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AN INTEGRATED APPROACH TO FLOOD WARNING IN ENGLAND AND WALES

A thesis submitted to Middlesex University in partial fulfilment of the requirements for the degree of Doctor of Philosophy

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ABSTRACT

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An integrated approach to flood warning in England and Wales

Flood warning systems have been researched and discussed for several decades and there is a high degree of consensus in the literature that the most effective structure for a flood warning system is that of an integrated system. Experience suggests however, that few, if any, operational systems are designed in an integrated way and that few practitioners fully appreciate the benefits of integration. Through an analysis of arrangements in the Thames Basin, this research addresses this issue by identifying the necessary criteria and actions required to introduce an integrated system.

The limited number of models that attempt to conceptualise flood warning systems in an integrated way have been critically examined and have found to focus too narrowly on selective integrative criteria. It is concluded that there is a need for a wider and multi-dimensional perspective. This study rectifies this deficiency by presenting a conceptual model that is derived from a more comprehensive assessment of the most relevant integrative factors. A two-staged process is adopted with an initial identification of a wide range of issues and variables, leading to a more focused set of factors presented under four main headings that are used to structure the substantive chapters of this thesis. These integrative factors can be conceptualised as crosscutting strands running through and drawing together the main components of a flood warning system (detection, forecasting, dissemination and response) that help ensure that these components work together collaboratively towards a common aim.

Few of the integrative factors identified in this research were found in operational flood warning practices in England and Wales prior to 1996. A number of improvements were made with the establishment of the Environment Agency as the lead authority in both flood forecasting and flood warning dissemination, but a number of weakness still prevail. Through the use of case studies the plausibility of introducing a fully integrated approach to future arrangements has been tested and found to be both practical and feasible.

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LIST OF ABBREVIATIONS

AOD	Above Ordnance Datum
AVM	Automatic Voice Messaging
BMRB	British Market Research Bureau
BSE	Bovine Spongiform Encephalopathy
CASCADE	Catchment Assessment System Concerned with the Accurate Dissemination of flood warnings
CC	County Council
CIMS	Computer Integrated Manufacturing System
CDM	Criteria-Development Matrix
DC	District Council
DTM	Digital Terrain Model
EU	European Union
EFAG	Easter Floods Action Group
FDFWRS	Flood Detection, Forecasting, Warning and Response System
GANDOLF	Generating Advanced Nowcasts for Deployment in Operational Land-based Flood forecasts
GIS	Geographic Information System
Hyrad	HYdrological RADar display system
IOS	Inter-Organisational Information Systems
IT	Information Technology
LAs	Local authorities
LESLP	London Emergency Services Liaison Panel
MAFF	Ministry of Agriculture, Fisheries and Food
mm	millimetres
m^3/sec	cubic metres per second
NEXRAD	NEXt generation Dopplar RADar network
NOAA	The National Oceanic and Atmospheric Administration
NRA	National Rivers Authority
OECD	Organisation for Economic Co-operation and Development
PSTN	Public Switched Telephone Network
RFFS	Regional Flow Forecasting System
VDU	Visual Display Unit

Chapter 1

Introduction

1.1 Warning and hazard mitigation

Exposure to hazards is an inherent part of everyday life on Earth and the way in which human beings respond to the hazards they face can be both complex and unpredictable. Hazards take many different forms and can be both natural and man-made. Flooding is one natural hazard that modern society has to face, relate to and understand, others include earthquakes, volcanic eruptions, tsunamis, hurricanes, snow avalanches, mudflows, drought and disease. In addition, there are the man-made or technological hazards that are an increasing phenomenon in the early twenty-first century, and these include nuclear radiation, pollution, food safety and genetic modification. In fact, new hazards are discovered every day, such as the effects of high-voltage transmission lines, the low-level radiation emanating from VDUs and mobile telephones, and the exposure to toxic substances used in warfare (the Gulf War Syndrome). Whatever the hazard, when human beings are faced with a real threat to themselves, to their families, and to their homes and possessions, the basic human need for increased safety and security can be a strong driving force that can govern our behaviour. This stems from the deep psychological desire to reduce fear and anxiety and minimise stress and insecurity that human beings develop from an early age.

The ways in which humans seek to reduce insecurity in the face of a hazardous situation can be numerous. These can include permanent relocation or temporary evacuation to lower risk locations, the construction of homes and offices that are resistant to natural forces (e.g. earthquakes) and the building of defences designed to keep natural forces at bay (e.g. coastal flood embankments). But whatever measures are taken the *raison d'être* is usually the same - to meet the basic behavioural desire for greater safety and security.

There are of course always exceptions to this rule and there are those who choose to live or work in close proximity to hazardous situations despite periodical reminders of the destructive power of natural forces. Communities that occupy undefended coastal areas that are prone to hurricanes, the slopes of volcanoes and cities in earthquake zones are examples of where people put the desire to live in a given locality before safety and security considerations. There are also those who have little or no choice but to occupy hazardous areas due to their economic circumstances. Many people in developing countries are drawn to the large urban metropolises but often have little option but to live in areas that are subject to landslide or flooding for example.

Irrespective of peoples' reasons for living in hazardous locations, an important way of reducing their risk and increasing their safety and security is for them to become informed and knowledgeable of the impending danger they face before it strikes. Having the ability to predict hazardous events allows people time to think and respond appropriately to danger and reduce the potential effects. An early warning of danger gives humans time to consider their situation and to modify their behaviour and actions and this in turn increases their safety and security.

It is not surprising that over the last thirty years much scientific attention has been given to increasing human ability to detect the onset of natural hazards and predict when these may impact adversely upon human communities. In recent times this process has become more sophisticated as science and technology has been brought to bear both on the forecasting of the severity and timing of the hazard, and to assist with the communication of warning messages to communities about to be affected. These activities have been co-ordinated largely by government departments and by specialists or "experts" who have developed an in-depth knowledge of hazard forecasting and warning techniques. But the "experts" have been guilty of frequently working in isolation from the rest of society and in particular the at-risk communities that they are employed to serve, and as a consequence the risks and the potential impacts have not been fully comprehended.

In certain sections of western society the public awareness and concern about the increasing hazardousness of society has become quite pronounced. Nevertheless, there continues to be variations, with some risks feared more than others, with individuals perceiving comparable risk differently, and divergent views between the public and the "experts". With this growing public perception of hazards there is a growing expectation that the experts in the relevant government agencies with the aid of technology are able to forecast the onset of a given hazard and warn those at risk before it strikes. The challenge facing modern societies, therefore, is to bring the experts and lay people together in a closer working environment so that they can jointly address the risks they face and are more aware of the other's ability to understand and respond to those risks.

Risk communication is an important part of this process involving the delivery of a warning message from the expert or agency to the public to enable better understanding and preparedness. As Cutter (1993) notes this is complicated by the fact that significant differences exist between how the public perceives and responds to risk *vis-à-vis* experts. A good example of this would be the recent BSE crisis where significant differences in the interpretation of the word "safe" arose between the authorities and the public in relation to this problem. Cutter believes that the controversy over expert versus public views on risks is a product of the social changes that have occurred over the last three decades. She lists increased affluence, technology and the public's trust of institutions as being key factors. As western society has become more affluent a more comfortable level of economic security has been achieved resulting in the public becoming almost cocooned from the reality of hazards facing them. In addition, the public has become increasingly distrustful of institutions especially those created to protect the environment and public health. There is a growing tendency to try and apportion blame for environmental catastrophes that were previously accepted as being "acts of God" and to resort to the courts for legal redress. The public expectation about being warned of hazards is now widespread and meeting these expectations can be extremely problematic. The outbreak of meningitis in South Wales in February 1999 is an example (Laurance, 1999). To break out of this climate of mistrust and unrealistic expectation it is important that warning systems and flood warning systems are operated in a more participative way, with the experts addressing risk communication in partnership with those they serve rather than in isolation.

1.2 Flood warning and the quality paradigm

Flood warning systems in operation around the world today have a number of functions including the saving of life, the prevention of floodwater intrusion, the protection of property, and the minimisation of economic disruption. They are often necessary to trigger the operation of structural flood control measures, such as barriers and gates, the timely monitoring and repair of fixed flood defences, and removal of obstructions to flow in rivers.

In some countries, the main objective of flood forecasting is as an aid to navigation, such as on the Rhine in Germany (EUROflood, 1994). In the main however, flood warning systems work on the principle of reducing flood losses through remedial action by the recipients of warning messages prior to a flood. It is important that any system should be viewed as comprising of a number of interrelated components or elements, all of which must operate smoothly and efficiently as a totality to have any significant effect on flood losses. The principal elements of a flood warning system can be defined as:

1. **Detection** - this involves the evaluation of hydrological and meteorological processes that could generate a flood event in a given river catchment. Information from weather forecasts, weather radar and satellite, telemetered rain, river and tide gauges, is used to carry out this function with the aid of computer and communication technology.
2. **Forecasting** - this involves the prediction of rainfall, river levels, tides and flows, and the time of occurrence, severity and duration of a flood. Methods of achieving this can vary in technical complexity from rudimentary techniques based on experience, to sophisticated modelling capable of predicting rainfall, in-bank flows and flood plain inundation.
3. **Warning and dissemination** - this involves the making of decisions concerning the issue of flood warnings on the basis of catchment conditions and forecasts, and the passing of information to flood-plain inhabitants and response agencies in sufficient time for remedial action to be taken to protect life and reduce flood losses.
4. **Response** - this stage encompasses the immediate action taken by agencies involved in the flood warning process to eliminate the threat to human life, and to minimise flood damage to property. It also includes the public response to a flood warning and their reaction to flood risk, and the role of public education programmes to improve awareness.

Mileti (1994) states that warning systems have been researched and discussed for several decades and there is a large degree of consensus among researchers that the most effective structure for a warning system is that of an integrated system. It is clear that the links between the system elements outlined above are substantial and complex, and that any deficiency in any one component will affect the performance of the overall system resulting in wasted resources and investment. It is vital then, that sound relationships among the subsystems be developed and maintained. In addition, because flood warning is a multi-dimensional activity, it is likely to require inputs of expertise from a number of different organisational and professional cultures and these inputs must mesh together for the total warning system to be effective. This idea of integration and total flood warning system design is analogous in many ways to the concept of total quality management discussed by Clarke and Clegg (2000). In essence this paradigm advocates a holistic approach to quality management, emphasising the need for continuous improvement to achieve greater effectiveness, group problem solving, quality assurance, good customer relations, people involvement and training, good communication and the building of high-trust relationships. All of these aspects are equally important to the development of integrated warning systems.

In practice however, flood warning systems in most countries are incomplete and fragmented and as a consequence tend to function sub-optimally (Keys, 1997). It is doubtful whether any warning system justifying the title of "total flood warning system" yet exists. Keys (1997) argues that many systems presently in use tend to take a reductionist, even minimalist view of the warning process, with often only the more technical facets having evolved to an advanced state. Handmer (1997) reinforces this view when he states that until comparatively recently the most significant changes in flood warning arrangements in most developed countries have been in the areas of flood detection and monitoring. He considers that a reasonable generalisation is that the dramatic improvements in information technology have yet to play a role in getting messages to the public at risk. Conversely, in developing countries it is often the flood detection and forecasting systems that have not been developed as quickly as expected. Response measures based on evacuation, relief and rehabilitation have been the main strategies employed to reduce flood losses (Chan, 1997). Nevertheless, there is evidence that in a few countries in the world the concept of integrated flood warning systems is taking root. In Australia, for example, attempts are being made to develop such an approach using the basic premise that the scientific, technical and procedural elements of the system must focus on its clients, those at risk from flooding (Emergency Management Australia, 1999). Closer inter-agency liaison, better information, public education programmes and closer community involvement are some of the techniques being adopted and this approach has strong parallels with the quality paradigm referred to above.

A key question that needs addressing, therefore, is "what integrates flood warning systems?" Handmer (1997) believes that a total (integrated) system is much more than a list of components, of greater importance is how they function together to serve the purpose of the overall system. There is a need therefore, to identify the factors that can influence the drawing together of the component parts that make up a total flood warning system. These factors can be conceptualised as crosscutting strands running through the main elements, and if they can be precisely defined and successfully applied to flood warning programmes, it is probable that improvements in performance and functionality will result. The identification and analysis of these integration factors, therefore, is a key aim and objective of this research project.

1.3 Aims and objectives of the research

The aims and objectives of this research project can be summarised as follows:

- to determine whether or not a policy of integration would be beneficial to flood warning programmes;
- to identify relevant integration factors that may be of significance and to present these in a conceptual model;
- to assess whether these factors are recognised and used in existing operational flood warning programmes in England and Wales;
- and through the use of case studies, determine the plausibility of introducing a fully integrated approach to future programmes.

To achieve this it will be necessary to critically review the literature, not only in the area of flood warning and hazard management, but also in a wide range of other fields where a policy of integration has been implemented, so as to determine good practice. This will then be combined with the experience and operational work undertaken over the last twenty-five years by the author and others working in the Environment Agency and its predecessors.

1.4 Impetus for the study

This research was motivated by the growing realisation in the mid-1990s that flood warning arrangements in England and Wales, and in the Thames Basin in particular, were often not functioning optimally. The author brings first hand operational evidence that the multi-agency approach to flood warning, that had functioned reasonably well in the past, has been breaking down. This has resulted in the flood warning systems operated by the Environment Agency and its predecessors often failing to provide the at-risk public with a credible service. This view is supported by research carried out in the 1980's and 1990's in the Severn, Trent and Thames catchments, that concluded that flood warnings were often poorly targeted and this resulted in a high level of public dissatisfaction with the service (Penning-Rowsell et al 1986(b); Neal and Parker, 1989; Tunstall et al, 1991; Tunstall, 1992; Hyde, 1992; Parker et al, 1995). It is also evident that few if any flood warning systems in England and Wales have been designed in an integrated way and that the institutional arrangements and statutory framework, on which such systems are based, have contributed significantly to their increasingly fragmented nature (Parker, 1989; Parker 1993; Haggett 1997).

One consequence of this problem is that the considerable investment that has been committed to detection and forecasting systems in certain areas over the last 25 years has not been realised, and that this is due to a large degree to the fragile nature of public warning arrangements. It should be noted that the Government's recognition of this issue and the resulting reform of arrangements in England and Wales have taken place during the period of research. This has enabled an assessment to be made of the adequacy of the old and new arrangements in the context of integration.

The author's role as manager of the fluvial flood forecasting and warning service in the Thames Region of the Environment Agency gives him a unique insight into these issues and helps focus the analysis on the practicalities of real-world problems. This position was reinforced during the period of research as the author was given the role of project managing the implementation of the new flood warning dissemination procedures in the Thames Region, and became a member of the National Flood Warning Implementation Team within the Environment Agency. The research work presented here was conducted during the period 1994 to 1999 when these new arrangements were first debated, formulated and then implemented in September 1996. The procedures were tested during the floods that affected the Midlands during Easter 1998 and have been subject of a wide-ranging independent review to assess their adequacy. The author became a member of the Agency's Easter Flood Action Group in 1998 tasked with implementing the recommendations of the Independent Review. Arrangements have continued to evolve since this time and it is likely that the research findings presented here will help shape this evolutionary process.

1.5 Research focus and boundaries

The research focuses on flood warning programmes in their widest sense, from detecting and forecasting the environmental factors that may give rise to flooding, through to warning those of risk of the potential dangers, so as to ensure effective response to save life and minimise damage to property. Particular attention is given to flood warning arrangements in the Thames Region of the Environment Agency, which covers the natural river catchment area of the River Thames and its tributaries (see Figure 1.1).

This study considers the total warning system that can be defined as that which ".... integrates flood prediction, the assessment of likely flood effects, the dissemination of warning information, the response of agencies and the public in the threatened community, and review and improvement" (Emergency Management Australia, 1999). The study does not examine the technical functioning of each element in great detail, but rather contemplates how they interact, particularly in the operational environment, to ensure that the whole operates optimally. The wider issues surrounding emergency planning and management, evacuation, post-event response and recovery etc. are beyond the scope of this study.

1.6 Structure of the thesis

The thesis is structured into nine chapters, six of which can be termed substantive, one presenting case study material, with this introductory chapter and a conclusion forming the remaining two. The logical sequencing of the chapters is governed by a conceptual model of the integration process that is presented in detail in Chapter 3. The ordering and content of the chapters is summarised below:

- Chapter 2 contains a critical review of the literature that focuses on integration and total flood warning systems. Its purpose is to identify what is generally known about integration, how integration may be understood and what makes it work or not work as the case may be. A number of integration factors are identified which assume importance in subsequent chapters. Total flood warning systems are essentially fully integrated ones and so are particular pertinent concepts on which to base analysis of flood warning systems in England and Wales.

- Chapter 3 presents a precise and comprehensive description of the research philosophy, design and methods adopted in the thesis.

- Institutions and laws were found in Chapter 2 to have important implications for integration, and therefore Chapter 4 examines the influences that institutions and the law have had on integration in England and Wales in general and the Thames Basin in particular.

- Institutions frequently look to technology to provide solutions and Chapter 5 analyses by what means, and to what extent, the application of technology has enhanced and can further enhance the integration of flood detection, forecasting, warning and response systems.

- Technology can be of benefit to integration but sociological factors can temper its influence. Chapter 6 examines the extent to which human interaction can provide barriers to integration in some cases, but can provide a positive influence in others.

- The free flow of information and knowledge around institutions and communities is fundamental to successfully integrated flood warning systems, and technology can often facilitate this process. Chapter 7 explores how information and knowledge is used and interpreted in flood warning systems, and how it influences the consolidation of system components to make the whole more effective

- The analysis presented in each of the substantive chapters above is tested through the use of case studies. Chapter 8 presents the results of the principal case study undertaken in the Mimmshall Brook catchment (see section 1.7 below).

- The principal conclusions of this work are summarised in Chapter 9 as are the implications for the institutions charged with delivering effective flood warning systems and to flood hazard management in the wider context.

1.7 The use of case studies

Throughout the thesis, attempts are made to test and strengthen the main issues and arguments raised in each chapter by reference to case study material. Particular attention is given to arrangements and experiences of organisations and communities in the Thames Basin (see

Figure 1.1), drawing on a raft of material that has been collated into a flood event database as part of this project (see Appendix 1). In addition, one area has been selected for greater analysis within the Thames catchment. The Mimmshall Brook catchment in Hertfordshire (see Figure 1.2) offers a good example of where a community has had to live with a flood hazard for many years. The community has to a certain extent organised its own affairs in relation to flood warning in the absence of a credible official service, but it is judged that there is scope for introducing a more integrated approach to flood warning arrangements in the future. The criteria for choosing case studies are explored in more detail in Chapter 3.

1.8 Summary

This thesis focuses on the concept of integration and how this can be applied to flood warning systems to improve performance. There are many parallels with the quality paradigm that stems from a concern for greater effectiveness, quality and performance through an integrated or holistic approach to achieve total quality management.

It is recognised in the literature that the component parts of flood warning systems rarely function as a unified whole and are often fragmented. It could be argued therefore, that to simply analyse each of these components in turn would perpetuate the problem that this research project is seeking to breakdown. Accordingly, an alternative approach has been adopted that identifies "strands", "themes" or "factors" that run through each of the system elements and can be used to integrate or bind them together and hence improve the functionality of the total system. The research sets out to identify the most relevant crosscutting integration themes, to present them by means of a conceptual model, and analyse them in the principal chapters of the thesis. Through the use of case studies, analysis of archival records and documentation, and through direct and participant observation, the research sets out to determine the viability or otherwise of introducing a fully integrated approach to flood warning programmes.

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Figure 1.1
Location map for the Thames Basin

Figure 1.2
Location Plan of the Mimmshall Brook Catchment

Not to Scale

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Chapter 2

Integration and Total Flood Warning Systems

2.1 The concept of integration

Integration is pertinent to most aspects of human endeavour, and is perhaps initially most easily conceptualised as individuals, organisations or system components working together to a common end which is not easily achievable by separate working or by working in a confrontational environment. Integration can be defined as the act of combining or adding parts to make a unified whole (Hanks, 1986), and to ensure that all components of the whole work together collaboratively towards the same goal. In a number of fields a process of integration has been shown to be beneficial and there are many outstanding examples of success when individuals, organisations or system components work in concert with one another towards a common objective. It could be said that the creation of large spectacular structures such as the Thames Barrier or the Channel Tunnel offer examples where complex human and organisational systems combine with innovative design and technology to accomplish the construction of stunningly ambitious edifices. It is certain that many conflicts had to be overcome before these structures were completed, but they do offer examples of the benefits of making integration work.

The aim of this Chapter therefore, is to analyse the concept of integration in order to understand what is known about it and its components and how this might be applied to the subject of flood warning systems. This will be achieved by looking at what is known about integration from a wide range of fields, identifying good practice and determining how flood warning systems might be improved by applying what is known about integration to them.

2.2 Integration factors

When considering the implementation of an integrated approach it is important to identify and consider systematically the various factors that are judged to be of significance. Lawrence and

Lorsch (1967) refer to these factors as integrative devices. Some of these factors or devices will be appropriate only to the function or organisation under consideration, whilst others are more universally relevant. Lawrence and Lorsch (1967) observe that such devices are often used in different combinations to achieve integration depending on local circumstances. By analysing these factors it is possible to determine the degree to which integration is present in the area of interest. A number of factors are discussed in the literature and their relevance to integration is explored below.

2.2.1 Institutional arrangements

One of the key areas of universal significance to successful integration is a consideration of institutional arrangements. Mitchell (1990) believes that such arrangements can provide stimuli or potential leverage points to foster integration. If however, institutional arrangements are poorly configured an extremely fragmented situation can arise that runs counter to a policy of integration. The OECD (1989) identifies four key areas of significance that will be examined in detail.

