72%	70%	75%	75%
Ability	75%	80%	75%	85%	85%
Effective Action	61%	75%	78%	85%	85%

Source: Environment Agency Work Instruction AMS 395_03, *Flood warning performance measures*, Version 3, 2005 (reproduced from Sene et al. 2007)

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