Political credibility and legitimisation

If integration is to occur it must be given explicit political credibility and legitimisation through political commitment. Clear integration objectives must be established and the role that each agency has in meeting these objectives should be defined. Mitchell (1990) believes that three important elements should be identified; the objectives of pertinent agencies; the responsibility, power or authority of these agencies; and the rules for intervention and arbitration by higher authorities when conflicts arise that cannot be resolved by the participants directly involved.

Knowing the objectives of each participating agency should help to identify both common and divergent interests and Aucott et al (1995) recommend the creation of a written plan that can gain general support. Mitchell stresses however, that clarity of objectives by itself will not ensure integration, since different agencies almost inevitably will have objectives that conflict. Furthermore, while clarity of objectives is desirable, if they are specified in great detail it is possible that an organisation will be unreasonably constrained in being able to respond to changing conditions and in being able to negotiate with other participants. He argues that some careful generalisation in objectives is desirable so that flexibility can be built in.

It is also important to establish the authority and jurisdiction of each agency and who has the responsibility to initiate action and arbitrate in the event of conflict. When the relative power of different participants is not specified or made clear, the potential for stalemate is high, as various agencies jostle and manoeuvre for a lead position. Even when objectives and powers are stated explicitly, there is still a strong probability of conflicts between participating agencies as a result of boundary effects. Thus, it is important to identify who has the right and duty to intervene to resolve such impasses and it is desirable to incorporate a mechanism into the government structure to facilitate resolution of legitimate differences of opinion.

The OECD believes that the credibility for integration can be provided by several means. Political commitment from the Government provides a clear signal to civil servants that integration is expected. When this political commitment comes from politicians at several levels of government, it is even more powerful and compelling. Legislation is another means to provide credibility and the OED believe that this means is normally the most stable and compelling (this is explored in more detail in 2.2.2 below). A third means is through administrative or bureaucratic policy within agencies. It is normally within the discretionary power of senior public servants to direct their departmental activities towards co-ordination and integration of activities with other public agencies. Aucott et al (1995) emphasise the need for leaders who are committed to the approach and are willing to authorise the resources to make it a success. Administrative directives often provide only a veneer of support for integration, however, while the "hidden" or "unofficial" agenda supports the furtherance of agency interests.

Mitchell (1990) concludes by stating that the likelihood of effective integration is not great unless the concept has been given legitimacy. A statutory basis offers the most enduring support for integration, but the probability of real achievement increases substantially when a statutory base is combined with strong political commitment. He believes that without legitimisation of some form, any initiative to encourage integration and co-ordination faces an arduous, uphill struggle.

Functions and organisational structures

Once the objectives, power and rules for conflict resolution have been established, the management functions and organisational structures need to be considered. Mitchell (1990) believes that the alignment of functions should be examined in a systematic manner, and that it should not be assumed that the current way in which functions are organised, that may have evolved over time, is necessarily either the most systematic or sensible for current conditions. Song and Dyer (1995) looked at the recent trend of cross-functional integration in industry and found that such a strategy could be highly effective in some circumstances but counterproductive and costly in other situations. They recommend that cross-functional integration should not be uniformly applied, but introduced only where the benefits of such a strategy can be demonstrated. Venkatachalam et al (1993) see the integration of functions in industry as a key strategy for survival and growth. They recognise, however, that implementation can be difficult and point to inflexibility of organisational structures as being one of the main factors hindering its adoption.

The OECD (1989) stresses that what is damaging for integration is for functions to be split between competing agencies, without any superior national body to co-ordinate planning and management across these agencies. To deal with overlapping responsibilities and interests, designation of a lead agency can be used to co-ordinate an integrated set of activities. This might take the form of a regulatory agency that sets the criteria for other organisations to operate within. Flexibility is also important so that agencies have the ability to respond to changing conditions, newly emerging issues, ideas and information, and are able to adopt new technology and to deal with uncertainty. Another important consideration is accountability, ensuring that those who take decisions are accountable to those receiving goods and services. This can be enhanced by making relevant data and information routinely available and by encouraging public participation in a climate of open decision making.

Organisational structures should normally flow from the required management functions. In selecting an organisational structure, Mitchell (1990) identifies several considerations that should be remembered. First, there never will be a perfect match between functions and structures. Second, regardless of the structure chosen, boundary problems will emerge. The nature of the structure will simply determine whether the boundary problems occur among units within a larger agency or among a number of smaller, more specialised agencies. Third, alternative structural forms should be considered, and fourth, it is not necessarily appropriate to look for a single structure to handle all aspects of the management problem.

A number of authors have expressed views on the form organisational structures should take. Leonard et al (1994), for instance, believe that organisations need to transform the way in which they are structured to increase vitality and efficiency. They recommend that responsibility should be shifted out of the boss-subordinate dyad into teams; that diversity and interaction across traditional boundaries should be encouraged; and the flow of information and exchange of ideas should be stimulated. Hickes and Brydges (1994), stress the importance of flexible structures to deal with changing strategies. Considering pollution monitoring, they see an increasing trend towards integrated monitoring that brings together a number of disciplines to address complex environmental questions. It is important that organisations are structured to deal with these changing strategies. Aucott et al (1995) describe the changes being adopted in health care, moving away from a departmental approach to care that is uncoordinated to an integrated interdisciplinary approach i.e. the introduction of lateral teams across vertical lines of functions. This has resulted in a major shift in the way organisations are structured and affects planning, documentation and the general work environment in these organisations.

Processes and mechanisms

No matter how carefully considered and designed, functions and structures are unlikely to fit together perfectly. The presence of lose ends because of imperfect fits suggests the need for processes and mechanisms to facilitate bargaining, negotiating and mediating at the boundaries, thereby encouraging the likelihood of integration and co-operation. Processes and mechanisms such as select committees, interdepartmental committees, commissions, task forces and review procedures are often used for this purpose. If integration is truly sought, then provision should be made to ensure that the views of the general community and of individuals are fed into the planning process. Consultative committees, advisory groups, public meetings and public surveys are mechanisms that can be used in this context. It is important to determine which combination of processes and mechanisms will best meet the needs in a given situation.

Organisational culture

Mitchell (1990) believes that there are usually few explicit incentives for integration and co-ordination and organisational structures often foster parochialism. Through fuzzy legitimisation, unclear functions and cumbersome structures, an organisational culture develops that creates real barriers to integrated and co-operative effort. Thus the combination of organisational culture, personalities and participants attitudes can pose a major obstacle to integration. If a strong declaration about the need for integration is given at the political level however, a positive signal will be sent to those responsible for implementing integration. A systematic linking of functions to different hierarchies will help to pinpoint areas in which integration could be pursued and careful design of organisational structures should ensure that diverse viewpoints are bought together. Saleh and Wang (1993) found that organisational culture was an important factor in the running of successful businesses. They analysed firms in Canada and those that were most innovative showed differences in management strategy, organisational structure and organisational climate. These companies took more risk, gave more management commitment to entrepreneurial activities and innovation, encouraged the integration and intermingling of talents into teams and task forces, and operated a reward system that reinforced entrepreneurial behaviour. Mead (1995) believes that by developing a management and organisational culture, staff will be encouraged to think more about their roles and help an organisation deliver an integrated policy that the staff may be inspired to own.

In conclusion, therefore, when considering organisational arrangements, the following factors are of importance to integration.

1. For a policy of integration to be successful it must be backed by firm political commitment. Organisations should be given clear objectives and roles and responsibilities within an integrative framework and these should be defined preferably in a written plan. There is a need however, for a degree of flexibility to be built into these aspects so as not to unreasonably constrain organisations. Rules for intervention and arbitration when conflicts arise should also be established.

2. Consideration should be given to the functions and organisational structures. Functions should be assigned to the most relevant organisations in a systematic

manner and not necessarily following current patterns. From this the structure of organisations should flow and these structures should be flexible and accountable. It is recommended that a lead agency be designated if possible to co-ordinate activities in an integrated way and deal with overlapping responsibilities and interests.

3. Processes and mechanisms need to be in place to facilitate negotiations between organisations to encourage the likelihood of integration and co-operation. These can take many forms and the right forum needs to be established to meet the needs of a given situation. The need for processes for arbitration when negotiations breakdown are essential.
4. To avoid obstacles to integration, organisations should foster a positive internal climate and culture to such a strategy and this can be triggered by a strong declaration about the need for integration at a high level.

2.2.2 Legal arrangements

Laws can be the source of important constraints on integration. Laws are often specific to particular sectors and one resource therefore, can have a number of acts controlling various aspects of its use. With respect to water resources for example, the OECD (1989) reports that many countries have different acts for water supply, water transport, flood mitigation, energy generation and environmental protection and conservation, to name a few. This multiplicity of legal enactments can create considerable constraints to integrated management.

To overcome the constraints to integration that poor legislation can bring, the OECD have put forward a set of guidelines that was specifically developed to improve water resource management. It is likely that some of these guidelines will have wider application and these are summarised below.

The OECD (1989) stresses that all legislation should be compatible and not contradictory in the implementation of management principles. They recommend that present legislation should be reviewed, revised and updated as required with this purpose in mind. Secondly, legislation should delineate as clearly as practicable respective roles and responsibilities of different levels of authority and it should require that agencies seek to resolve specific inter-agency conflict. Thirdly, public participation in the process of formulating and considering management options should be promoted as a valuable means of generating more comprehensive options and the political support for such options. Legislation should provide open and well understood procedures for consultation on objections to and appeals against administrative decisions. User rights and responsibilities should be defined. Fourthly, whenever appropriate the use of economic principles and instruments should be enforced by legislation to allow the more cost-effective attainment of goals. Finally, legislation should be subject to review at regular intervals to be able to take into account the evolving nature of many disciplines.

Mitchell (1990) points to the fact that some organisations do have statutory powers to achieve a number of aspects of integration. He stresses, however, that even with the most astutely crafted legislation integration may not be achieved without political commitment that needs to be cultivated and sustained. Without this, moves towards integration may be blocked and unsuccessful even when a single powerful statutory base has been put into place.

In summary, therefore, the following factors are important when considering legal arrangements and a policy of integration.

1. Legislation should be compatible and not contradictory and present laws should be reviewed, revised and updated with this purpose in mind. Although this may be a laudable aim it is likely to be difficult to achieve especially when the number of organisations and pieces of legislation is large.

2. Legislation should clearly define the respective roles and responsibilities of the relevant authorities and mechanisms for resolving inter-agency conflict should be delineated.

3. Legislation should provide clear and open procedures for public consultation as this would help generate more comprehensive options for integration and will bolster political support.

4. Sustained political commitment should be sought and cultivated to underpin the legislation and the principles of integration.

2.2.3 Economic aspects

It has been suggested (OECD, 1989) that economic mechanisms are crucial in driving processes of integration. Penning-Rowsell (1997) identifies a number of economic instruments that can influence aspects of policy implementation. These include taxes, subsidies, and regulatory price regimes. The adoption and application of appropriate resource pricing is considered to be another important element. It is argued that the implementation of such a policy will require close co-operation amongst agencies, government departments and consumers and will therefore, improve the effectiveness of their integration.

The OECD (1989) outlines in detail how the principle of resource pricing can influence integration in water resource management. The general principle is that the consumer and the polluter should be required to pay the full social cost of providing water and related services, including treatment and damage costs. It is argued that by adopting this principle, not only will there be improved use of water resources and less pollution, but also the creation of more efficient administrative arrangements for the integrated management of water and other natural resources. The implementation of such a principle however, has been opposed in many countries. User groups, such as farmers, have enjoyed substantial government subsidies and are reluctant to pay more for water. Natural resource development agencies have also been concerned that such an approach would reduce the use of the resource leading to smaller budgets and loss of power in the bureaucratic hierarchy, and loss of independence by the closer inter-agency co-operation. To overcome these objections the OECD argues that government should create the conditions for the application of the resource pricing principle and phase out the issuing of grants and loans.

In manufacturing industry, economic integration is a strategy that has been adopted with mixed success. Tannous and Mangiameli (1993) state that the design of a manufacturing strategy often incorporates the decision on whether to focus or vertically integrate. Complete focus refers to one manufacturing step and the production of a single component; full integration refers to 100 per cent internal manufacturing to produce a finished product. Daveni and Ravenscraft (1994) looked in detail at the advantages and disadvantages of vertical integration in industry. They found that it resulted in economies particularly in administration, sales, advertising and R&D expenditure, however, production costs were generally higher. Overall, integrated businesses were found to be only marginally more profitable than non-integrated businesses in the industry in question. Stuckley and White (1993) warn that vertical integration is a risky strategy being complex, expensive, and hard to reverse. They advise not to integrate unless it is absolutely necessary to create or protect value.

Godard and Beaumais (1994) consider that for industry to be sustainable, a tighter integration of environment policies and economic processes is needed. In addition, they believe that a greater attention should be given to the cost-effectiveness of policies through the greater use of economic strategies. Scientific uncertainties and controversies coming from environmental problems should lead to a range of costed options and a search for "minimum regret" strategies. As an example they point to fiscal reform incorporating "ecotaxes", such as the carbon/energy tax currently under assessment by the European Union.

At a national and international level, economic integration has been a significant driving force for change, however, the merits of this policy are now being questioned. In the European Union for instance, the creation of complete economic and monetary union is much talked about but has yet to be achieved. As Tsoukalis (1994) observes, there is considerable disagreement over the benefits of such a policy and the legitimacy of this new economic order is now being challenged. There is concern in some quarters that such a policy could give rise to high unemployment and growing economic inequality. Some authors believe that economic integration is actually hindering the expansion of the Union. Gibb and Michalak (1993) recognise that the Eastern European countries see membership of the European Union (EU) as essential not only to the successful transition from Soviet-style economies to a free market, but also as a guarantee of long-term political stability. Welfens (1995) however, sees the desire of Eastern European states to integrate economically with the EU as having dangers. Structural adjustments needed for integration could result in political instability and conflict. Gibb and Michalak believe that the EU lacks the political capacity to deepen economic integration and incorporate new member states simultaneously. Sinnott (1994) sees the obstinacy of the nation-state as one of the main forces against economic integration and expansion of the EU. The large European states in particular see such a policy as resulting in a decline in their political influence both within the Union and at home.

From the literature therefore, it is clear that a policy of economic integration will bring mixed results. The tendency of organisations such as the OECD to promote the idea that economic criteria are the most natural and powerful mechanisms for promoting integration is probably misplaced. Accordingly, three main conclusions can be drawn from the review of the literature.

1. It has been argued that by introducing a policy of resource pricing closer co-operation will inevitably result amongst agencies and consumers thereby improving the effectiveness of their integration. In practice however, it has been shown that such a policy may lead to resentment and conflict that can be counter-productive.
2. To promote a strategy of sustainable development, tighter integration of economic processes and environmental policy is needed. Such an approach, however, should be subjected to a rigorous cost-benefit analysis and a range of costed options should be evaluated before implementation.
3. The merits of economic integration are being questioned in the literature. Some authors feel that such a policy could lead to conflict and instability and recommend that implementation should only be considered after careful evaluation.

2.2.4 Technology

The influence of technology has increased markedly over the last twenty years in all walks of life. It is also apparent that technology can have a significant impact on integration in a range of activities, with technological solutions facilitating the bringing together of many functions, a practice that would not have been achievable in many instances even in the recent past. It is noticeable however, that technology does not feature as a key integrative factor, either in terms of reducing or increasing integration, in the guidelines put forward by the OECD (1989) and this must be seen therefore as a main weakness of this analysis.

The driving forces for technological integration can be numerous. Morgan (1992) for instance, identifies an increasing trend in industry to integrate telecommunications, computing and office systems. He identifies the driving forces for this as; radical advances in technology, the quickening pace of deregulation and the growth of global markets. Morgan believes that such integration will redefine the parameters for competitive advantage for cities, regions and industries. Venkatachalam et al (1993), highlight the fact that due to growing global competition, organisations around the world are constantly under pressure to produce high-quality products at an economic price. Accordingly, the integration of design and manufacturing effort into one common engineering effort has been recognised as a key strategy for survival and growth. Rao and Wang (1993) see that computer integrated manufacturing and processing systems as being the development direction of the future. Ichimura et al (1994), describe the approach to this strategy in Japan and the introduction of CIMS, the computer integrated manufacturing system. This integrated system of hardware and software for production management attempts to meet market requirements and counteracts fluctuations in users' demand by maintaining effective production planning and control.

In the fields of science and engineering a policy of integration has also been shown to be beneficial. Michalak (1993) for example, documents the increasing use of geographical information systems (GIS) and shows how such systems facilitate the integration of spatial information, including its storage, processing and representation. Although GIS help provide a technological solution to complex and difficult issues, they do have limitations. In planning for instance, Michalak states that tasks including analysis, projection and evaluation have proved difficult to automate and remain outside the scope of GIS.

Several authors emphasise the impact that technological integration can have on the way organisations are structured. Noble (1995) illustrates how the integration of technology linked to office systems can develop from a rather narrow conception of "office automation" into systems that have strategic significance. He points out that the process of integration in such circumstances can necessitate extensive organisational redesign in some cases. McGrath et al (1994), looking at advances in telecommunications technologies, note the common desire to integrate data and systems in many organisations. On closer examination however, it is apparent that in many instances organisations fail to implement planned strategies. This is thought to be directly due to such action causing major changes in the balance of power and political turbulence in the organisations concerned.

Rodgers (1995) presents a good example of how technology can be used to promote integration and reduce operating costs. He records that London's financial district is one of the most densely computerised areas with more than 350 institutions - banks, brokerages and fund managers - making millions of deals every working day. Despite a massive investment in information technology however, including seven fibre-optic cable networks, the City does not have any single, comprehensive system on which it can do business. Instead, it supports dozens of incompatible and often competing, systems. Dealing rooms typically have connections to about 15 different networks, each costing about £500,000 a year. By integrating them all into one common network savings of up to £25bn a year could be made. Rodgers believes that an integrated IT network would help entrench London at the centre of world finance and give the City a competitive edge. Integration does have its critics in the City of London however, and there are many vested interests wishing to maintain the status quo. Institutions for instance, are wary of sharing any technology that gives them an edge and are concerned that confidential information could be stolen.

There is little doubt therefore, that technology can be beneficial to integration, but is this universally the case and are there instances when the introduction of new technology can reduce integration possibilities? One of the key issues in this respect is social access to new technology. Thomas (1995) draws attention to the fact that it is usually the relatively privileged and affluent members of society that have access to and benefit from new technology. There is often a failure to acknowledge that the disadvantaged and underprivileged members of society have a far more limited access to this technology and this can lead to fragmentation and inequality. The pace of change in technological developments is likely to result in a widening of the gap between those who have access to new technology and those who do not. This is compounded by the fact that certain sections of society, such as the old, infirm and disabled, have difficulty in mastering technological systems and find them confusing and inhibiting. For integration to succeed therefore, there is a need to ensure that technology is received and allocated effectively within different social groups and that adequate training is provided.

In conclusion, therefore, technology can facilitate integration but only if it is implemented appropriately. Social access to new technology for instance, needs careful consideration to avoid the reinforcement of existing social inequalities and the creation of new inequalities. To optimise the benefits for integration a number of key factors should be considered.

1. Organisations, that adopt a policy of technological integration, should be structured with sufficient flexibility and robustness to respond successfully to changing conditions that such a policy will inevitably bring. Without this, internal power struggles and protectionism will conspire to prevent technological integration from being implemented.

2. Technological advances should be applied to all functions in the area under consideration, where this is feasible to do so. Technological solutions should not be dedicated to one element in isolation from the rest, as this will militate against the process of integration.

3. The application and integration of technology should not become an end in itself. The temptation to "chase" technology and implement technological solutions to their fullest extent without considering the end results should be avoided. Well integrated, low-technology solutions may be more effective than high-technology approaches applied in an unbalanced fashion.

4. The way technology is introduced into society can be divisive and can lead to fragmentation. To avoid variations in social access to new technology care is needed in its use and how it is allocated to different social groups.

2.2.5 Human interaction, expertise and training

Mitchell (1990) stresses that ultimately integration, co-operation and co-ordination depend to a significant extent upon the willingness of individuals to make them happen. As Kellow (1985) remarks, "what is unwritten - the degree of co-operation and goodwill ... - is more important than what is written down". People who are inclined to cooperate and are enthusiastic can often make a poor system work well. Conversely, a well-designed system may falter if the participants are determined not to work with each other. As O'Riordan (1976) observes, decision making for resource management often has little to do with organisation, statutory guidelines and co-ordinating arrangements. Rather, it has more to do with the outcome of the determination, vision, indifference, antagonisms and bloody-mindedness of particular individuals who are in positions of influence. These views appear to be at odds with the emphasis placed on legislation and formal organisational issues highlighted in sections 2.2.1 and 2.2.2. In truth, both viewpoints are valid indicating that there is an underlying need for integration between these formal and informal approaches.

Many companies for instance, are adopting formal policies to better integrate human resource management and these strategies are proving to be beneficial. Shadur and Rodwell (1995) for example, found that high productivity companies were characterised by particular human-resource management practices such as performance-related pay, performance appraisal for all employees and a policy of employment security. Such firms adopted a team working approach and linking or integration mechanisms into their working practices. This finding is reinforced by Saleh and Wang (1993) who, when looking at factors that differentiate innovative and less-innovative companies in Canada, found that the former adopted policies of integration and intermingling of talents in teams and task forces. They also found that reward systems were widely used and these reinforced entrepreneurial behaviour and created incentives.

In contrast, the OECD (1989) recommends that informal strategies need to be used in government organisations to encourage integration. It is valuable in that regard to identify social networks that exist and are used, and to encourage the reliance upon informal contact between people working in related agencies. Action can be taken to arrange informal meetings to discuss matters of mutual interest and concern, to cultivate a network of key contacts and sources of information, to place people on key committees and to befriend officials at various scales of hierarchy of government. As Mitchell (1990) points out however, informal activities can be used to hinder integration. Deliberate delay of responses, withholding of information and other similar methods can be used to frustrate efforts of realising integration and co-operation.

Good staff quality is also needed for integration. The OECD found that through their education, training and work experience, many staff working in government agencies are accustomed to think in terms of narrow objectives and strategies. As a result, most staff have poor abilities in the important skills of inter-agency communication, negotiation, and bargaining, that are crucial if integration is to occur. The OECD recommends that governments and agencies should actively encourage a broadening of education, training and work experience of staff. For the longer term, education programmes at universities and colleges could be encouraged to incorporate the development of such skills in their programmes. Agencies should also recruit staff from a wider range of expertise than is conventional, create joint appointments between agencies, and allocate specific budgets to staff development.

One element that is not featured in the OECD work and has important implications for integration concerns social structures and social exclusion. It is becoming widely recognised (Thomas, 1995; Alcock, 1997; Oliver and Barnes, 1998) that one of the problems of enhanced prosperity in society is that of social exclusion. Certain disadvantaged groups, such as ethnic minorities, the old and infirm, the disabled and the poor, loose access to information, education, employment, etc. and become trapped in a downward spiral that needs intervention through policy action. Judd (1999) reports for instance, that 23 per cent of Britons have serious problems with literacy and 23 per cent with numeracy, and that the figure for 19 year olds is only slightly lower than that for older people. Such problems for individuals "can hardly be a surer way to social exclusion" (Judd, 1999). The Government has put in place national initiatives to help people with literacy and numeracy problems, but local plans are also in place to tackle these issues. In North London for example, an Alliance has been formed to identify key communities who are excluded from playing a full part in the local economy and society, and put in place strategies for raising basic skills (North London Alliance, 1998). For integration to succeed it is vital for disparities between social groups to be reduced and for social exclusion to be eradicated by enabling individuals to achieve their full potential.

Mitchell (1990) concludes by saying that a key consideration is the recognition that the "human dimension" can be crucial to the success of an integrated approach.

In conclusion then, it is apparent that the following factors are important in ensuring that a policy of integration is successful.

1. The adoption of formal human-resource management strategies, such as multi-disciplinary team working practices, has shown to aid integration and improve effectiveness.

2. The encouragement of informal contacts and use and cultivation of social networks can support the process of integration.

3. A broadening of education, training and work experience through staff development programmes is crucial to integration. This coupled with a policy of recruiting staff from a wider range of expertise will ensure that the necessary skills to facilitate integration are available to an organisation.

4. A policy of social integration or social equality is needed in society as a whole with the aim of reducing the exclusion of disadvantaged groups from gaining access to information, education and employment.

2.2.6 Information and knowledge

In many areas the way in which information and knowledge flows, is used and interpreted can have an effect on how well components integrate together. Technology can help facilitate this process considerably. Seabrook (1993), for instance, describes the pan-European videophone trials where recent advances in the integration of digital technology means that high quality, full motion, colour images can be transmitted economically across the continent. In industry, the integration of information systems has been shown to be beneficial. Greenwell and Tannock (1994) state that for effective operation, manufacturing information systems must access a number of data sources. Most systems are disjointed or only partially integrated, leading to a number of problems with data access, format, translation and transfer. The solution to this involves either rebuilding the entire information system from scratch, which is costly and disruptive, or the adoption of an integrated strategy to build a more cohesive system. They describe an integrated strategy that uses an open systems approach to recover data from the existing information system components and transfer the data to a common format. The information can be then used by new and existing applications across the organisation or transferred to new information systems. Holland et al (1994) record that some companies are implementing inter-organisational information systems (IOS's) with trading partners that allow them to share data and information across organisational boundaries. Motorola and Citibank, for instance, have effectively meshed parts of their organisations and information systems together to provide a mechanism for the seamless collection and disbursement of cash payments between the companies and their suppliers. In the public sector also, the trend to integrate data systems has been beneficial, improving the level of service offered to the public. Lewis (1993) describes how Marconi has developed systems for integrating data archived by the police. Integration has posed an interesting task for the analyst who has had to identify the "common thread" from the mass of information used by a police force and develop a single access system of common information. The resultant system allows for highly efficient use of stored data and ultimately an improved public service.

The integration of knowledge has brought advantages to many fields. Owens and Philippakis (1995) describe efforts to integrate knowledge into expert and decision support systems that have led to approaches that incorporate techniques to derive rules from data. Batanov and Lekova (1993) show how a feature-based approach to the integration of knowledge has been applied to manufacturing. Features are "bearers of knowledge" about data and the necessary relations among these data relating to a specific product. Intelligent systems for feature-based modelling in computer-aided design and computer-aided manufacturing are beginning to be introduced into manufacturing industry. Lee and Kim (1995) explore the mechanisms needed to integrate human and machine knowledge synergistically to improve performance of expert systems. They define machine knowledge as that which is algorithmically derived from past instances; whereas human knowledge implies either expert knowledge, judging the trends of external factors, or user knowledge, representing users' personal views about information given by both expert knowledge and machine knowledge. By integrating such knowledge, Lee and Kim show that a significant improvement of performance of an expert system can result even in a turbulent decision-making environment such as a stock market.

Parker and Handmer (1997) stress the importance of the interface between scientific knowledge generated by a technocratic body, and "folk" or "traditional" knowledge possessed by lay people. The latter is characteristically local as opposed to the former that is inclined to concentrate on universal rules. Parker and Handmer recognise the importance of capturing, retaining and harnessing all appropriate forms of knowledge in the context of hazard management. Williams (1964) and Foster (1980) emphasise the importance of a circular rather than a linear flow of information in warning systems through feedback mechanisms. This process involves both "official" and "unofficial" knowledge and information and has important implications for system integration as it helps bind constituent components of the total system together. The recognition that knowledge and information may be held and originate from "unofficial" sources however, is often denied. In many instances this may be due to the vested interests of major institutions wishing to maintain their power-base. This denial can result in closed systems and the integration process becoming blocked.

The OECD (1989) mentions a crucial and related element, that of pressure from well informed and knowledgeable interest groups. Often, such groups can push agencies and government for more sensitive policy co-ordination over some particular emerging problem. This can act as a trigger for a policy of integration to be followed. The OECD cites the issue of bathing water quality in Britain that was highlighted by pressure groups using official data to show low standards of pollution treatment.

As discussed in Section 2.2.5 and in sharp contrast to what has been discussed above, the social differentiation that is present in society tends to impact on the ability of certain groups to gain access to information and knowledge from official sources. In general, it is the well educated and more prosperous members of society that tend to benefit from the latest communications technology and have the ability to interpret and act on the information they receive (Thomas, 1995). A sizeable number of disadvantaged and socially excluded groups do not have access to such information and knowledge however, and this can be divisive and can lead to fragmentation. Many official sources are quick to resort to technology to disseminate information and fail to recognise that sections of their target audience may be unable to receive and/or interpret this information at all. This obviously has significant implications when introducing a policy of integration into society as a whole.

To summarise, therefore, both information and knowledge are important criteria for integration and the following factors are of particular relevance in this context.

1. The free flow of information within and between organisations and ready access to that information in a common format can further a policy of integration. The use of technology can facilitate this process.

2. Expert systems, that attempt to merge machine knowledge with human knowledge, have a role in decision making and the furtherance of integration.

3. The acknowledgement of the fact that information and knowledge may originate from "unofficial" sources and that their utilisation, via feed-back mechanisms, can aid integration.

4. Organisations should be aware that certain groups in society might have difficulty accessing and interpreting the information and knowledge they disseminate. Integrating these groups into the communication process is important.

Summary

When contemplating a policy of integration an initial consideration of a wide range of possible issues and variables is required and this approach has been successfully adopted in this section above. A second stage requires the identification of a more focused set of factors that, when met, should lead to overall improved effectiveness in the field in question. This strategy has been has followed, resulting in the identification of 24 factors for integration and these are presented in Table 2.1 under six broad headings:

- institutional arrangements
- legal arrangements
- economic aspects
- technology
- human interaction
- information and knowledge

Although the framework for integration put forward by the OECD (1989) has been used in part in this analysis, it has found to have some serious shortcomings. Most notably this includes an over emphasis on economic mechanisms as being the driving force for integration, a tendency to focus on a limited number of key integrative criteria (institutional and legal arrangements, and economic), and a rather undeveloped consideration of social issues, especially social differentiation and exclusion.

After reviewing the literature in this section it is concluded that the merits of economic criteria for furthering integration are less than stated by some authors (notably the OECD) and in some instances can actually lead to greater conflict and instability. For these reasons such factors are not considered further. The remaining 21 factors (identified in bold in Table 2.1) are assumed to have universal relevance to integration in a range of fields including flood warning. It is recognised however, that adopting these factors will not guarantee the successful implementation of a strategy of integration, but it is anticipated that they should facilitate this process in the area of interest. This hypothesis will be fully tested in this thesis with particular reference to flood warning systems.

2.3 Examples of integration policy implementation in other fields

A policy of integration has been followed in a number of different fields with varying degrees of success. It will be beneficial to gain insight into the practical problems and difficulties in achieving greater integration in some of these areas before considering the implications of such an approach in the field of flood warning. The approach to integration in three natural resource sectors will be briefly reviewed; water resources, coastal zone resources and soil resources and this will be contrasted with the approach taken in the field of marketing. The advantages and disadvantages of adopting an integrated approach to environmental protection and enhancement within the Environment Agency will also be discussed in this section.

Table 2.1: Integrative factors

Institutional Arrangements	1.	**Political commitment should be secured, clear objectives established, and roles and responsibilities defined within a flexible, integrative framework, preferably in a written plan. Rules for conflict resolution should be agreed.**
	2.	**Functions and structures to foster integration should be established, and consideration given to the designation of a lead agency.**
	3.	**Forums for negotiating and liasing between organisations should be established.**
	4.	**A positive organisational climate and culture for integration should be instilled into organisations – triggered by a strong declaration for integration from top management.**
Legal Arrangements	5.	**Legislation should be revisited and updated with a view to making laws compatible and not contradictory.**
	6.	**Legislation should clearly define roles and responsibilities of relevant authorities and the mechanisms for resolving conflict.**
	7.	**Legislation should provide clear and open procedures for public consultation.**
	8.	**Legislation should be periodically reviewed and continued political support should be sought to underpin the principles of integration.**
Economic Aspects	9.	A policy of resource pricing could lead to closer integration between agencies and consumers. But it could also result in resentment and conflict that can be counter-productive.
	10.	To promote a strategy of sustainable development tighter integration between economic processes and environmental policy is needed.
	11.	The merits of economic integration are being questioned. It could lead to conflict and instability and should only be implemented after careful consideration.
Technology	12.	**Technological integration could lead to organisational change and structures should be flexible enough to cope with this, thus avoiding power struggles and protectionism.**
	13.	**Technological advances should be applied to all functions rather than focusing on one function in isolation.**
	14.	**The application of technology should not be an end in itself. Low-technology solutions may be more effective with respect to integration. Application should be balanced.**
	15.	**The social access to technology can be variable and certain social groups can become excluded from the benefits it brings, causing fragmentation. Steps should be taken to integrate these groups into communications systems.**
Human interaction, expertise and training	16.	**Organisations should adopt formal, human resource management strategies, such as multi-disciplinary team working practices.**
	17.	**The use and cultivation of informal contacts and social networks should be encouraged both in organisations and communities.**
	18.	**Broadened staff development programmes and recruitment of staff from a wide base of expertise will ensure an organisation has the necessary skills to facilitate integration.**
	19.	**A policy of social integration is needed in society as a whole with the aim of reducing the exclusion of disadvantaged groups from gaining access to information, education and employment.**
Information and Knowledge	20.	**The free flow of, and ready access to, information within and between organisations and communities should be encouraged.**
	21.	**Expert systems that effectively merge machine and human knowledge, have a role in decision making and should be explored.**
	22.	**The incorporation of information and knowledge from unofficial sources should be encouraged and feed-back mechanisms established.**
	23.	**Steps should be taken to ensure that recipients of information understand it and believe it, and are able to confirm its accuracy.**
	24.	**Organisations should be aware that certain groups in society might have difficulty accessing and interpreting the information and knowledge they disseminate.**

2.3.1 Water Resources Management

In 1989 the OECD presented the results of an examination of integrated practices in water resources management in member countries. A total of six case studies were targeted for each country to represent the range of water resource policy issues active there, resulting in a total of 106 case studies being completed. The analysis of the case studies was guided by a focus on 13 administrative/institutional characteristics that were judged to be important for the successful integration of water resource management policies. For each case study a points system was used to score the importance of each characteristic to the process of integration.

As Penning-Rowsell (1997) concludes, the lessons learnt from this analysis are, first, that most countries have got some way to go before their water resources policies are integrated with other resource and environment policies. What appears to be the most damaging result of this deficiency is the splitting of water functions amongst competing agencies without any superior national body to co-ordinate national policies across all agencies.

Secondly, the analysis showed that there are few incentives for policy integration in the countries analysed. In many countries the pattern that is most likely to dominate is a number of specialist agencies operating in relative isolation often exhibiting little desire for policy change.

Thirdly, the range of policy tools for promoting integration was shown to be narrow. There was a reliance on traditional planning instruments and regulatory instruments, with economic instruments only found to be important in a minority of cases.

Fourthly, it was often the case that water agencies had little inclination to change their structures and would only move towards more integrated policies when faced with resources crises or pressure from interest groups.

2.3.2 Coastal Zone Management

Penning-Rowsell (1997) reports the results of 16 detailed case studies undertaken in OECD countries that evaluated, amongst other things, the implementation of integrated approaches in coastal resource management.

The cases studied show that there are considerable problems in this area. The development pressure on the coast is increasing; pollution problems are extensive, marine resources are over-exploited, and natural hazards continue to pose a threat to selected coastal communities. The way these problems have been tackled by individual countries is haphazard with policy conflicts between different sectors and levels of government often being the norm. Although there are many coastal zone management plans in existence, implementation is often weakly pursued. In many case examples this implementation follows a step-by-step pattern, with responsible agencies taking one problem at a time, rather than in an integrated and holistic fashion. In this respect the inter-dependencies that are particularly inherent in coastal zone resources are largely ignored.

Penning-Rowsell highlights the lack of a coherent body of coast zone legislation and the lack of policy co-ordination between agencies as major factors in limiting integration. This also has an international dimension with difficulties apparent in policy integration between as well as within countries. The Helsinki Convention has led to progress but with an emphasis on pollution control rather than other coastal issues.

2.3.3 Soil Resources Management

The OECD carried out an analysis of soil resource protection policy in member countries. Data from 18 case studies were analysed and the results have been used to gauge the level of policy integration in this discipline.

In a review of the results of this work, Penning-Rowsell (1997) identified four main conclusions. First, the length of time that occurred between the implementation of inadequate policies or poor soil practices and the soil degradation that follows can be many years or decades. This means that many problems currently being tackled by governments are inherited or residual problems, rather than resulting from current policies or practices. There is often therefore, a remedial task of government before policy integration can take a positive effect. The same type of time lag will also effect the implementation of better policies and practices.

Secondly, there are continuing problems with enforcing and implementing policies of integration. Despite recent improvements in vertical integration between the different levels of government, there is evidence that horizontal integration across the different resource sectors is not well developed i.e. soil and water; soil and recreation. A related problem is that in many countries the management of soil conservation and agricultural development policies are not integrated, and indeed are in conflict. Another problem is that much soil conservation legislation is still framed in isolation from other natural resource sectors, however, the case studies indicated that there is less concern about the limitations in the strength of legislation and more emphasis on the way it is introduced and implemented.

Thirdly, while the case studies show that political commitment at the highest level is needed for integrated soil conservation legislation and practices with other resource management areas, local involvement is also crucial to the successful adoption of better land management practices. While a regional perspective is necessary for better policy integration in water resource and coastal zone management, it is important in the case of soil resources that decision making is devolved to the lowest possible level of government.

Fourthly, information dissemination and education is important to success in this field more than in many others, because there are so many parties involved.

2.3.4 Marketing

In the field of marketing, the approach to integration is very different with the emphasis placed firmly at the operational level. Linton and Morley (1995) identify a range of benefits that a policy of integration brings to marketing, these include; creative integrity, consistency of messages, unbiased marketing recommendations, better use of all media, greater marketing precision, operational efficiency, cost savings, high calibre consistent service, easier working relations and greater agency accountability. They believe that a policy of integration offers powerful creative and cost benefits and cite two examples where integration in marketing has improved effectiveness.

Rover Metro's integrated marketing strategy

The Metro was launched in 1979 and became the highest volume seller in Rover's history. In 1991, competitive pressure on the Metro increased dramatically with the launch of the Renault Clio and Peugeot 106 and sales share began to fall despite pricing activity. In 1992 an integrated marketing strategy was adopted aimed at reversing this decline in share that had slipped to below 2%. The objective was to lift share to more than 4% with a settled down rate in excess of 3%.

An integrated campaign was developed consisting of 40-second television commercials, 48-sheet posters and a national press campaign featuring a direct response mechanism offering further information. Those who responded to this received their information pack containing a test-drive incentive based on the offer of a range of Harrod's merchandise. This promotional offer was also carried through to point-of-sale. The entire campaign was turned around in eight weeks from the marketing agency receiving the brief to the first television commercial and first press advertisement appearing.

The result of the campaign has been highly satisfactory. Metro's share of the industry rose from 1.9% to 4.3%, subsequently settling down to a share in excess of 3.5%. Previously Rover's highest ever response to a test drive incentive programme had been 7,000. The integrated campaign generated over 13,500-test drive enquiries. The total cost was under £2.5m and Rover estimated that the activity boosted profitability by over £7m.

Re-positioning ICL customer services.

When ICL launched a comprehensive range of customer services, they brought together hundreds of services provided by different divisions and business units, each communicating individually with customers. A complete integrated communications strategy was developed to position ICL as a long-term business partner providing professional services that were vital to achieving the client's business objectives. The programme lasted over two years and a key feature was the inclusion of consistent positioning messages and visual standards in all internal and external service communications. All activities were handled by a single agency and the result was consistent presentation of a single integrated communications strategy to all decision-makers. The customer service division became the largest single contributor to ICL's total revenue and profit.

Linton and Morley (1995) believe that an integrated approach to marketing is one of the most exciting developments in this field and provides a powerful range of business benefits. They do stress, however, that introducing integrated marketing represents a considerable risk and they recommend that its potential and implications be reviewed before commitment is made to a single-source solution. Solving internal political problems, selecting the right agency and operating pilot programmes are important stages in a successful transition to integrated marketing.

2.3.5 Environment Agency

The Environment Agency was formed in April 1996 by the bringing together of a number of organisations, including the National Rivers Authority, Her Majesty's Inspectorate of Pollution and the waste regulation authorities. One of the key objectives that the Government set the Agency was to "adopt an integrated approach to environmental protection and enhancement", and accordingly a high level (director level) policy group was established to determine and implement a strategy. It was given the following terms of reference: " ensuring that a continuum is established between the Agency's overall environmental strategy and the policies to implement it, and that those policies are coherent and integrated". It was considered that integration had two dimensions. At one level it meant developing a management or organisational culture that encourages and enables the staff in the Agency to think more widely about their roles and how they help the organisation deliver its "mission". At another level integration was designed to make a meaningful connection between a number of key issues related to environmental management. It was felt that a policy of integration could help deliver the following targets:

- a greater understanding of the state of the environment
- better information about the nature of environmental impacts and recovery
- better assessment of the costs and benefits and risks associated with environmental management, and prioritisation and targeting of management strategies
- the development of effective strategies to influence other bodies and organisations
- the successful introduction of sustainable development and improvement and the ability to measure the success of such a policy (Mead, 1995).

To implement the integration strategy within the Agency, the Policy Group commissioned a number of working groups made up of staff from each of the former organisations. Once fully formulated, the strategy was given priority at the highest level and the Chief Executive initiated a major organisational change to ensure its implementation during 1997.

The strategy was considered to be appropriate and successful for some functions more than others within the Agency. In the area of pollution control and environmental protection for instance, the policy worked well. Each of the former organisations carried out these functions in one form or another and a more integrated approach was considered to be appropriate. In other functions, notably flood defence (formerly the responsibility of the NRA and taking half the Agency's budget and manpower), the policy was considered by some to be less appropriate. Indeed the Independent Review of the Easter 1998 floods states: "the structure (of the Agency) may be effective in promoting the integration of skills and resources to bring about efficiency and effectiveness in holistic management of the environment. It appears feasible for flood defence to operate satisfactorily within this structure but there could be disadvantages for an essentially operational public protection service" (Bye and Horner, 1998).

Summary

The studies presented here illustrate the way in which progress is being made in introducing an integrated approach to a number of different fields. They also highlight how the concept of integration is being contemplated in different ways and at different levels and this has important implications for flood warning. The approach to integration in the natural resource functions for example, has been to take a broad strategic perspective by examining how each discipline interacts with other systems and how high level policy decisions affect the process of integration. This contrasts markedly with the approach taken in marketing where a very focused policy has been adopted at the operational level, integrating key elements in a "building block" approach to improve sales performance. It is clear from the former that integration is often difficult to achieve especially when it involves the bringing together of policies from a number of agencies often with an inadequate legislative framework to facilitate implementation. In such cases the incentives for integration are few, with many agencies preferring to preserve their power-base and maintain the status-quo. In the marketing examples, integration involves the bringing together of activities carried out by individual companies and hence it could be argued that in such circumstances an integrated approach is easier to achieve. The main inducement to integration in marketing is economic and by demonstrating that such a policy can improve the economic performance of a company can be a powerful incentive for its implementation.

In the case of the Environment Agency, a policy of integration was introduced with high level support within the organisation after receiving political direction and commitment from the Government. The necessary functions and structures were established and steps were taken to try and inspire a positive organisational climate for the policy. The Agency chose however, to implement the policy rapidly and in a rather dogmatic fashion. Without the full grassroots support of its employees, the Agency had failed to "inspire" the universal support that it originally intended.

2.4 The relevance of integration to flood warning

Mileti (1994) states that the most effective structure for a flood warning system is that of an integrated system. He defines such a warning system as a means of getting information about an impending emergency, communicating that information to those who need it, and facilitating correct decisions and timely responses by people in danger. He recognises that integrated systems in this field are complex in both organisation and work process. They tie together work in a variety of specialities within and across many different organisations. For example, they can link science (physical and social), engineering and technology, a number of government departments (national and local), and the public. He goes on to state that integrated systems in flood warning should be viewed as comprising of a number of interrelated components or subsystems that cover the activities of detection, forecasting, warning dissemination, and response. Integration requires that sound relationships among these subsystems be developed and maintained. Penning-Rowsell (1986) emphasises this point and states that it is through the integration of the various constituent parts of a flood warning system that the effectiveness and efficiency of that system will be maximised. Handmer (1997) believes that a total or integrated flood warning system is more than a list of components, of more importance is how the components function together to serve the purpose of the whole.

As Mileti (1994) remarks, the structure of flood warning systems has been researched and discussed for several decades and there is a large degree of consensus among researchers about how systems should be structured to be effective. Penning-Rowsell (1986) states however, that few flood warning systems are designed in the integrated way advocated by Foster (1980) and Mileti (1975). He contends that much attention has been given to the detection and forecasting subsystems and that this attention appears to be disproportionate. It is irrelevant how accurate a flood forecast could become, using all the latest data-gathering and information technology, if the warning is not disseminated efficiently and the public do not respond. He believes that more emphasis should be placed on integrating the remainder of the warning process with the state-of-the-art forecast production technology, rather than taking that technology further in isolation from the use of the forecasts thereby produced.

Penning-Rowsell (1986) highlights three key factors that influence the performance of integrated flood warning systems; institutional arrangements, the technology of forecast production and dissemination, and the education of the warning recipients about the warnings they are likely to receive and the response expected.

Under institutional arrangements Penning-Rowsell includes administrative structures, the legal position and the resources devoted to the system. He stresses the point that there are numerous different ways of organising these arrangements, each of which may be perfectly workable and efficient for the particular local circumstance. He also highlights the need to review the technology of flood warning systems in light of local experience and to integrate the appropriate forecast technology with the character of the dissemination system and the likely levels of public response. It may be more appropriate, he suggests, to base forecasts on low technology and concentrate resources on efficient dissemination and response, rather than producing very accurate forecasts that are either too late or, when they reach those intended to respond, are in a form that cannot be understood or used. Penning-Rowsell considers that pre-event publicity and awareness programmes are important in raising public response. Such programmes are a poor substitute to actual experience of flooding, nevertheless, forms of pre-flood publicity should be examined, perhaps using the experience of market research and marketing methods.

Keys (1997) states that because flood warning is a multi-dimensional activity it requires inputs from expertise from a number of organisations and professional cultures. Technical interests will be involved, as well as those from the social and behavioural sciences. He stresses the importance of these inputs meshing effectively together and the need to overcome sometimes significant inter-cultural barriers between the different groups involved, to ensure that the total system functions well.

2.5 Conceptual approaches to flood warning systems.

When analysing flood warning systems it is important to develop a conceptual framework in which to work. This should identify the main components of the total warning system and recognise how they relate to one another. It should also offer a means of focusing on areas where improvements are necessary to enhance overall system effectiveness. As Penning-Rowsell and Handmer (1986b) highlight however, there is little in the field of flood warning that can be called "theory" and few overall hypotheses regarding the totality of the warning process from which to proceed. They are concerned that this may encourage researchers to proceed empirically and through data-orientated case studies rather than by refining the concepts to be deployed. They point to the all too frequently expressed view that the "answers" relating to optimising flood warning processes are "out there" and all that is needed is to devise techniques of measurement and evaluation rather than going through the process of creative thought.

Nevertheless, several models have been developed over the last thirty years that usefully attempt to conceptualise the warning process. These are based on the wider hazard perception model developed by Kates (1962, 1970) which, although being too generalised to be useful in the specific flood warning context, helped consolidate and stimulate research in the field. The most useful conceptual statements concerning integrated or total warning systems, therefore, are those developed by Williams (1964), Foster (1980) and Mileti (1975, 1994). The main features of these models are presented in Appendix 2 and they are critically examined in the next section.

2.5.1 A critical assessment of the literature

Penning-Rowsell et al (1982) believe that important observations regarding warnings in general can be derived from conceptual models such as those presented by Williams, Foster and Mileti. They underline that a warning is a process and not a discrete message or action and emphasise the interdependence of the various activities involved. They also point to the fact that warnings are best analysed by following a systems approach that identifies components of the system, their interaction, and the need for feedback that may create change or stability in the system. Williams, Foster and McLuckie (1973) all make the important distinction between prediction of danger and behavioural advice. They also differentiate between a forecast, that is a prediction of an event of a specific magnitude occurring at a certain time and location, and a warning, that includes the prediction but also a recommendation to take precautionary, protective of defensive action. Penning-Rowsell et al (1982) also stress the importance of recognising the complex nature of warning response and the effect this has on total warning efficiency. McLuckie's (1973) stimulus-actor-response model therefore, is considered to mirror reality more appropriately than a simple stimulus-response approach as it focuses attention on the perceptions and experiences of the warning recipient that can have important ramifications. In general, conceptualising flood warning systems in this way draws attention to the fact that such systems are complex processes that involve the interaction and integration of physical, technical and social disciplines. The effectiveness of any warning system is dependent on how well these three disciplines can be satisfactorily coordinated.

Penning-Rowsell (1986) highlights the dangers of a systems approach to flood warning and makes reference to Foster's model in particular. He believes that, although this model describes the interactions between parts of the whole, it does nothing to either explain the nature of that interaction nor to analyse power within the system, nor necessarily to point towards ways of optimising the efficiency of the interaction. He feels the oversimplifying and over-rationalising systems framework also tends to emphasise stability and equilibrium rather than dynamic change. All parts of the information flow within the warning process are dynamically interacting.

Parker (1991) believes that conceptual models such as Foster's have a number of strengths such as looking at the total system and stressing the need to examine feedback between constituent parts of the system. They also recognise that changes to one part of the system have implications for all other parts and its total performance. A forecaster for example, may upgrade flood forecasting technology but may in so doing degrade the warning process, the technological change may result in an amended warning message that may differ from what the recipient is expecting. Nevertheless, Parker also considers that Foster's approach is flawed in a number of respects:

1. it lacks a recognition of the importance of history, it must take into account the successes and failures in the past as these will have an effect on the behaviour of the actors involved.

2. the model gives no guide as to what is meant to happen in the constituent parts of the system. Little consideration of institutional arrangements e.g. the hierarchical layout of the agencies involved, the levels at which decisions should be made and reviewed.
3. no emphasis is given to the environment in which the agency or individual exists - decision making is rarely calm or operates in perfect surroundings, for example, data deficiencies, political pressures, power of mediating influences, etc.

To overcome some of these deficiencies, Parker et al (1994) have developed a generic model that is derived from existing research from a wide variety of sources with different disciplinary bases.

The main components of the model as illustrated in Figure 2.1, are forecasting (that includes detection), warning and response, and information flow, whether intrinsic (i.e. official warnings) or extrinsic (unofficial warnings), is seen as an important factor for integrating these three components. The model incorporates important feedback loops. The model has been expanded to include the principal activities involved in each component of the process, the principal agencies and stakeholders, and the factors that are considered important to inducing effectiveness.

Parker et al (1994) make reference to Lazarus's stress model (1966), where stress is a function of the challenge or demand of the event and the resources available to meet the challenge. The challenge is determined by the flood characteristics (rate of rise, flood depth, velocity of flood water, flood duration etc.) and for every possible challenge there are one or more appropriate adaptations (e.g. prevent water entering property, raise property and evacuation). To be effective, each adaptation has certain requirements (warning lead-time, prior information etc.). Thus flood-detection-forecasting-warning-response-systems (FDFWRS) need to be matched to both flood characteristics and adaptive response requirements. In order for the FDFWRS to increase in efficiency there is a need for concerted public information and education programmes before flood events. This will enable flood victims to assess more adequately environmental cues prior to the receipt of warnings and to respond more effectively on receipt of warnings.

Parker et al (1994) test and expand the initial generic conceptual model. They apply the model to climatic change and identify the principal functions of FDFWRS in this context. They develop a single conceptual framework and apply it to a number of countries in the European Union. They expand each component of the model and identify each activity associated with each component and the main agencies and stakeholders involved at various stages in the process. They begin to identify the factors that are important to the effectiveness of FDFWRS.

Parker et al (1994) also present a staged development model that complements the process model. This is used to compare FDFWRS in different countries and is used to identify where a FDFWRS is located on the path between rudimentary to advanced. From the model a criteria-development matrix (CDM) is developed. 14 criteria were identified by which the level of development of FDFWRS may be gauged. A system is categorised in one of five categories – or levels of development (from rudimentary to advanced) – according to each criterion, generating a profile of the condition of the system under review. Parker and Budgen (1998) developed the CDM approach further by increasing the number of criteria from 14 to 27 and then applied it to the tropical cyclone warning dissemination system in Mauritius.

The 27 categories adopted by Parker and Budgen (1998) are:

1. legitimisation and authority accorded to warning dissemination
2. legislative foundation
3. flood warning philosophy
4. forecast and warning parity
5. application of technology to forecasting
6. application of technology to warning dissemination
7. geographical coverage
8. extent of links with stakeholders
9. arrangements for night time warnings and response
10. arrangements for remote areas
11. arrangements for social groups with limited resources
12. arrangements for groups with special needs
13. redundancy in communication networks is developed
14. multiple reinforcing sources of warnings
15. content of warning messages to the public
16. degree of local detail in warnings
17. extent to which warning system allows for warning confirmation processes

18. presentation of warnings by broadcast media
19. extent of integration of forecast and media agencies
20. extent of informal communication network activity
21. availability of hazard information
22. attitudes towards freedom of hazard information
23. public awareness raising about warnings
24. public education about flood warnings
25. knowledge of FDFWRS effectiveness by agencies
26. performance targets set and monitored
27. organisational culture

In their reassessment and development of the CDM model, Parker and Budgen added emphasis in a number of key areas, all of which have relevance for integration:

- arrangements for public warning - including different social groups with different needs and resources, in remote areas and at different times of the day.
- communication of warnings – including multiple sources and redundancy in communication networks.
- the mass media and media broadcast technology.
- informal as well as formal communication networks.
- the provision of locally specific information.

2.5.2 What integrates flood warning systems?

From the literature it is clear that the conceptual models presented here are considered to offer a useful framework in which to contemplate flood warning systems. But how far do they go in giving a full representation of the relevant factors needed for the effective integration of flood warning systems?

The models presented by Williams, Foster and Mileti tend to focus on information, knowledge and human expertise as being the main criteria that integrate warning systems. Williams for instance, conceptualises a warning as a process involving the flow of information that binds all components of the system together. Information may originate from a number of sources, both official and unofficial, and this needs to be collated and evaluated before being transmitted by various means to those at risk of flooding. He stresses the need to regard a warning system as a circular rather than linear process that involves feedback mechanisms from the warned to the warner. Foster also highlights the importance of information in his model emphasising the need for it to flow both ways, passing to and from those threatened, and for it to disseminated via several channels. The importance of "multiple reinforcing sources of warnings" is highlighted by Parker and Budgen (1998) as well as the need for warning messages to the public to be "iconically, factually and behaviourally" sound, with a high degree of local detail. Williams and Foster tend to assume however, that the receiving population of warning information is homogeneous and they fail to take into account the important issue of social differentiation. Parker and Budgen (1998) recognise that special arrangements need to be made for social groups with limited resources and with special needs. But further work is required to identify mechanisms for integrating excluded social groups into a conceptual representation of warning arrangements. Greater emphasis should also be placed on the role of unofficial or informal flood warning arrangements where communities often activate extensive social networks to disseminate flood related information. Parker and Handmer (1997) find that such arrangements are often more resilient than official systems and that there is much merit in seeking to integrate the two approaches and thereby enhancing overall system performance.

Human expertise and knowledge are seen as variables that can either help facilitate or hinder the integration of flood warning systems. Williams sees poor training and education of "human operators" as a potential blocking mechanism for warning systems. This can occur at any of a number of "sub-points" within the overall warning process and may involve individuals that forecast and issue the warnings as well as the warning recipients. Foster believes that the effectiveness of warning systems can be enhanced through education, without this he sees a greater reliance upon peoples' unconscious and irrational responses that may distort the incoming information. Mileti considers the need to reconcile the differences in interpretation of flood warnings of those who issue warnings and those who receive them and this can be achieved through education and training. Parker and Budgen (1998) refer to public awareness and public education in their model and talk about the issue of varying levels of education and awareness in different social groups. They pay particular reference to the plight of special needs groups and the ethnic minorities, an issue that is not addressed by the other conceptual models. In contrast, Parker and Handmer (1997) highlight the fact that local communities can be a "storehouse" of knowledge and wisdom about the flood hazard, a fact that is often not appreciated or ignored by managers of official flood warning systems.

Williams, Foster and Mileti make little reference to other integration criteria in their approaches. There is little regard of institutional arrangements for instance, and how agencies perceive and carry out their role in flood warning operations and how this is influenced by the statutory framework in which they function. Where this framework is weak and ill-defined, agencies may not operate in an optimum way and this can impair the warning process. Williams and Foster make no reference to institutions in their models and merely lump together official organisations as "decision makers". Mileti recognises that different agencies have different roles and responsibilities in the process and differentiates between those who detect floods (detectors) and those who manage floods (managers). He fails to address however, how these agencies should interact or elaborate on the influence institutions have on the success or otherwise of flood warning systems. In contrast, Parker and Budgen (1998) identify a number of organisational criteria for assessing the level of development of warning systems that also have relevance for integration:

- the need for a well-developed organisational culture for emergency preparedness and collaboration.
- the need for legitimisation and authority to be accorded to warning procedures within organisations.
- for fully developed links to be established with a full range of stakeholders and frequent dialogue.
- for there to be seamless integration between forecasting agencies and media organisations.

The role of technology is another criterion that receives little attention. Technology has revolutionised many aspects of flood detection and forecasting in recent years and is being used increasingly to improve warning dissemination. Parker and Budgen (1998) identify the application of technology as being of fundamental importance to system integration. They stress the need for technological application to be advanced and state-of-the-art, and for equal attention to be given to forecasting and warning dissemination. What is not accounted for in any model however, is the key issue of social access to technology that may be fragmented and hence not conducive to integration. The growing problem of social exclusion is an important one within the process of warning especially when many organisations are increasingly reliant on technology to disseminate their warning information to the general public.

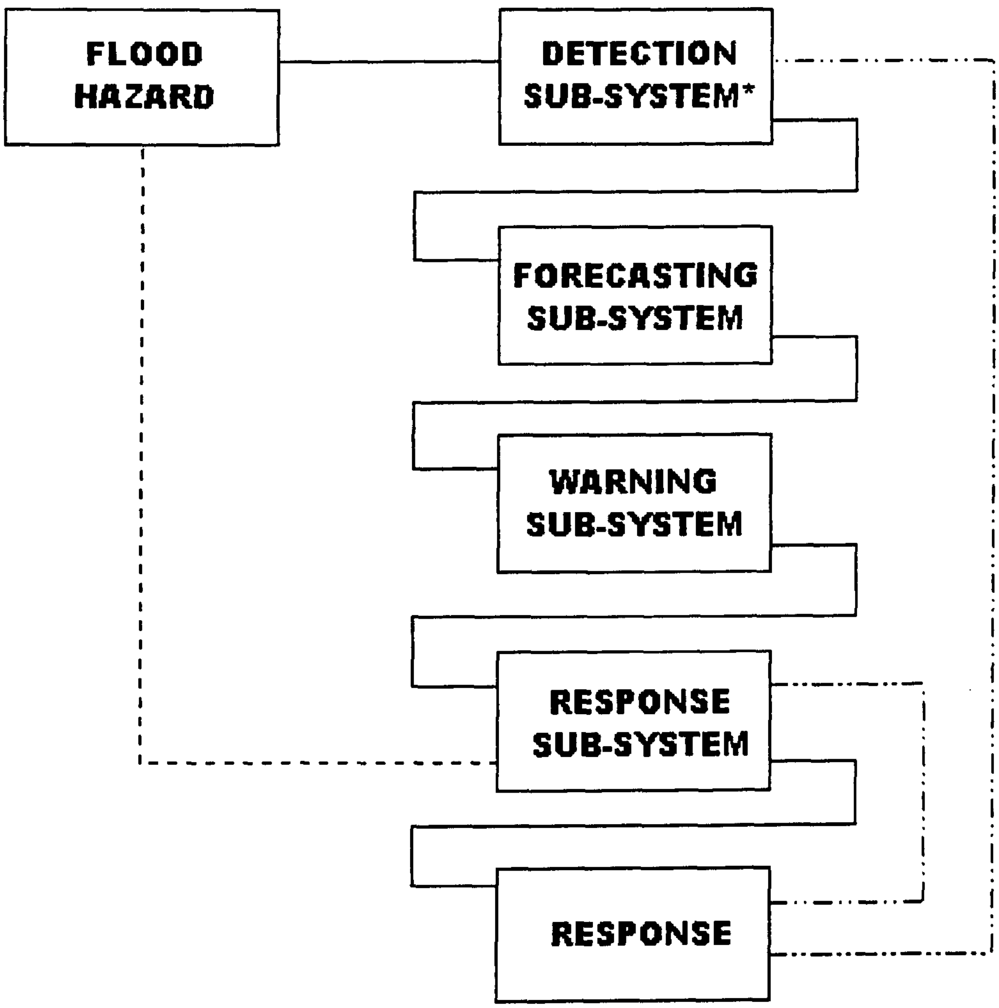
In general, therefore, although the models presented offer a useful framework, they tend to focus on a limited number of factors that have relevance to integration. To be of value as representations of integrated flood warning systems a wider perspective is required. As Mitchell (1990) states, a wider appreciation of those issues and variables judged to be of most significance to system integration should lead to overall improved effectiveness in the field in question. This is the central issue to be tackled in this thesis.

2.6 Conclusions

In general, integration can be beneficial. Such a policy can lead to enhanced co-operation and co-ordination that in turn may lead to overall improved effectiveness. Integration can be contemplated in a number of different ways and at a number of levels. Mitchell (1990) recommends a two-staged approach to integration – an initial comprehensive viewpoint, considering a whole range of issues and variables, followed by a more focused approach that concentrates on those issues and variables judged to be the most significant to the area in question. When considering the implementation of an integrated approach it is important to identify and consider systematically these variables and criteria. A number of these have been presented and discussed in the literature that are considered to be of universal relevance to the successful implementation of a policy of integration. These have been summarised in this chapter under the following headings;

- institutional arrangements,
- legal arrangements,
- economic aspects,
- technology,
- human interaction, training and expertise
- information and knowledge.

Figure 2.1: Generic conceptual model of flood detection*, forecasting, warning and response system (adapted from Parker et al, 1994).



———— Intrinsic information channel
- - - - - - - - Extrinsic information channel
—··—··— Feedback loops

* - "Detection sub-system" added

The implementation of an integration policy has been recorded in a number of fields with varying degrees of success. The examples presented here illustrate how the concept of integration is being contemplated in different ways and at different levels. In some fields a broad strategic perspective is being followed, whilst in others a more focused policy is being adopted. It is clear, however, that integration is most difficult to achieve when it involves the bringing together of policies from a number of agencies often within an inadequate legislative framework and where the incentives for integration are few. In contrast, where integration involves the bringing together of activities carried out by individual companies and where the incentives include improved economic performance, the success rate for implementation can be very high. In all cases, it is important to introduce a policy of integration in a balanced way, to identify and address all the relevant criteria for the area in question, and not to focus on a limited set of attributes whilst ignoring others.

There is a general consensus in the literature about how flood warning systems should be structured. Many researchers believe that the most effective structure is that of an integrated system and by integrating the various constituent parts of a flood warning system, the effectiveness and efficiency of that system will be maximised. Few flood warning systems are designed in an integrated way however, and more fundamentally, there are few overall hypotheses that regard the totality of the warning process. The limited number of models that attempt to conceptualise flood warning systems in an integrated way have been summarised and critically examined in this chapter.

Although the models presented by Williams, Foster and Mileti offer a useful framework in which to contemplate flood warning systems, a number of fundamental flaws in their approach have been identified. These include a tendency to oversimplify what is a complex process, to be rather too descriptive with little emphasis placed on the less-than-perfect situations in which flood warning systems operate, and an inclination to focus on a limited number of criteria that have relevance to integration. There is limited reference for instance, to the impact of technology, a range of social issues and informal warning arrangements on overall system integration.

It follows therefore, that the implementation of a successful policy of integration requires the consideration of a wider range of factors than those identified in the conceptual models referenced in this chapter. This will be approached by taking the factors identified from the literature in this chapter as a starting point (see Table 2.1), analysing them in greater detail under the relevant substantive heading (using case study material from the Thames basin where appropriate), and adding to them if possible. The methodology to be used to achieve this will be fully outlined in Chapter 3.

Chapter 3

Methodology

3.1 Introduction

Research can be viewed as a systematic process to establish facts or principles on a subject such as integrated flood warnings, and the way in which this is conducted can fundamentally effect the resultant findings. As a consequence, it is particularly important to detail and make transparent the research philosophy, design and methods adopted in any research work such as this. These aspects are explicitly examined in this chapter so as to enable the reader to evaluate the research findings. An analysis of the research design and a justification of the validity and reliability of the study follow an examination of the philosophy of and approach to this project. The principal sources of information are presented and an assessment given of the use of case studies and the selection criteria adopted. The research methodology draws on a number of information sources, including case study material, unpublished work archived by the Environment Agency, its predecessors and other organisations, and extensive participant observation made by the researcher through over 25 years of experience in the field of flood warning.

3.2 Philosophy and approach

Broadly speaking, research is carried out in order to discover something that is not already known about (Hughes and Sharrock, 1997). It can be categorised by two dominant philosophies. The first is known variously as "experimental", "hypothetico-deductive" or "positivist" (Henwood and Pidgeon, 1993). This paradigm advocates a view that the subject of study is external to the research and the researcher, and that reality consists of a world of objectively defined facts. It is a system of philosophy based on experience and empirical knowledge. Positivist concepts were first proposed by Auguste Comte in the 19th century who believed that the empirical sciences were the only adequate source of knowledge and in the importance of scientific verification. This quantitative approach is seen as crucial to the natural sciences because it enables the concepts embedded in theoretical schemes or hypotheses to be observed, manipulated and tested. It is underpinned by the need for research findings to be capable of replication and generalisation, and for predictions to be made upon the basis of observed regularities.

The alternative epistemological position is expressed in the naturalistic or interpretative paradigm. This approach accepts the view that the world is socially constructed and the research and indeed the researcher are part of the investigation. The nineteenth century German philosopher Wilhelm Dilthey argued that a clear distinction should be drawn between the disciplines of natural science and the moral or human sciences. In Dilthey's view ([1894] 1997), whilst the former could be supported by external observation and explanation of regularities in physical events, the human sciences should be premised upon the search for meaning and understanding. Hughes and Sharrock (1997) see the prime task of this phenomenological approach as describing the everyday experience of the "life world": the world as given in immediate experience and independent of and prior to any scientific or other interpretation. It deals with the social reality in which action takes place and the outcome of the interpretations made and courses of action undertaken by social actors.

Through the 1930's to the 1960's many workers such as Durkeim (1953) tried to make legitimate a conception of social science consistent with the prevailing positivist image of natural science. Many had strongly held views that the social sciences should endeavour to emulate the most advanced of the natural sciences, namely physics. Some tried to design proper empirical experiments for social research. Attempts were made to purge these experiments of all emotional, ideological and theoretical preconceptions, in an attempt to provide a clear criterion of truth independent of human whim and prejudice in order to seek knowledge of the highest order. Carrying these principles into the human sciences gave rise to a number of problems. Accordingly, in the latter half of the twentieth century there was a reaction against and rejection of positivist doctrines. Winch (1990) sees that many of the problems the social scientist faces are indeed philosophical in nature and not empirical. He contends, therefore, that it is inappropriate to attempt to solve philosophical problems by empirical, especially scientific means. He believes that the world is deprived of certainties and that a much more sceptical approach to all questions of knowledge is required, emphasising the uncertainty and undecidability of everything that might be taken for knowledge.

Hughes and Sharrock (1997) stress the importance of recognising that not all problems of the social sciences are philosophical rather than empirical or scientific in nature, for there clearly are all kinds of empirical investigations that can be and are made. Nevertheless, other research methods have come to the fore, associated with the more qualitative research advocated by the phenomentogists; these include participant observation, case studies, ethnography and discourse analysis. These methods are widely used in the social sciences today, but as many authors' stress there is a continuing need to ensure that high aspirations to scholarly rigour are maintained in what ever research approach is adopted. Bryman (1988) believes that the distinction between qualitative and quantitative research is really a technical matter whereby the choice between them is to do with their suitability in answering particular research questions.

This study draws from many aspects of qualitative methodology. These have been usefully summarised by Henwood and Pigeon (1993) to include:

- an emphasis on description rather than explanation
- the representation of reality through the eyes of participants
- the importance of viewing the meaning of experience and behaviour in context and in its full complexity
- a view of the scientific process as generating working hypotheses rather than immutable empirical facts
- an attitude towards theorising which emphasises the emergence of concepts from data rather than their imposition in terms of *a priori* theory.

Many of the techniques commonly used for such an approach have been adopted in this study, including participant observation, interviews, and case studies. These have allowed the researcher to examine and analyse flood warning arrangements in England and Wales from the perspective of a wide selection of participants with differing levels of knowledge and expertise, and with a wide range of interpretations.

The approach adopted has been heavily influenced by the position of the researcher, namely as an employee of the Environment Agency. The research question has been addressed by applying the researcher's own knowledge and expertise to the issues in hand, with that of colleagues and other staff who operate in the researcher's professional network, both inside and outside the Agency. An attempt has been made to view the issues from the perspective of different disciplines, and to incorporate the interpretation of common problems by a range of "experts" working in different fields. Although the researcher is a physical geographer/hydrologist by training, there is an awareness of alternative perspectives articulated by workers in other disciplines, such as social scientists, technologists, physical scientists and engineers. The researcher also makes a conscious effort to blend the views of practitioners in the operational environment, with those of academic workers, and where possible bridge the gap between the two communities.

By undertaking research whilst occupying the role of an "insider", gives the opportunity to widen not only one's own perspectives in relation to the subject matter, but to influence the thinking of others. This is achieved with colleagues, staff and managers through informal discussions, meetings, and via other means of communication such as electronic mail, both at a regional and national level within the organisation.

Another important element of the project is gaining an appreciation of the layman's interpretation and assessment of key issues. This is achieved through close reference to activities in one study catchment in particular, but opinions of the public in other parts of the Thames Region are also analysed in detail. The researcher's position allows direct access to these communities and key individuals within them. The emphasis on action-research is manifested by the researcher's ability to take certain findings and implement them operationally. Much value is placed on being able to observe the impact of the resultant operational changes both within organisations and in the communities benefiting from the flood warning service.

3.3 Role of the researcher

The researcher finds himself in a unique position with respect to analysing flood warning systems. He has spent most of his career developing, implementing and operating such systems, spanning a period of over 25 years. This started in the London area in 1975 and was extended to the whole Thames catchment from 1989 onwards. The researcher's role as Regional Flood Warning Manager for the Thames Region of the Environment Agency gives him a particular insight into the practical realities of operating a flood warning service in England and Wales. Such a position offers a number of distinct advantages over a more conventional PhD student, and these can be summarised below:

- unlimited access to data, information, unpublished reports operational procedures, and other relevant material.
- unrestricted access to experienced, professional staff in the Thames Region of the Environment Agency and other regions.
- ready access to professional staff in other organisations, such as local authorities, emergency services, research institutes, forecasting agencies, both in the UK and overseas.
- having a general familiarity of the workings of organisations, and being aware of where to find information and with whom that information resides.
- the ability to implement operationally many ideas and strategies that may be identified in a research project.
- participating in operational duties and thereby gaining first hand experience in the use of implemented procedures.
- the ability to bridge the gap between the research and operational fields and communities.
- the ability to commission research to enhance operational practices.
- being a professional in the flood warning field gives a higher level of credibility than a conventional student and more influence with staff in the Environment Agency, other organisations and the general public.

The researcher's role as an "insider" therefore, has enabled him to have access to information not normally available to research students, to have unique access to key institutions and individuals, and to have the ability to participate directly in many of the activities central to this project.

Conversely, being an "insider" does bring a number of disadvantages and potential problems when undertaking research of this kind. These can be summarised below:

- there is a danger that the researcher will have difficulty moving towards the position of an impartial and objective scientist.

- the ability to be constructively critical may be difficult especially of things that the researcher may have developed and in which he/she may have a vested interest.
- the insider may become "blinded" by prejudiced opinions and have developed a rigid way of doing things (Chan, 1995).
- the researcher may be too close to the subject area and his/her views may not be as objective as those of an outsider.
- the insider may have developed over-zealous feelings for the organisation of which he/she is part. He/she may not be able or willing to critically evaluate that organisation and in extreme cases be in fear of reprisals. An outsider would be able to offer a far more open assessment of such an organisation.
- as a professional, the insider may have become conditioned into a certain way of thinking. He/she may also have professional relationships to maintain which could cloud his/her assessment of certain issues.

To cope with these disadvantages the researcher adopted a number of strategies.

- an open, self-critical approach to the research was adopted. A conscious effort was made to try and guide the research more from the viewpoint of the recipients of the flood warning service and less from the official perceptions of the Environment Agency.
- the researcher developed his own critical analysis of the way his employer approaches issues within the area of flood warning, and attempted to adopt alternative values and perceptions where these were felt to be appropriate.
- a flexible approach was adopted when conducting research to try and avoid the imposition of preconceived ideas on interviewees. Allowance was made for unexpected developments by modifying the research focus when this became necessary.
- fresh perspectives were sought through the attendance of conferences and seminars both in this country and overseas and through discussions with colleagues and other workers.

The researcher undertook a Masters Degree in Earth Science and the Environment at Kingston University (Haggett, 1981), whilst working in a full-time capacity for the Greater

London Council. The thesis was entitled "The Benefits of an Improved Fluvial Flood Warning System in London" and some of the issues being addressed in this research project were first examined at that time. The researcher therefore, brought some experience of undertaking a project of this kind in such an environment and was aware of the effects of some of the issues alluded to above.

3.4 Research framework

When analysing flood warning systems it is important to develop a conceptual framework in which to work. This should identify the main components of such systems and recognise how they inter-relate. As discussed in Chapter 2, there is a general consensus amongst researchers that the most effective structure for a flood warning system is that of an integrated system. There is also general agreement on the main components, namely: detection, forecasting, warning and response, and that sound relationships need to be developed and maintained between them. Indeed, a limited number of models have been proposed over the last 30 years that usefully attempt to conceptualise the flood warning process and identify factors that serve to integrate the constituent parts. It has been demonstrated in Chapter 2, however, that many of these models focus too narrowly on a limited (but nevertheless important) number of these integrative factors and that there is a need for a wider perspective.

This research project attempts to rectify this deficiency by presenting a conceptual model derived from a more comprehensive assessment of "integrative devices" (Lawence and Lorsch, 1967) that are considered to be most relevant in the context of flood warning. The approach adopted is a two-staged process with an initial identification of a wide range of issues and variables, leading to a more focused set of factors presented under four broad headings: institutional and legal arrangements, technology, human interaction, training and expertise, and information and knowledge. These integrative factors can be conceptualised as crosscutting strands running through the main components of a flood warning system and are illustrated in Figure 3.1 and described below.

- The institutional aspects are dominated by the need to identify a lead organisation that is mandated to secure the smooth functioning of the entire system (represented by the solid black line). This lead organisation should interact with other relevant organisations that have specific roles in certain aspects of the system (represented by the fine lines), and this should be undertaken in a collaborative way (represented by the circles).

- The technological aspects are depicted by the need to expand technology more evenly across the four main elements, but recognising that the opportunities for and appropriateness of technological development lie more in detection and forecasting than in dissemination and response (represented by the wedge shape).
- The human interaction, expertise and training aspects are represented by the recognition that such features need to extend from the few to the many (represented by the widening wedge shape) and for learning to be encouraged at each stage (represented by the linking lines and arrows).
- The information and knowledge aspects are represented by the need for a circular process to be established (represented by the circle) and the avoidance of one-way information and knowledge exchange.

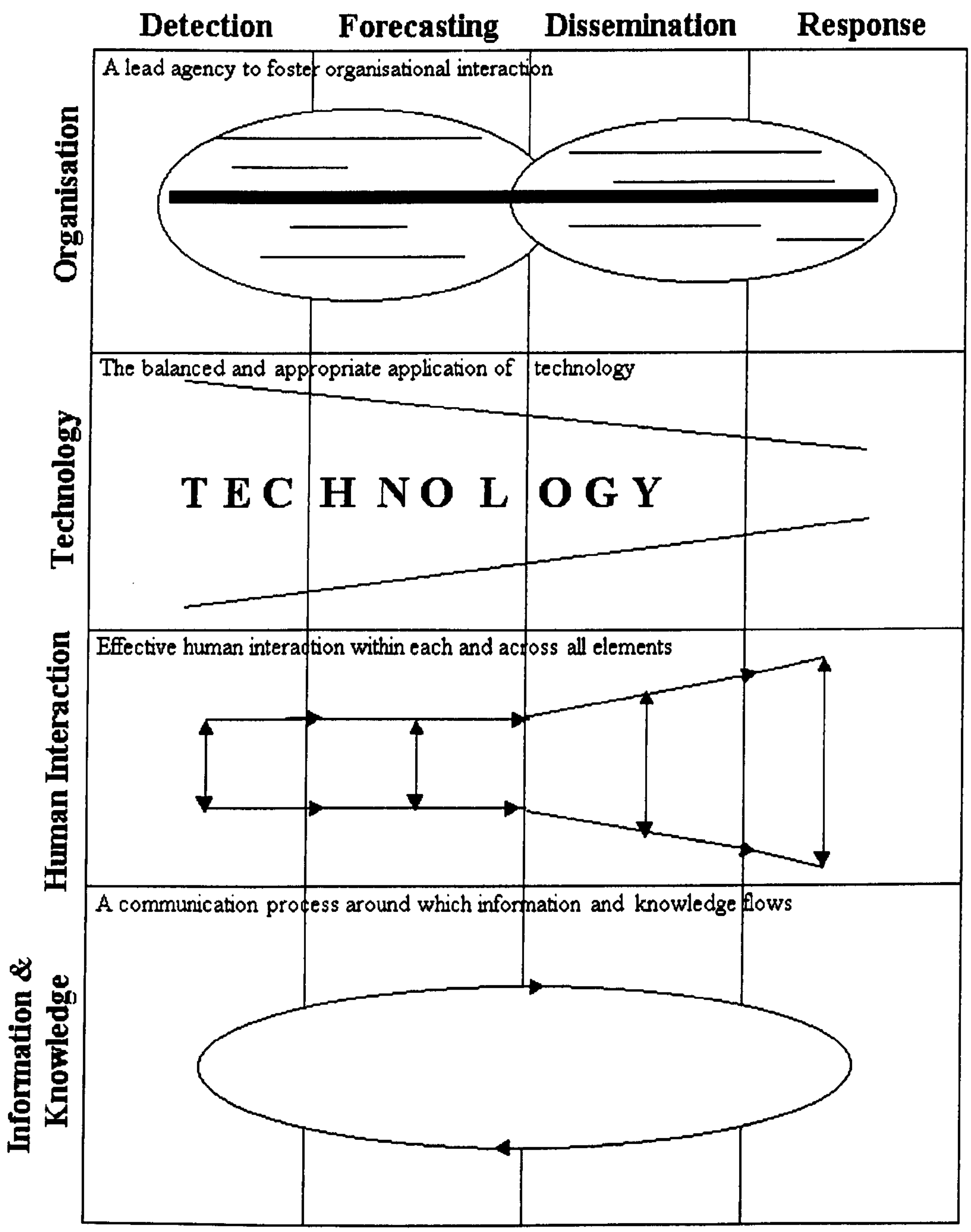
Each of these aspects is examined in detail in Chapters 4 to 7 using information from the Thames Region, including a database of flood events (Appendix 1), and participant and direct observations. These are discussed in more detail in the next section.

3.5 Research design

Yin (1984), defines research design as the logic that links the data to be collected (and the conclusions to be drawn) to the initial questions of the study. It is the action plan for getting from here to there, where "here" may be defined as the initial set of questions to be answered, and "there" is some set of conclusions (answers) about these questions. Between the two, Yin suggests, may be found a number of major steps including the collection and analysis of relevant data.

A number of methods and techniques were adopted in the research design to meet the specific needs of this project. It was felt important that the design encompassed a variety of methods of investigation and made full use of the extensive data and information available to the researcher. A central technique was the use of case studies that seemed to offer

Figure 3.1: Conceptual Model of the Flood Detection, Forecasting, Warning and Response Process



flexibility and the ability to focus on the characteristics of real-life events. The researcher chose to focus on the Thames catchment as the main area of case study, supported by a more in-depth analysis in one particular sub-catchment. To focus entirely on a single case study would hinder the ability to use findings to generalise more widely (Schofield, 1993).

Another technique that was adopted was that of analysing archival information, to which the researcher has unique access. A database of nearly 80 flood events, extending from 1975 to present day, was collated (Appendix 1). This empirical information resource of past events was either used to support the findings from case study analysis or to highlight where findings were atypical and could be inappropriately used to generalise more widely.

The final technique used was that of participant and direct observation. The researcher not only participated in the management of many of the flood events referred to above, but also had direct access to communities and other organisations in flood risk areas across the Thames basin.

All these techniques are examined in more detail in Section 3.8.

3.6 Case study selection

As outlined in Chapter 1, attempts are made throughout the thesis to test and strengthen the main issues and arguments in each chapter by reference to case study material. Yin (1984) considers that a case study approach is preferred when "how and when" questions are being posed, and when the focus is on contemporary phenomenon with some real-life content and where behaviours cannot be manipulated. He sees the case study's strength as being the ability to uniquely deal with a full variety of evidence, documents, artifacts, interviews and observations. It is felt, therefore, that the advantages of a case study approach are ideally suited to a research project of this nature. The use of case studies as a research method is not without criticism however, and it is important to be aware of the limitations of such a strategy.

A criticism of quantitative research generally and case studies in particular, is the limited degree to which findings can be generalised to other or larger populations (Bryman, 1988;

Schofield, 1993). Lack of rigour and researcher's bias are other criticisms that have been levelled at case study methodology (Yin, 1984). The counter argument is that although the generalisation of case study data to larger populations is inconsistent with the requirements of statistical sampling procedures, such information can be legitimately used to expand and generalise theories (Yin, 1984). Schofield (1993) believes that the goal is not to produce a standardised set of results that can be replicated by others with the same set of circumstances. Rather it is to produce a coherent description of and perspective on a situation that is based on and consistent with detailed study of that situation. It is impractical to make precise replication a criterion of generalizability in qualitative work.

On the issue of generalizability in qualitative research, Schofield (1993) detects that a consensus appears to be emerging. She considers that this concept is best thought of as a matter of the "fit" between the situation studied and others to which one might be interested in applying the concepts and conclusions of that study. She stresses the need for "thick descriptions" so that an informed judgement about the issue of fit can be made.

The importance of rigour in qualitative research is examined in more detail in Section 3.7 below.

As outlined in Section 3.5 above, case study material underpinning the project is taken from the Thames Region. The Thames basin (see Figure 1.1) has a wide range of river catchments and communities at risk of flooding, with a significant flood event occurring somewhere in the catchment on average three times per year. Although the Thames basin covers an extensive area of southern England it does have some limitations when studying flood warning arrangements. For example, with the exception of the Thames Tideway in London, all rivers in the catchment are fluvial and there is an absence of steep, upland rivers. Nevertheless, the region does have a mixture of urban and rural catchments and communities, and fast and slow responding rivers that are subject to flooding from winter and summer storms. Another reason for selecting this catchment is because it is the area in which the researcher has worked since 1975, he currently manages the flood warning service, and has an intimate knowledge of the rivers and areas at risk of flooding. Within the Region, the researcher is able to draw on a range of examples of different catchment types, organisations and communities to bolster analysis and arguments throughout the project. An example would be the Mimmshall Brook catchment that was selected for an in-depth case study.

The Mimmshall Brook is a tributary of the River Colne in south Hertfordshire and drains a catchment area of 53 km^2 (see Figure 1.2). The Brook has a history of flooding with records stretching back to 1928, and it has been estimated that 55 properties are at risk of flooding from a 100-year flood, mainly in the lower reaches. Although flooding has occurred relatively frequently (16 recorded flood events in the last 70 years), official flood warning arrangements have been rudimentary. This offers a good opportunity to study a community that has lived with a flood hazard for many years, has to some extent organised its own affairs in relation to flood warning in the absence of a credible official service, and where there is scope for introducing improvements to flood warning arrangements in an integrated way.

The community is relatively stable and is made up of professional and skilled homeowners, residing in a mixture of bungalows and semi-detached and terraced houses in the Warrengate Road and Water End areas of North Mimms. Many of the residents are elderly and retired, but the frequency of flooding means that the community is acutely aware of the flood risk. They have an active residents association that has been agitating for a structural flood alleviation scheme to reduce the risk for many years. This community institution formed a useful vehicle with which to establish an enhanced official flood warning service.

The obvious advantages of studying such a community are balanced by the fact that it is unlikely to be typical of the "average" community at risk of flooding in the Thames catchment. To address this issue, reference is made throughout the thesis to work carried out with other communities to develop improved flood warning arrangements. These communities have a range of flooding experiences dictated by differing flood risk, are of varying social make-up and are located in rural, urban and suburban environments. By such an approach it is intended to give a more balanced picture of the issues arising from implementing a more integrated flood warning service in the Thames Region.

3.7 Validity and reliability

One of the criteria for judging the quality of research is an assessment of its reliability and validity (Henwood and Pidgeon, 1993). Reliability refers to the degree of consistency found in research findings, whereas validity is the extent to which the finding accurately represents the situation to which it relates (Hammersley, 1992).

Baxter and Eyles (1997) stress the importance of rigour in qualitative research and consider that this can be achieved through the satisfaction of validity, reliability and objectivity. They refer to a set of criteria that may be used to evaluate the rigour of research that were first proposed by Lincoln and Guba (1985), and these are summarised in Table 3.1.

Yin (1984) has refined these concepts further with particular reference to case study methodology. Yin refers to four tests that should be undertaken to ascertain the quality of research, and suggests how these tests can be applied to case study work (see Table 3.2). In this project a conscious effort has been made to try and ensure that the research is both valid and reliable. Using the criteria set out in Table 3.2 (after Yin (1984)) as a framework, a number of strategies have been adopted.

By using **multiple sources of evidence** collected using a variety of techniques the validity of the research was constructed. This was achieved through techniques such as direct and participant observation, interviews, assessment of empirical data, official and unofficial reports, and attendance of national and international conferences. A **chain of evidence was established** through the maintenance of a journal or notebook in which research findings were detailed, and through the review of draft papers by peers. **Internal validity** was secured through **pattern matching** between the work of the researcher and that of others working in the field. **Explanation building** has been attempted through the presentation of a conceptual model of the flood warning process, outlined in Section 3.4 above. This has allowed the causal links between the variables or elements to be explained in some detail. **A time-series analysis** of flood warning data held by the Environment Agency from 1975 to the present day has been undertaken and this information has been collated into a database (Appendix 1). This allows casual relationships between the flood warning system elements to be better understood.

Table 3.1: Criteria for evaluating qualitative research (after Lincoln and Guba, 1985)

Criteria	Definition	Strategy
Credibility	Authentic representations of experience	• Purposeful sampling • Disciplined subjectivity • Prolonged engagement • Persistent observation • Triangulation • Peer debriefing • Referential adequacy • Member checking
Transferability	Fit within contexts outside the study situation	• Purposeful sampling • Detailed description
Dependability	Minimisation of idiosyncrasies in interpretation, variability tracked to identifiable sources.	• Mechanically recorded data • Multiple researchers • Participant researchers • Peer examination • Triangulation
Confirmability	Extent to which biases, motivations, interests or perspectives of the inquirer influence interpretations.	• Audit trail products • Detailed description of the audit process • Autobiography • Journal/notebook

Table 3.2 Validity and reliability (after Yin, 1984)

Tests	Definition	Strategy
Construct validity	Establishing correct operational measures for the concepts being studied.	• Use multiple sources of evidence • Establish chain of evidence • Have key informants review draft reports
Internal validity	Establishing causal relationships, whereby certain conditions are shown to lead to other conditions, as distinguished from spurious relationships	• Do pattern matching • Do explanation building • Do time-series analysis
External validity	Establishing the domain to which a study's findings can be generalised.	• Use replication logic in multiple-case studies
Reliability	Demonstrating that the operations of a study can be repeated, with the same results.	• Use case study protocol • Develop case study database

External validity and transferability is achieved by recognising that a single case study offers a poor basis for generalising. As Yin (1984) stresses, a theory must be tested through replications of the findings in a second or even a third area. Once such replication has been made, the results can be applied to a much larger area with more confidence. This replication logic was followed in this study by reference to a number of different areas in the Thames catchment. By necessity however, this study draws on research based on different hazards, different time periods, and different institutional and cultural backgrounds, and caution is needed when using derived data and conclusions in the UK context. This caution must be held in the background throughout this thesis. **Reliability** has been strengthened through the regular comparison of research findings with those presented by other workers to determine the degree of consistency.

3.8 Sources of information/data collection

A range of data collection techniques was used in this study, including information from primary and secondary sources. It was felt important not to rely on single sources of information and wherever possible to utilise data from different sources. As Yin (1984) describes, such an approach allows for the development of convergent lines of enquiry, a process of triangulation. Corroboration of findings is likely to be much more convincing and accurate. Accordingly, for the purposes of this study, information was gathered from the following sources:

1. The published scientific and other literature.
2. The Environment Agency and other relevant organisations, including unpublished reports, procedures, environmental and other data, expert opinion, operational experience and observation.
3. Case study material from across the Thames basin, including the Mimmshall Brook catchment.

Interviews

One of the most important sources of information was the interview. Semi-structured or open-ended interviews were most commonly adopted where key respondents were asked for the facts of a matter as well as their opinions about events. A commonly used technique was to ask the respondent to propose his or her own insights into certain matters and to use such propositions as the basis for further inquiry. As Yin (1984) suggests, the more a respondent assists in this manner, the more that the role may be considered one of an "informant" rather than a respondent. Key informants are often critical to the success of a case study and can often suggest sources of corroboratory evidence. Such informants were found not only in local communities but also in the Environment Agency and other organisations. It is important, however, not to become overly dependent on such informants and to seek out other sources of evidence as far as is possible.

Interviews were conducted mostly on a face-to-face basis, but occasionally short interviews were carried out using the telephone. Detailed notes were taken during each interview and written up in full following their completion.

The professional network was an important source of information and contact with key informants within and beyond the Agency took place at varying frequency. A deliberate attempt was made to capitalise on the researcher's position as an insider and to utilise the professional network available to him. The benefits of this approach were significant in that it gave access to views and opinions not normally available to researchers. The disadvantage was that formal sampling methods were not used, but in this context they may well have been limiting. It was felt that a more action-orientated approach made best use of the openings and resources available to the researcher. In practice, interviews were conducted as part of the researcher's normal course of duty through group meetings and face-to-face discussions. New ideas emanating from this research project were purposely injected into the debate and this generated a stream of responses (and hence data) from managers, colleagues and peers.

Questionnaires

In one instance a questionnaire survey was undertaken among seven flood warning practitioners in the Thames Region. This was designed to identify possible differences in intuition, perception and interpretation between flood duty officers. The questionnaire that was used in the survey is presented in Appendix 4.

Archival Records

Archival information was a vital data source in this study. A previously untapped archive of flood event and flood warning data became the object of extensive retrieval and analysis. The archive extends back to 1975 and includes information on 80 flood events where formal flood warnings were issued in one form or another. The researcher, following participation in the management of the events in fact wrote many of the reports contained in the archive. The information was collated into a database and it was important to retrieve not only data on the magnitude and hydrological significance of flood events, but other aspects such as institutional arrangements, behavioural information and operational effectiveness. This was gleaned from transcripts of duty officers' logs, correspondence, and newspaper cuttings, etc. The retrieval exercise also triggered many facts from the researcher's memory that had not been written down at the time. The database is presented in Appendix 1 and information from this was used to support the case study material and strengthen arguments throughout the thesis.

The researcher is aware, however, that the accuracy of archival evidence is not always as high as it might appear and some caution is needed when interpreting such evidence.

Documentation

Documentary information was very relevant to this study. The following types of document were referred to at various stages:

- Letters, memoranda, and other correspondence held by the Environment Agency and other bodies.
- Minutes of meetings, written reports, and newsletters.
- Formal studies or evaluations of the same sites under study made by the Environment Agency and research bodies.
- Media articles in newspapers.

Although these documents were extremely useful to the study, it was recognised that they should not necessarily be accepted as literal recordings of events or that the information contained lacks bias. The documents were used mainly to corroborate and augment evidence from other sources. If the documentary evidence was contradictory, however, it did point to the need for further inquiry into the topic concerned.

Although documents held by the Environment Agency were freely accessible to the researcher, documentation from other sources was found to be particularly valuable. The researcher did, for instance, ask to be placed on the mailing list for community newsletters that provided useful insights into the perspectives of local people on matters such as flooding and flood warning in the area concerned.

Direct Observation

Observational evidence can be used to provide additional information about the topic being studied. As Yin (1984) suggests, if the study involves the use of technology, for instance, observations of the technology at work are invaluable aids to the further understanding of the limits or the applicability of the technology. Similarly, observations of a community or an organisation can add new dimensions for understanding. Baxter and Eyles (1997) stress the importance of building rapport and trust with the respondents. They suggest using this to develop "information-rich" conversations that can help shape the data gathered and to gain an understanding of perceptions.

The techniques used in this study were both formal and informal, with greater emphasis placed on the latter than the former. Within the Environment Agency this included detailed observation of operational activities, both before and after changes made as a result of this research work. This occurred during actual flood events and during pre-planned exercises, at meetings, and through ad-hoc discussions with key informants. Within communities and other organisations the techniques included formal meetings, ad-hoc discussions with key informants (both during "normal" times and during and after flood events), attendance of public meetings, and site visits. Observation was not always through conversation and discussion, the ability to stand-back and watch others operate without interference was found to be important. Peer debriefing was also found to be useful, whereby data and interpretations were exposed to respected colleagues for comment.

Participant observation

Yin (1984) defines participant observation as a special mode of observation in which the researcher is not merely a passive observer. Instead, the researcher may take a variety of roles within the study and may actually participate in the event being studied. The researcher's role as manager of the flood warning function meant that this technique was one of the dominant ones used in this project. Yin goes on to say, however, that such observation provides certain unusual opportunities for collecting study data, but it also involves major problems. The most distinctive opportunities can be defined thus:

- The ability to gain access to events or groups that are otherwise inaccessible to scientific investigation.
- The ability to perceive reality from the viewpoint of someone "inside" the study rather than external to it.
- Opportunities arising from the researcher's ability to manipulate events or situations.

The major problems involve the potential biases produced. The researcher has less ability to work as an external observer, may become overly supportive of the organisation for which he or she works, and may find combining the participant and observing roles too demanding. These aspects have been discussed in detail in Section 3.3.

In this study, the researcher's position gave him the flexibility to legitimately influence staff under his direct supervision. He was able to persuade staff to focus, in more depth than would normally be required, on the key issues under consideration in this project whilst carrying out their normal duties. This helped broaden the information gathering process. He is also in frequent contact with flood warning managers in the other seven regions of the Agency and at Head Office, giving a good opportunity to canvass opinion and influence policy.

As a Flood Duty Hydrologist, the researcher is responsible for operating the flood warning system and was able to pay special attention to the service provided to communities in the study areas. He was able to gain first hand knowledge on how arrangements were functioning and, by interacting with the relevant communities and organisations during flood events, was able to gain a clear understanding of their perceptions and needs.

Secondary sources

The researcher compiled a range of information for the areas under study in the Thames catchment. This included hydrological, geological, meteorological, and socio-economic details that are summarised in Appendix 1. Data was also collated on flooding histories from sources within the Environment Agency, local authorities and local communities. Discussions with older residents were particularly useful in supplementing official records.

The researcher also gained valuable information and fresh perspectives from attending national and international conferences and workshops during the period of study. The most relevant conferences are listed below:

1. NATO Advanced Scientific Institute on Flood Defence and Flood Plain Management. Budapest, Hungary. May 1994.

2. International Conference on Hydrological Applications of Weather Radar, Sao Paulo, Brazil. August 1995.

3. International Workshop on Flood Warning: Issues and Practice in Total System Design. Middlesex University, September 1995.

4. Conference on Flood Warning Systems, Technologies, and Preparedness. Second national conference of the US National Hydrologic Warning Council. St Louis, Missouri, USA. October 1997. Follow-up visit to Urban Drainage District, Denver, Colorado – tours of operational and research facilities.

5. International Conference on Hydrological Applications of Weather Radar, San Diego, California, USA. April 1998.

6. Workshop on Social and Institutional Responses to Climate Change and Climatic Hazards, Middlesex University, March 2000.

3.9 Limitations of research methods

The main limitation to the research work carried out in this study was time. Although the researcher is working in the flood warning field, undertaking a part-time PhD does result in some quite severe time constraints.

During the period of study, the Environment Agency went through extensive organisational change that impacted on the researcher in a number of ways. These can be summarised as follows:

- Time that could have been allocated to research work was invariably taken up with organisational issues – both inside and outside office hours.
- The loss of staff and continuity in the Flood Warning Team resulted in disruption to the operational effectiveness of the service.
- Organisational change had a negative impact on the efficient working of the flood warning service.

Although case study material was taken from across the Thames Region, in-depth analysis was limited to the Mimmshall Brook catchment in Hertfordshire. With extra time it would have been desirable to carry out more in-depth studies in other river catchments. This would have allowed a greater analysis of communities with differing social attributes, and river catchments with differing hydrological responses and land-use.

The advantages and disadvantages of being an "insider" have been discussed at length in this chapter. The Environment Agency is essentially a positivistic organisation and adopts a quantitative approach to scientific issues. One limiting aspect of this approach is that it is easy to become trapped into this positivist mind-set and to step outside this "box" without bias can be difficult. Consequently, the researcher encountered a certain amount of prejudice from colleagues who questioned the validity of the more qualitative research methods adopted in this study which were considered by some to be less relevant and less worthy. The very fact that the research approach generated a certain amount of hostility was considered to be a positive factor and confirmation that the researcher was developing alternative values and challenging the status quo.

3.10 Summary

The research philosophy and approach, framework and design, and methods used in this project have been outlined in this chapter. The ongoing epistemological debate within the social sciences has been recognised, as has the relative benefits and disadvantages of conducting quantitative and qualitative research. The importance of obtaining multiple sources of evidence to ensure validity and reliability is also understood.

It is clear that the approach and methodology adopted in this research project are influenced by the unique position in which the researcher finds himself. Occupying the post of manager of the flood warning service in the Thames Region of the Environment Agency offers particular advantages in terms of access to information, staff expertise and operational know-how. This coupled with the length of experience in this field, gives the researcher particular insight into the problems associated with the provision of an effective flood warning service. There are dangers however, in being too close to the issues resulting in a possible lack of impartiality and objectivity, and these problems have been recognised and discussed in this chapter.

The research methods used in the project centre around the use of semi-structured interviews, both with staff and experts in the field and the general public in flood risk areas. This allowed the researcher to blend his own views with those of others, be they "experts" or lay-people living in at-risk communities. A conscious effort was made to view the issues from the perspective of different disciplines and to gain insight into how people in local communities perceive the issues surrounding flood warning provision. Another key element is the interpretation of views and opinions of workers in academia by an operational practitioner, and the ability to test certain theoretical ideas in an operational environment. Other techniques adopted were the analysis of archival material and other documentation, direct observation and participant observation.

The analytical framework is based on the key concept of integration and an assessment of whether an integrated system is more efficient than a more disparate arrangement. The aim is to identify a suite of integration factors that can be universally applied to flood warning systems. The approach is presented by means of a conceptual model that is described in this chapter and forms a framework for the other chapters in the thesis. Case studies offer a useful way to test the model and gain feedback from local communities on the effectiveness of the approach.

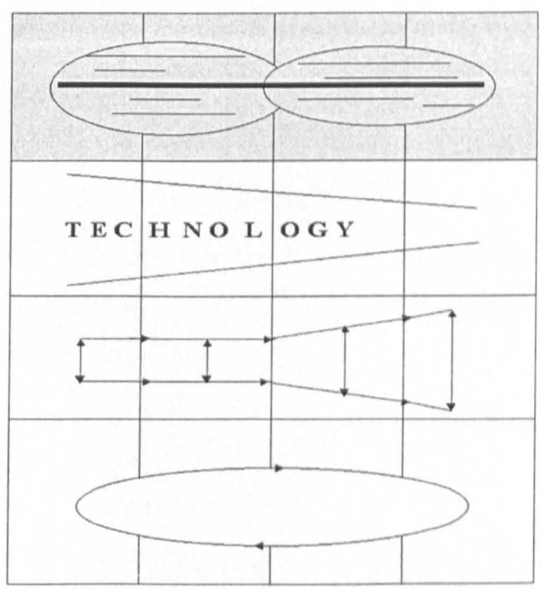
Chapter 4

Institutional and Legal Arrangements

4.1 Introduction

This chapter addresses the first element of the conceptual model presented in Chapter 3 (shaded area in Figure 4.1). It examines the influence that institutions and the law have had on the integration of flood warning systems in England and Wales in general and in the Thames catchment in particular. The recent evolution of legal and organisational arrangements is analysed and an assessment given on how these arrangements help or hinder the integration process. Recommendations for change and improvement are presented, based on the factors outlined in Chapter 2 of this thesis, and modifications are suggested to further enhance flood warning integration. Reference will be made to organisational and legal arrangements before and after the 1 September 1996 when significant changes were introduced in England and Wales, and how these arrangements have operated in practice, particularly during the severe floods of Easter 1998. Arrangements will be examined at both the national and regional scale, using the Thames Region as a case study.

Figure 4.1: Conceptual model of the FDFWR process



(see Chapter 3 for full details)

4.2 The legal framework covering flood warning

As detailed in Appendix 3, the Environment Agency (and its predecessors) is the only organisation empowered by legislation to establish and operate flood warning systems. The legislation focuses very firmly however, on providing powers to install equipment to detect storms and floods. Critically for the development of an integrated approach, the issue of flood warning dissemination has not been specifically addressed in the statute and reliance has been placed on voluntary agreements between the Environment Agency (and its predecessors), local authorities and the emergency services. These agreements were first established across England and Wales in 1968 following severe floods in that year, prior to that only ad hoc procedures existed for some river catchments. The informal and co-operative agreements remained virtually unchanged for almost 30 years and have worked well in the past, even with the evolution of local variations.

The establishment of the Environment Agency in 1996 gave the Government the opportunity to strengthen the legal position, but the enabling Environment Act of 1995 did not address the issue and merely consolidated previous legislation. The Government did recognise however, that voluntary arrangements between the key players were not functioning as well as they should and that there was a need for greater clarity in defining roles and responsibilities. The progressive deterioration in arrangements was due in part to tightening resource constraints, growing concerns over legal liability and a failure to formalise procedures between organisations. Accordingly, arrangements for flood warning dissemination were modified by means of a Ministerial Direction under Section 40 of the Environment Act. This required the Environment Agency to take the lead role from 1 September 1996 and to "take steps as appear to it to be reasonable and practicable to provide warning of any danger of flooding". The Direction relates to the manner in which the Agency provides a flood warning service when it elects to exercise its permissive powers and not to a strengthening of those powers i.e. into a statutory duty. The legislation relating to other organisations involved in flood warning and response remained unchanged.

4.2.1 Critical assessment of the legal framework

The legal framework covering flood warning and flood response presents a number of severe integration problems. This framework seemed adequate in the 1960's when resources in the organisations concerned were sufficient to meet the contingencies of the service. When resource constraints were placed on these organisations however, the informal co-operative arrangements that had developed between them started to break down. This situation has been compounded over the last decade by a growing fear of legal liability both in organisations generally and specifically following the "Cardiff Judgement" (see Appendix 3). The reaction of many organisations to these issues has been to minimise involvement in activities that are not designated as statutory duties and this can include flood warning and flood response. There is also the added danger that some authorities may use the excuse of the fear of legal liability to withdraw from selected functions.

The legislation itself focuses on the provision of equipment to detect and forecast flooding. The arrangements needed to disseminate warnings and to ensure public awareness are not explicitly addressed. Similarly, the Government's grant-aid policy for flood warning supports the provision of new capital equipment and gives less attention to the social and environmental aspects of flood warning. There is an in-built bias therefore, towards the financing of equipment that tends to favour the development of detection and forecasting systems often at the expense of the dissemination and response elements. This is a legacy from the original legislation that was drafted in the 1970s and highlights the need for review at appropriate times such as when new legislation is being drafted. Without modification, the Government's grant-aiding procedure will continue to work against the integration of flood warning systems and may indeed lead to greater fragmentation.

The law relating to flood defence responsibilities perpetuates fragmented arrangements that impact on flood warning. In particular, there is distinction in law between main and non-main river (ordinary watercourses) and a complexity of arrangements regarding coastal matters. So, although the general supervisory duty for flood defence falls on one organisation, the Environment Agency, the management of flood defence varies depending on the designation of the watercourse, resulting in very fragmented arrangements across the country. The Agricultural Select Committee (1998) found these arrangements to be confused, outdated and incapable of delivering effective policies. It recommends the rationalisation of the legislative base of flood and coastal defence policy and sets out the following proposals for change:

- the introduction of integrated management of flooding issues for main rivers and non-main rivers, with responsibilities transferred from local authorities to Regional Flood Defence Committees.
- the introduction of integrated management of flooding and erosion issues at the coast, with all responsibilities transferred from local authorities and Regional Flood Defence Committees to coastal groups.
- strategic direction to be given by the Ministry of Agriculture, Fisheries and Food (MAFF), with the Environment Agency responsible for all flood and coastal defence issues in an advisory and supervisory role, and implementation of policy executed at a regional level through Regional Flood Defence Committees and coastal groups.

It remains to be seen if the Government will act on these recommendations. Indeed, the Government has had ample opportunity to strengthen the legal framework covering flood warning activities but has chosen not to act. The new flood warning dissemination role of the Environment Agency for instance, is only formalised by a Ministerial Direction that directs the Agency to use its **permissive powers** and liaise with a limited number of external organisations. Several reasons have been suggested for this minimal action on the part of the Government, but an overriding factor must be the unwillingness to fund an increased demand for resources that will inevitably follow the replacement of the Agency's permissive powers with statutory duties. Without this strengthened legal framework however, institutions will continue to give priority to other areas and functions where duties are required by statute and this can result in severe integration problems.

The Ministerial Direction has in fact placed the Environment Agency in a difficult situation. The Agency has not been given extra (long-term) financial resources to implement the Direction and has undertaken this work by rescheduling its existing flood defence programme. It can be argued, therefore, that the Agency is not adequately resourced to offer a total flood warning service across England and Wales to the estimated 1.6 million households at risk. At the same time, the Direction has provided other organisations with an excuse to opt out or reduce their involvement in flooding issues and to focus their limited resources on other matters. Indeed, the Agency has experienced some difficulty in getting local authorities and police forces in particular, to address the issues surrounding flood warning and response with any priority. Many have the mistaken view that these issues are now totally in the domain of the Agency. In London, for example, no organisation is taking the lead in the development of a strategic flood plan for the city. The lack of guiding legislation and national standards are given as mitigating reasons. Some authorities mistakenly think it is the Agency's role to develop major incident response plans for floods. Confusion such as this leads to inaction and "buck passing" that can block the implementation of an integrated system.

The media has an important role to play in flood warning dissemination and the Agency has begun to work much more closely with a range of media outlets, especially local radio and television stations. Although most stations are keen to broadcast flood warning information, there is no guarantee that for a given flood event that this will take place and there is a general reluctance on the part of the broadcasters to relinquish editorial control. This can result in the Agency becoming less reliant on these outlets and this in turn impacts on the establishment of a multi-channelled warning system. There is no statutory duty placed on the media to broadcast flood warning notices and this forces the Agency to enter into voluntary agreements with large numbers of individual media companies, resulting in fragmented dissemination arrangements. This contrasts with arrangements in the United States where media stations have an obligation to transmit warning messages written into their operating licences which is far more conducive to integration. The Agriculture Select Committee (1998) states "we were particularly surprised that it was not already obligatory for all local public and commercial radio and television stations to carry flood warnings on air, and would urge MAFF to make this a requirement in future".

For an integrated flood warning system to operate effectively therefore, there is not only a need for the legislation to address the total warning process, but to also clearly define the roles and responsibilities of relevant authorities and the mechanisms for resolving conflict that may arise between them. The authorities that are relevant to this process extend beyond the Environment Agency, local authorities and the emergency services (referred to in the Ministerial Direction) and should include organisations such as the media, the Met Office, utility companies and even the insurance industry. The laws that govern these different organisations need to be reviewed to ensure that they are compatible and not contradictory and there is a need to ensure continued political support and resources to underpin the principles of integration. These aspects will be analysed in more detail later in this chapter.

4.3 Assessment of the institutional framework in England and Wales prior to September 1996

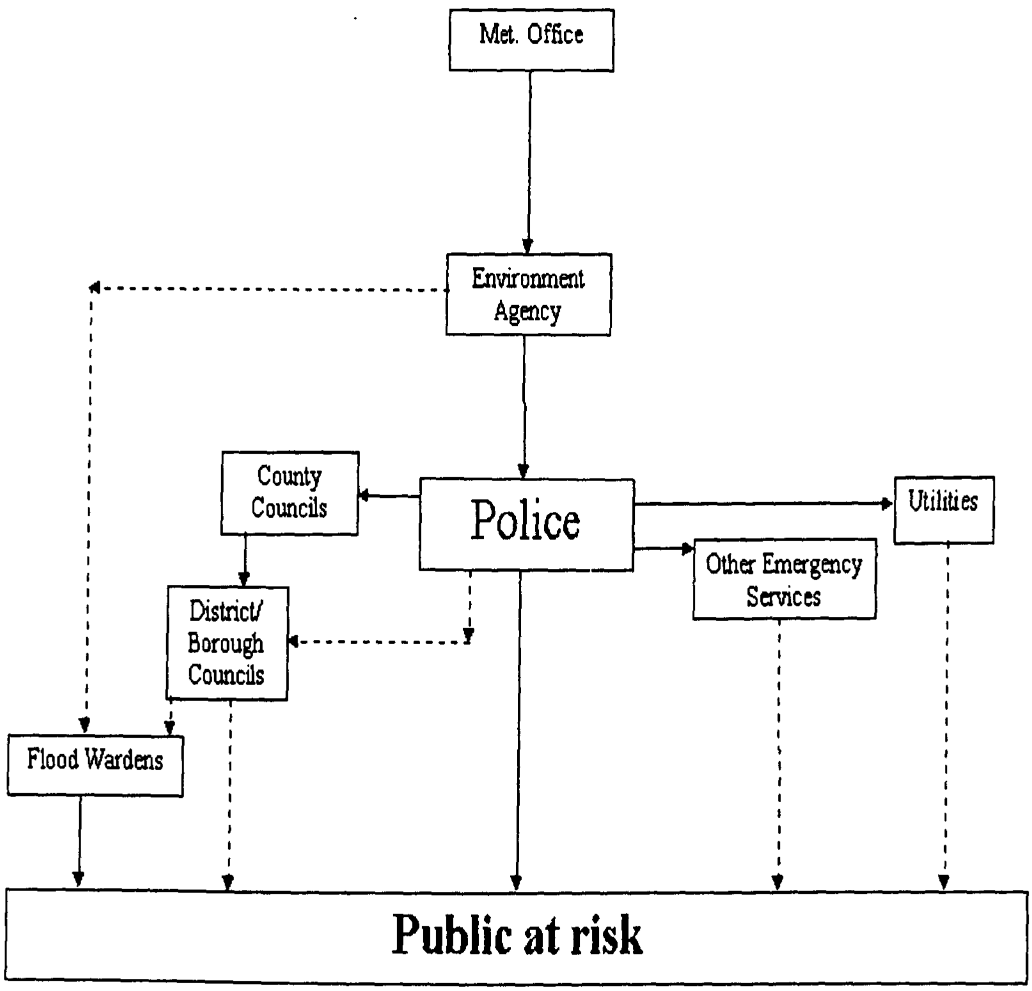
Parker et al (1995) comment that although flood warning systems in England and Wales have reached a relatively mature level of development, legal and organisational weaknesses are undermining their effectiveness and integration. As outlined in Appendix 3, prior to September 1996 national policy towards flood warning dissemination relied on voluntary liaison between the then National Rivers Authority, the police, local authorities and others (see Figure 4.2). This voluntary arrangement that had been a strength in the past however, was proving to be a central weakness. One of the main problems was uncertainty over precise roles and responsibilities. Under these arrangements, none of the relevant agencies had a clear statutory duty to issue and disseminate flood warnings. This non-statutory approach came under severe pressure as local authorities and the police faced tighter budgets and an increasing array of statutory duties. In many cases both the police and local authorities had retreated from their "responsibilities", encouraged by perceived legal liability hazards, and the flood warning dissemination system was in severe danger of breaking down altogether. Parker and Penning-Rowsell (1991) believe that non-statutory co-operative arrangements are not conducive to integration and tend to degrade over time, particularly during periods of financial stringency, making statutory arrangements necessary for effective service delivery.

In 1989 Parker stated that the administrative arrangements that encompass flood warning systems needed overhaul and improvement and that additional legislation may be necessary in order to secure improvements in the effectiveness of these systems. He put forward a case for change and identified that the lack of statutory duties and the relative immaturity and embryonic nature of English law as being limiting and counter-productive. The main defence of the current legal framework is that it is preferable to avoid tightly defining the roles and statutory responsibilities of each agency within the warning dissemination chain. This may lead to strict role and responsibility demarcation, thus discouraging discretionary use of powers which, it is argued, is essential during periods of uncertainty, such as flood emergencies, when the nature of the threat may be difficult to define, or unexpected circumstances may arise. Parker (1989) argues that discretionary powers can lead to problems, including lack of clarity about liability. Without statutory duties being defined the closest attention will always be focused on priorities where there are statutory duties. Parker believes that this is leading to insufficient priority being given to planning for peacetime emergencies, such as floods including the dissemination of warnings. If flood warning systems are to become more effective and integrated then more defined liability, including the clearer statutory definition of roles and responsibilities, is required.

Another key requirement for integration is periodic review of legislation underpinned by sustained political commitment. As discussed in Section 4.2, despite opportunities presented by the Water Act 1989, the Water Resources Act 1991 and the Environment Act 1995, successive governments have chosen not to modify the legal arrangements relating to flood warning. With regard to political commitment, governments continue to send out mixed signals. While the Ministry of Agriculture, Fisheries and Food places the provision of adequate and effective flood warning systems at the top of its priority list, the Home Office, which administers civil defence and police policy, has a quite different outlook. Over the last three years, the Home Office has reduced civil defence expenditure by a third, and has been actively encouraging the police to focus on law and order issues and reduce their involvement in "peripheral" activities, such as flood warning dissemination. All these factors have helped to constrain the integration of flood warning systems.

Just prior to 1996, the then National Rivers Authority had attempted to put pressure on local authorities and the police to continue to disseminate the flood warning notices they issued by articulating what they saw as being current practice in local flood warning procedures. It was felt that by setting out the perceived roles and responsibilities of the agencies involved, the flood warning dissemination process would be clarified and would, as a consequence, function more effectively. The police and local authorities rejected this approach however, because they did not accept that at that time the NRA had a co-ordinating role and they feared that responsibilities would be placed upon them for which they may become liable.

Figure 4.2: Organisational arrangements prior to September 1996



Another issue that has had a negative impact on the integration of flood warning arrangements over the years is that of organisational boundaries. Although the boundaries of local authorities, police and other emergency services generally (but not always) coincide, those of the Environment Agency and its predecessors, which are based on river catchments, are unique to those organisations. Add to this the differing boundaries of organisations such the Met Office, utility companies and the media, then it is easy to see how this issue can make integration between organisations difficult to achieve. The establishment of unitary local authorities in certain areas and the formation of new utility companies have compounded this problem. The number of organisational boundaries in the Thames Region alone has been estimated at 157 (see Table 4.1). This is almost certainly an underestimate, as it only includes those organisations that are currently in receipt of flood warning notices from the Agency and does not include the many internal boundaries that exist within these organisations.

Parker et al (1989) draw attention to the importance of the organisational culture that surrounds flood warning systems. Generally they found organisations to be co-operative and interested in developing effective flood warning arrangements. In the years leading up to 1996 it was noticeable however, that public agencies began to carefully delimit their participation, in some cases withdrawing services previously provided. This created gaps or seams in flood warning dissemination and response procedures leaving the flood prone with a greater burden of poorly appreciated responsibilities for protecting their own property.

Table 4.1: Number of Organisational Boundaries in the Thames Region

Organisations in receipt of flood warning notices	**Number of non-coincident boundaries**
County Councils	11
London Boroughs + City of London	33
District Councils	54
Police Forces	7
Fire and Rescue	1
Ambulance	0
Utility Companies (water, gas, electricity, telephone, rail)	14
Navigation Authorities	5
Weather Centres	7
Local Radio Stations	14
Other Media Outlets	7
Environment Agency	4
Total	**157**

In general, therefore, the legal and organisational framework that existed prior to September 1996 was not particularly conducive to integration. In this section the main areas of concern have been identified and a number of recommendations for change and improvement can be made:

- The reliance on non-statutory co-operative arrangements between organisations is not satisfactory in the long-term. As Parker (1992) puts it, the legal "fog" surrounding responsibilities for flood warnings requires the attention of legislators. The legislation should be clarified and the respective roles and responsibilities of the relevant agencies should be clearly delineated. The counter argument that tightly defined roles and responsibilities may discourage the discretionary use of powers during flood emergencies does not hold up in practice, especially during times of financial stringency. Organisations will always give priority to their statutory duties and this is one reason why the voluntary arrangements encompassing flood warning have degraded over time.
- There is a need to review and update legislation at appropriate junctures. The legislation covering flood warning systems was originally written in the 1970s and has been repeatedly assimilated into successive acts without substantive change. For integration to flourish there is a continuing need to revisit and update legislation and for laws governing different organisations to be made compatible.

- A key requirement for integration is sustained political commitment to the function in question. Flood warning has enjoyed mixed support from Government over recent years, with MAFF, for example, placing the function at the top of the priority list in its flood defence programme, but at the same time the Home Office has reduced civil defence budgets and encouraged police withdrawal from activities other than those linked to law and order. This inconsistent approach has placed strains on the service and the institutional framework that has hindered the process of integration. There is clearly a need to resolve the ambiguous policy stances of different government departments to ensure that flood warning systems are cultivated and sustained.

- An area of concern is the lack of effective fora that allow organisations to formally liaise and clarify objectives, roles and responsibilities, and the lack of detailed written plans that document these arrangements. Prior to 1996, the NRA attempted to address this issue on a number of occasions but with limited success due mainly to the lack of acceptance on the part of the local authorities and the police that the NRA had a co-ordinating role. This underlines the need for a designated lead agency that is accepted by all parties and capable of co-ordinating and improving the integration of organisational activities.

- There is a need for government agencies and local authorities to reach out to the media and to cultivate professional and personal relationships over time. By creating partnerships with the media the effectiveness of warning dissemination and public awareness campaigns can be increased. As Burkart (1991) mentions, the various media outlets can integrate different elements to meet the needs of the community in a hazard situation. By allowing public sector emergency managers to relay messages to mass audiences, the public receives information from the media which carries the status of official warnings and of unofficially, independently gathered and filtered news.

- The plethora of organisational boundaries is not conducive to integration and a greater effort is needed to minimise the impact of this issue by arranging procedures around boundaries that have the most commonality.

- Finally, importance should be attached to the development of a positive organisational climate and culture in agencies involved in flood warning activities. Just prior to 1996 a very parochial climate had prevailed with many organisations attempting to distance themselves from direct involvement on the pretext of legal liability fears and resource constraints. Integration requires a more positive approach but this will not be forthcoming until organisations have a clearer view of their roles and responsibilities.

4.3.1 Critical assessment of the pre-September 1996 arrangements in the Thames Region

From details set out in Appendix 3, it is clear that institutional arrangements in the Thames Region prior to 1996 exhibited few signs of being well integrated. To assess the degree to which integration is present, it is important to ascertain how many of the factors, identified in Chapter 2, were met in practice prior to 1 September 1996.

1. The first factor requires the securement of political commitment, establishment of clear objectives, definition of roles and responsibilities, preferably in a written plan, and agreement on rules for conflict resolution. Few if any of these requirements were in place in the Thames catchment. Roles and responsibilities were not adequately defined and attempts at clarification had largely failed. This left confusion in the minds of the organisations themselves and ultimately the general public as to who does what. The NRA produced written procedures outlining arrangements as it understood them, but failed to secure a consensus on the content. It can be argued that one of the main reasons for this failure was the lack of political commitment within the agencies involved and the refusal to accept that the NRA had a mandate to produce such a document. The NRA found itself in conflict with local authorities and the police in certain counties and this escalated as rules for conflict resolution were not in place, another prerequisite for integration (see Appendix 3 for details).

2. The second factor requires the establishment of functions and structures to foster integration and consideration of the designation of a lead agency. Institutional arrangements concerning flood warning in the Thames catchment were established in 1968 and had not been revised to any great extent since that time. As has been discussed in Section 4.2, no one agency was given a lead role to co-ordinate activities across the function. Each of the agencies involved was allocated a general area of responsibility and allowed to organise their organisational structures to suit their operational circumstances. Cross-functional integration was not given a high priority. The NRA recognised the need for a co-ordinating agency however, especially in the areas of planning and management, but was unable to gain the acceptance of other organisations when it attempted to carry out this role.

3. The third factor requires the establishment of fora to facilitate liaison, negotiation and mediation between agencies. In the Thames Region consultation between organisations had been mainly confined to annual Flood Warning Seminars hosted by the NRA. The NRA viewed the seminars as a means to remind the local authorities, police and other emergency services of the flood warning procedures and to update them of progress in flood detection and forecasting capabilities. Although a period of open discussion was allowed for, the seminars were not designed for close inter-agency liaison on matters of detail. Some local authorities, for example, had explicitly

stated that they did not accept that the seminars were the correct forum for consultation on matters such as flood warning procedures.

4. The fourth factor requires the instillation of a positive organisational climate and culture for integration. In the years leading to 1996 pressures on resources, confusion over roles and responsibilities and concerns about legal liability had conspired to develop a parochial attitude within many organisations involved in flood warning. This has created real barriers to integrated and co-operative effort. Many authorities had become inward looking and much energy was being devoted to minimising involvement in an attempt to reduce the risk of litigation and the commitment of resources. Some organisations however, continued to adopt an open and co-operative policy and this can often be traced to a small number of dedicated individuals who have built up a positive culture within their respective organisations. In the Thames Region a limited number of local authorities and police forces fall into this category and as a consequence have developed good flood warning and response arrangements in their area, but prior to 1996 this was increasingly the exception rather than the rule. An example would be Hertfordshire Police who were keen to establish effective dissemination arrangements in their area and demanded detailed flood plain information from the NRA in order to achieve this. This positive approach mainly emanated from an individual Inspector who was tasked with making these arrangements work effectively. Neighbouring forces felt that Hertfordshire was setting a dangerous precedent and tried to dissuade the Force from pursuing such a policy.

4.4 Critical assessment of the institutional arrangements post September 1996

In September 1996 a number of significant changes were introduced relating to flood warning arrangements in England and Wales (see Figure 4.3). These changes are summarised below and analysed in this section and presented in detail in Appendix 3.

- The designation of the Environment Agency as the lead organisation for flood warning arrangements.
- Clarification of organisational roles and responsibilities through the production of Local Flood Warning Plans and establishment of local multi-agency planning groups.

- Greater political commitment by the Government through the elevation of flood warning to the highest priority in the flood defence function and preferential grant-aid funding.
- A clarification of the legal position in relation to flood warning dissemination through the issue of a Ministerial Direction to the NRA/Environment Agency.

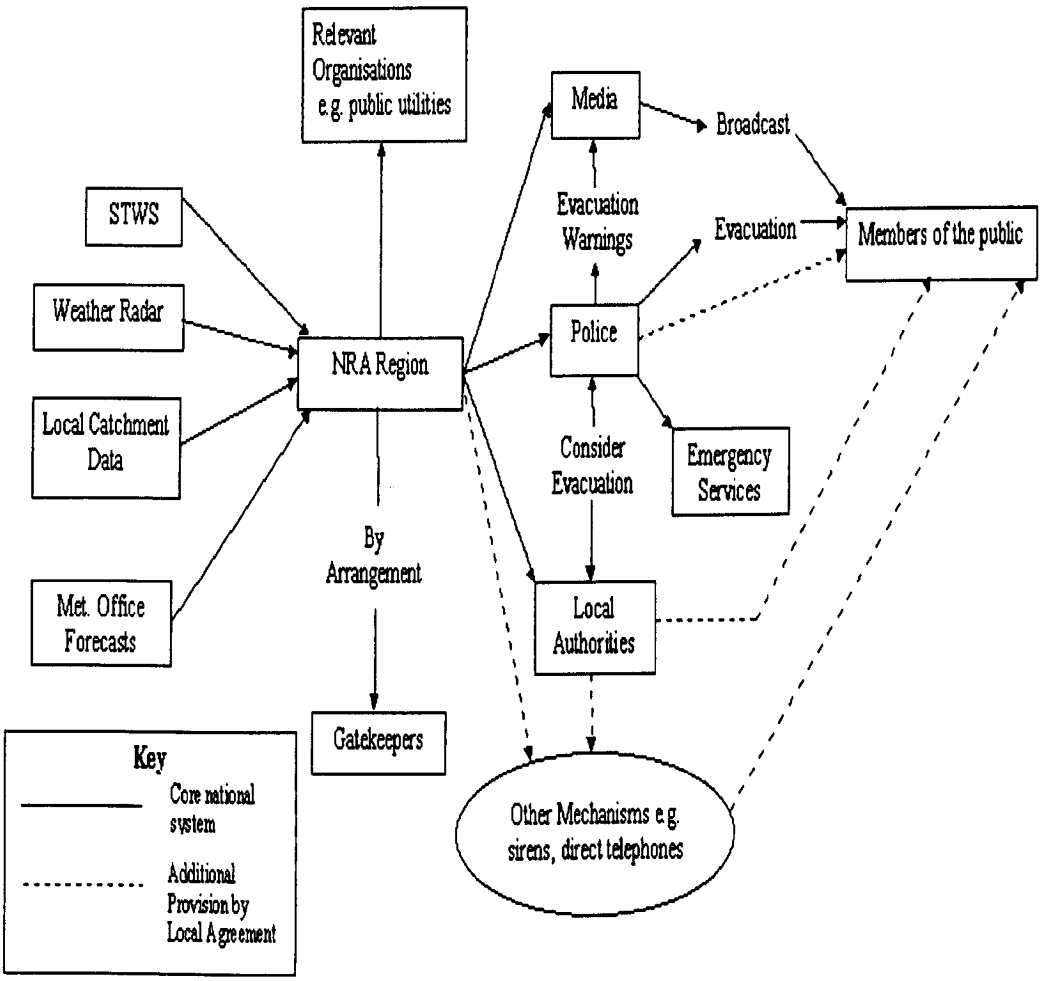
On the face of it, the new arrangements include a number of positive elements that should strengthen the process of integration. The way in which these changes are implemented however, and the support they attract from the range of organisations involved in flood response will influence their impact.

The designation of a lead agency is positive integrative development and it gives the Environment Agency a mandate to co-ordinate planning and management activities across the flood warning function and with all involved parties. However, this development came about in response to pressure from the police whose main objective was to reduce their involvement in flood warning activities rather than through a desire to improve the level of service offered to the at-risk public. It is important that other agencies such as the police and local authorities support the Environment Agency in its new role and do not just view these changes as an opportunity to minimise their involvement.

The legal changes have been kept to a minimum and no extra long-term resources have been made available to the Agency to fund the new service it is being asked to provide. There are two main dangers here;

1. the Agency may not commit sufficient resources, both in terms of manpower and equipment, to be able to offer a robust enough service, risking the possibility of failure especially during widespread and protracted flood events.
2. statutory duties have not been conferred on any organisation. The Agency can only bring about change through negotiation and influence which some local authorities and police forces may respond to but others may not.

Figure 4.3: Flood warning system in England and Wales (after National Rivers Authority, 1996)



In short, the Direction has been issued to only one organisation with responsibilities in flood response and within the context of existing institutional arrangements that, as has been discussed in Section 4.3, are seriously fragmented in a number of important areas. There has been no attempt by Government to fundamentally change these arrangements to minimise this fragmentation and address the need for greater integration. Nevertheless, the Direction does try to clarify the role and responsibilities of the Environment Agency and by doing so gives the lead organisation a greater degree of legitimisation with the other authorities involved in flood response.

The need for improved inter-organisational liaison is widely recognised as a key requirement for integration and the Ministerial Direction requires the Environment Agency to consult with some of the authorities involved in flood warning. The Agency is not obliged to reach agreement with these organisations however, and plans may be produced without going through the full process of consultation. Alternatively, other organisations may not consider that flooding is a sufficiently important issue to warrant extensive consultation with the Environment Agency. Other organisations such as the Met Office, the media and utility companies are not specifically mentioned in the Direction and an integrated and seamless partnership is required with all relevant bodies for the policy to be fully effective.

The raising of political commitment to flood warning by MAFF to the top priority in the flood defence function is a positive development for integration. Indeed, MAFF has agreed to fund work in this area at a special grant-aid rate of 50% and in preference to other flood defence projects. The commitment of other key government departments, such as the Home Office with their civil emergencies mandate, is paramount as this will influence the commitment of organisations such as the police and local authorities. The Home Office has in fact cut back on financial support for emergency planning in recent years and MAFF has very little influence with local authorities and the police to deliver an integrated flood warning policy in conjunction with the Environment Agency. MAFF has also made it clear to the Agency that enhanced financial support is a short term expedient and unlikely to extend beyond two years. A policy of integration will not succeed unless there is long term political commitment supported by the instillation of a positive climate and culture within organisations directly involved in its implementation.

4.4.1 Critical assessment of the new arrangements in the Thames Region

The implementation of the new arrangements in the Thames Region is described in Appendix 3. This section assesses their impact in the Region, and by revisiting the four factors examined in Section 4.3.1 it will be possible to judge how significant these changes have been in improving organisational integration in the Thames Region and to identify any shortcomings.

1. The first factor requires the securement of political commitment, establishment of clear objectives, definition of roles and responsibilities, preferably in a written plan, and agreement on rules for conflict resolution.

   In the Thames Region, as in keeping with national policy, local flood warning plans have been produced on a county/metropolitan area basis. To ease the process of consultation and to minimise the negative effects of non-coincident organisational boundaries, one Environment Agency region has taken the lead in the production of the plan for a given county. Accordingly, the Thames Region takes the lead in London, Hertfordshire, Buckinghamshire, Oxfordshire, Surrey and Berkshire, the Anglian Region leads in Essex, Bedfordshire and Northamptonshire, and so on. The plans attempt to set out clearly the objectives of the flood warning service and the roles and responsibilities of the various organisations in the process. The Agency drafted and circulated each document to all local authorities and emergency services by the end of 1996 and attempted to gain agreement on their content through consultation at local (county/metropolitan area-based) liaison meetings.

   Consultation meetings to discuss the plans in the Thames Region have generally been positive with local authorities and the police assisting the Agency in their production. Sections of the plan dealing with roles and responsibilities have had to be worded carefully so as not to contravene the policies of individual organisations. The danger here is that these sections may become watered-down and ineffective and hence perpetuate the lack of clarity that has characterised inter-agency arrangements in the past. It is also clear that in some cases authorities are not giving the plans sufficient priority, evidenced by a failure to comment on their content and to attend liaison meetings. This is particularly noticeable with some of the London Borough councils. One failing is that the Agency has not introduced a formal signing off procedure to ensure that outside organisations are formally in agreement with the content of the relevant plan and has not been rigorous enough in encouraging attendance at its liaison meetings.

Another area of concern is that of conflict resolution and arbitration, the rules for which have yet to be established and tested. MAFF has indicated, through the Ministerial Direction, that in the event of conflict over the content of the local flood warning plans, the Environment Agency will have the final say. In practice this may result in the Agency failing to persevere to resolve matters of conflict with other organisations and publishing the plans regardless of any disagreement.

Table 4.2 illustrates the increase in organisations in receipt of formal warnings from the Thames Region under the new arrangements from 13 in 1987 to 163 in 1999. Although warnings were cascaded to other organisations in 1987 by the police, the Agency's predecessors did not document the process and in many instances procedures were ad-hoc with varying degrees of success. The new procedures ensure that the process is now fully documented in the local flood warning plans, which is a positive integration point.

2. The second factor requires the establishment of functions and structures to foster integration and consideration of the designation of a lead agency. The placing of the Environment Agency in the lead role in the flood warning process has been universally welcomed by all parties in the Thames Region and is seen as a positive move to free-up the process which has been in stalemate over recent years. As lead authority therefore, the Agency needs to develop a clear understanding of the roles of all other relevant organisations in the flood warning process. The Agency does not have the power to instruct these authorities on their function however, or how they should be structured, it can only attempt to influence their actions and draw their attention to any shortcomings.

Although the Agency is moving towards consistent structures with regard to flood warning and flood defence, the same cannot be said of local authorities, for instance. There is significant variation in how the 98 different local authorities in the Thames Region are organised. Some authorities co-ordinate their operational response via their drainage departments, others via highways, and others still via emergency planning. One manifestation of this fragmented position is the variation in policy concerning the provision of sandbags to the public in times of flood. Table 4.3 shows that although a majority of local authorities hold no or limited stocks of sandbags for public use, some authorities have extensive stocks, Buckinghamshire County Council for instance, can have 20,000 sandbags available in an emergency. This variation results in considerable differences in the level of service provided to the public across the Region.

Table 4.2: Number of organisations in receipt of flood warnings in the Thames Basin.

Organisations	**Total in Thames Region**	**In receipt of formal warnings 1987***	**In receipt of formal Warnings 1999***
County Councils	11	0	7 (3 via police, 2 via fire and rescue)
London Boroughs/ City of London	33	0	27
District Councils	54	0	54 (10 via police, 14 via fire and rescue, 6 via county council)
Police Forces	13	12	13
Fire and Rescue	13	0	13 (8 via police)
Ambulance	12	0	12 (11 via police)
Utility Companies (water, gas, electricity, telephone, rail)	15	1	13
Navigation Authorities	3	0	3
Weather Centres	7	0	7
Local Radio Stations	41	0	14
Total	**202**	**13**	**163**

* as identified in Environment Agency or predecessor authority procedures.

Table 4.3: Provision of sandbags by local authorities in the Thames Region

Local Authority	Availability/Policy	Local Authority	Availability/Policy
Bedford CC	No stocks held	Surrey CC	Limited stock, not for general use
S. Beds DC	No stocks held	Epsom and Ewell DC	Limited supply - contractors
RB Windsor/M'head	500 filled, stocks of sand & bags	Tandridge DC	No stocks – rely on county council
West Berks DC	300 filled, 3000 unfilled	Waverely DC	2000 in stock, contractor can supply 1000 more
Reading BC	200 filled, stocks of sand & bags	Reigate & Banstead	Approx. 98 unfilled
Bracknell Forest BC	Some stocks of unfilled	Mole Valley DC	No stocks held
Buckinghamshire CC	2000,3000 unfilled – 20,000 available in emergency	Guildford BC	1000 filled
Aylesbury Vale DC	Very limited stock	Rushmoor BC	No stocks held
S. Bucks DC	Limited stocks	Surrey Heath BC	Limited unfilled stock
Chiltern DC	1000 filled, availability based on need	Woking BC	Limited stocks
Wycombe DC	Limited stock	Elmbridge BC	10 filled, 500 unfilled for emergencies only
Essex CC	No stocks held	Runnymede BC	A few hundred unfilled
Epping Forest DC	Contracted out to Tarmac who deliver and charge	Spelthorne BC	Limited stock of filled, larger stock unfilled
Uttlesford DC	Stocks of filled and unfilled – will deliver	City of London	No stocks held
Harlow DC	Stocks of filled - will deliver	Barking & Dagenham	Limited stock
Brentwood DC	Stocks of unfilled/ filled – charge made to private households	Barnet	300/400 unfilled
Gloucester CC	No stocks held	Bexley	No stocks held
Cotswold DC	200/250 filled, 500 unfilled	Brent	1000 in stock
Hants CC	No stocks held	Bromley	2000 unfilled
E Hants DC	Limited stock - collection only unless aged or infirm	Camden	No stocks held
Basingstoke & Dean DC	Limited stock filled, large stock of sand and bags	Croydon	50 filled
Hart DC	Limited stocks	Ealing	No stocks held
Herts CC	No stocks held	Enfield	No stocks held, ,can obtain supply
E. Herts DC	12 unfilled	Greenwich	Limited stock
N. Herts DC	No stocks held	Hackney	No stocks held
Welwyn Hatfield DC	200 unfilled	Hammers'th & Fulham	No stocks held
St Albans DC	No stocks held	Haringey	250 empty bags
Three Rivers DC	200 unfilled	Havering	100 filled
Dacorum BC	Limited stocks only	Hillingdon	No stocks held
Broxbourne DC	50 unfilled	Hounslow	No stocks held, can obtain supply
Watford BC	500 – 1000 bags only	Islington	No stocks held
Hertsmere BC	Limited stocks	Kensington & Chelsea	200 filled
Northampton CC	Very limited stocks	Lambeth	Limited stock
S. Northants DC	Very limited stocks	Merton	No stocks held
Daventry DC	Very limited stocks	Newham	No stocks, local firm can supply
Oxfordshire CC	Limited stocks	Redbridge	No stocks held
S. Oxon DC	No stocks held– contracted out	Richmond	Limited stock
Oxford City DC	1000 unfilled	Southwark	Limited stock
Vales of White Horse	Limited stock	Sutton	No stocks held, can obtain supply
W. Oxon DC	Limited stock of unfilled	Waltham Forest	Limited supply
Cherwell DC	A few hundred only	Kingston upon Thames	No stocks held

3. The third factor requires the establishment of fora to facilitate liaison, negotiation and mediation between agencies. In response to the requirements of the Ministerial Direction the Environment Agency has established flood warning planning groups in each county/metropolitan area in the Thames region. These groups have either been newly formed by the Agency (such as in Oxfordshire) or based on existing emergency planning groups run by the county councils (such as in Hertfordshire). In London however, the absence of a second tier of local government means that alternative fora have had to be sought. The London Emergency Services Liaison Panel (LESLP) and the London Emergency Planning Forum were possible options. The London Boroughs were not fully represented on these groups however, and some felt that they were not being adequately consulted as a consequence. Alternative and more locally based emergency planning fora were targeted by the Agency therefore, of which there are five in London, but experience shows that even these are not well attended by some of the key organisations, notably the police. Further work is needed to establish an effective inter-agency liaison forum for flood warning in London.

Outside London, the local authorities and police have co-operated reasonably well with the Environment Agency in setting up planning groups and the Agency has been actively seeking to obtain agreement with all parties on the content of the local flood warning plans. There is a danger however, that some authorities may not agree with the contents of a particular plan until reference to roles and responsibilities is made sufficiently vague to remove any possibility of litigation. The raison d'être of the plan will thereby be lost. An example of this problem is in Hertfordshire where the police had agreed informally to continue to warn the public on receipt of a RED flood warning, but failed to confirm these arrangements formally which meant that they could not be included in the Hertfordshire Flood Warning Plan. Another issue is that most of the planning groups are focused around the Agency, local authorities and the emergency services, other organisations such as the media, the Met Office and the utilities are often excluded. This can be detrimental to the development of an integrated approach across all agencies involved in flood response.

4. The fourth factor requires the instillation of a positive organisational climate and culture for integration. A very positive climate was initially evident within the Environment Agency both at national and regional levels following its designation as the lead authority in 1996. The Agency's Board had given the new arrangements a high priority and national and regional project groups had been established to oversee their implementation over a 5-year period. In the Thames Region, as in other regions, there is some evidence that this initial positive approach by senior management had begun to wane once procedures had been put in place. The Easter floods exposed serious problems with the adequacy of these arrangements in a major flooding incident, and there followed renewed vigour at the highest level in the Agency to address the shortcomings.

   Although the new arrangements are generally welcomed by police forces, local authorities and other organisations in the Thames Region, the political will to approach the issue of flooding and flood warning in a positive way is still largely lacking in these organisations. Following discussions with a number of authorities it is clear that there are four main reasons for this:

   - flooding is not a frequent enough problem in many areas and consequently receives a low political profile compared to other emergencies
   - there is continuing concern over litigation and a reluctance to exercise non-statutory powers
   - there is a general perception that flooding is an issue for the Environment Agency
   - there is little support from government departments such as the Home Office, which tends to rely on local political will to deal with flooding issues.

4.4.2 The performance of the new arrangements in the Easter 1998 floods

The test of any new arrangement or procedure is how it performs in a real event. The first comprehensive test of the 1996 procedures was during the Easter weekend in 1998 when between 70 and 90 mm of rain fell on saturated river catchments over an area of some 5,000 square kilometres in the Midlands and East Anglia. Five people died and many thousands of people were severely affected by the floodwaters and losses are estimated at over £400m. An independent review commissioned by the Environment Agency concluded that "flood warnings were issued in accordance with current policy in most locations but lack of public awareness, together with nationally inconsistent and inadequate procedures and systems, resulted in poor overall performance" (Bye and Horner, 1998). The Bye report calls for a "radically modified strategy for improving flood warning performance". A number of recommendations and observations in relation to institutional and legal arrangements are made in the report that have particular relevance to integration, and these are summarised below:

1. The adequacy of liaison between the organisations involved in flood warning and emergency response should be examined and strengthened where necessary. The report acknowledges that the Agency had made some good progress in improving liaison since 1996, but concluded that more work needed to be done. Individual organisations are encouraged to review their flood emergency procedures and bring greater clarity to command and control in the combined response to floods. The report concludes that most organisations were poorly prepared for dealing with the emergency that developed over the Easter weekend.
2. The Easter Floods demonstrated that the lack of an integrated partnership between the Environment Agency and the Met Office was a significant problem, leading to under-performance of the flood warning system. The report recommends that the two organisations should establish a "flood warning partnership" that would exploit more fully the resources, skills and public communication facilities of the two national organisations concerned with severe weather and its flood impacts. The report points to arrangements in Australia and the United States where flood forecasting is more integrated with the meteorological service and benefits from direct consultations and shared data sources.
3. The Agency, local authorities and emergency services should seek national consistency in their dealings especially as their boundaries are often incongruent. They should place greater emphasis on "testing response activity, interfacing and co-operation".
4. The Agency is encouraged to achieve a higher profile in the national and local media, and that better control and co-ordination of press releases between

Agency regions and with other agencies is secured to ensure accurate and consistent explanations of flood emergencies.

5. Although warnings through the media – some local radio stations, teletext and weather forecasts – appear to be helpful, they did not achieve the degree of awareness required to significantly lessen the impending suffering and damage. It is recommended to seek the full participation of radio and television with programme interruption for more worthwhile benefit.

6. The Agency should secure closer liaison with navigation authorities and utility companies to assess the feasibility of water supply and canal reservoirs being operated for the benefit of flood control.

7. The policy adopted by MAFF and the Welsh Office for approving investment in flood warning schemes is felt to be too narrow as it involves a rational and economic based justification and "disregards the social, environmental and political issues". Such modification would assist in ensuring that the interests of the public and other authorities are properly addressed in relation to future proposals for new or improved flood warning systems.

8. Within the Agency itself a number of organisational changes are recommended. These include the strengthening of functional management to permit more authoritative direction and greater national consistency; the establishment of greater local accountability for effective flood warning service provision; rationalisation of the Agency's flood defence committee structure; the centralisation of flood warning specialist staff resources either regionally or nationally to improve efficiency, effectiveness and national consistency.

4.4.3 The performance of the new arrangements in the Thames Region during the Easter 1998 floods

The flooding in the Thames Region was confined mainly to one river catchment, the River Cherwell and its tributaries in Oxfordshire. Nearly 60mm of rain was recorded over a 12-hour period on saturated ground that generated a peak flow with a return period in excess of 100 years (1% annual probability). This resulted in the flooding of over 560 properties in a wide area from Banbury to Oxford. Prior to Easter, the Agency's awareness of flood vulnerability was that areas at risk were not extensive and included few properties. Indeed, the flooding extended beyond the previously recorded flood "envelope" known to the Agency and was greater even than the "Great Flood" of 1947. The Bye Report states that although flood warnings were issued in accordance with the procedures in place, "most people affected received no alert and were surprised by and unprepared for the flooding. The deficiency in the scope of the Agency's warning arrangements is explained by its lack of knowledge about previous flooding" (Bye and Horner, 1998). The report also highlights a number of points that have a bearing on institutional arrangements in the Thames Region and integration:

- Emergency response and co-operation between all organisations appears to have been as effective as could be expected in the difficult circumstances resulting from; no prior awareness of extensive flood risk; short notice of flooding; and the expectation it would affect few properties.
- The local authority emergency planners, the fire service and the Agency's staff were in close contact during the event in Oxfordshire. The Agency's staff assisted Cherwell District Council with pumps, sandbags and labour, for example. There was no contact on the ground between the Agency and British Waterways Board however, and vital floodgates were operated without the knowledge of the Agency. In fact the Agency was unaware of the existence of one gate altogether. An operating agreement between the Agency and British Waterways is felt to be beneficial.
- There is a general need to improve understanding between all agencies involved in flood management, including the media, and this is likely to be best achieved through the implementation of regular, multi-agency exercises, and improved liaison and presence at incident sites and at incident management control centres. This approach would engender awareness of roles, responsibilities, tools available and limitations.
- The Agency is encouraged to set, publish and monitor Flood Warning and Emergency Response standards in consultation with MAFF, the Regional Flood Defence Committee, local authorities, emergency services and the public. This should lead to a better understanding of roles and responsibilities and on "how the boundaries of knowledge and of technology affect the standards attainable".

- The Agency's Flood Warning Reach System, which had been previously circulated to local authorities and emergency services, was not closely referred to during the event and it is felt that this could have enabled earlier, and more specific warnings to be given to residents in risk areas.

- The Agency is encouraged to investigate how best to institute formal arrangements for disseminating public flood warnings to areas at low risk of flooding. Although there is no agreed procedure as to achieve this, it is recommended that institutions such as Parish Councils are considered as well as using loud hailers on Agency and emergency service vehicles.

- A number of recommendations were made on how the Agency can improve its own internal management arrangements. These included; better co-ordination of incident management (staff were operating from 5 different centres during the event); written guidance for staff regarding organisational responsibilities (the roles and responsibilities of different internal sections was not fully appreciated by some staff); and firmer guidance on individuals' roles within sections (a better level of understanding and appreciation of individuals' responsibilities is needed).

Generally, flood warning notices were effectively disseminated by the Agency to other response organisations (including local radio stations) in good time. Table 4.4 gives the warning lead times in relation to the times of peak flow at Banbury and Enslow gauging stations located upstream of the main centres of population in the Cherwell catchment. What was lacking however, was the detailed communication and exchange of information between the key players during what was a major flooding incident, in particular between the Agency, local authorities, the emergency services and the media. During the early stages of the event all these organisations failed to fully appreciate its severity, due to a combination of consistent under reporting by the flood detection and forecasting systems and a poor level of flood risk information for the Cherwell valley. Experienced staff in the Agency were predicting that the flood would dissipate in the wide flood plain as it moved downstream and its effects would be minimal in Kidlington. Vital information that was being collected by on-site staff from a number of organisations that may have, if collated, produced a different conclusion, was not collectively available to decision-makers. The resultant lack of urgency was apparent across all response organisations in the early stages, including the media, and this contributed to the general lack of preparedness of the public.

Table 4.4: Flood warning lead times for River Cherwell - 9-10 April 1998

	Warning colour	Time of issue/ Occurrence	Lead time to Banbury	Lead time to Enslow
Reach 1	Yellow	10.30 9/4	16.5 hours	
Reach 2	Yellow	10.30 9/4		34.25 hours
Reach 1	Amber	17.00 9/4	10 hours	
Reach 1	Red	22.30 9/4	4.5 hours	
Reach 2	Amber	22.30 9/4		22.25 hours
First property flooded at Banbury		00.30 10/4		
Peak at level Banbury		03.00 10/4		
Reach 2	Red	14.45 10/4		6 hours
First property flooded at Kidlington		17.00 10/4		
Peak level at Enslow		20.45 10/4		

4.5 Summary and conclusions

The influence that institutions and the law have on the integration of flood warning systems is clearly significant. An attempt has been made in this chapter to ascertain the degree to which arrangements are either helping or hindering the process of integration at a number of levels; national, regional and local. To achieve this goal, reference has been made to the integrative factors defined in Chapter 2, to the arrangements in existence both before and after 1996, and to the performance of procedures during the Easter 1998 flood event.

The key findings are summarised in relation to the integrative factors referred to above.

Legal Arrangements

This chapter has highlighted the fact that in England and Wales no authority has an unambiguous statutory duty to prepare for, issue warnings for and respond to peacetime emergencies such as floods. The legislative framework covering flood warning and response in England and Wales is both weak and unclear and this is a major hindrance to establishing integrated institutional arrangements.

Prior to 1996, the cornerstone of flood warning arrangements was the voluntary agreement between the key organisations that was established in 1968, and this appeared to work well on some occasions in the past. Tightening resource constraints and growing fears over legal liability however, meant that these procedures began to breakdown and could not be sustained. The Ministerial Direction issued to the Environment Agency in 1996 was designed to clarify matters and established the Environment Agency as the lead authority. Although the Direction requires the Agency to produce written flood warning plans in consultation with the relevant local authorities and emergency services which is a positive development for integration, it fails to address the specific question of roles and responsibilities. This issue is left for the Agency to tackle thorough discussion but without the power of direction over other organisations. Other weaknesses include the failure to include other relevant organisations such as the media, navigation authorities, utility companies and the Met Office, all of which have important roles in forecasting, warning and response, and the lack of procedures and mechanisms for dealing with conflict situations between organisations. The Government's guidance on the latter point, that in the event of conflict over the content of the local flood warning plans, the Agency will have the final say, is unlikely to be effective in practice.

It is interesting to note that following the publication of the Easter Flood Review the Government felt it necessary to write to local authorities and the emergency services "to stress the importance of effective liaison with the Environment Agency". If the roles and responsibilities of these "key partners" and others had been more clearly defined in the legislation, there would be less of a need to send out reminders following flooding incidents. The continued vagueness of these arrangements is illustrated in the Government's statement to the House of Commons on 21 October 1998:

> "The Agency's responsibility is to issue flood warnings. Having done so, the emergency response is the responsibility of others. Local authorities **generally** co-ordinate the local planning process but when those plans are implemented the co-ordination role **normally** falls to the police, though they will **clearly need** strong support from the fire and ambulance services, and emergency planning departments in local authorities, social services and other similar agencies". (Hansard, 1998 – emphasis added)

Successive governments have had ample opportunity to review, revisit, update and strengthen the legal framework but have chosen not to act. The original legislation that specifically refers to flood warning systems was drafted in the 1970s and focuses specifically on the provision of equipment for gathering information on rainfall and river flow. These clauses have been repeatedly assimilated into successive acts without substantive change. The arrangements needed to disseminate warnings and ensure public awareness have never been explicitly addressed in the legislation. There is an in-built bias therefore, towards the provision of equipment that tends to favour the development of detection and forecasting systems often at the expense of the dissemination and response elements. This has been reflected in the Government's Grant Aid arrangements for flood warning that were criticised in the Easter Flood Review as "taking no account of social, environmental and political considerations" (Bye and Horner, 1998). It can be argued that the legacy of the apparent narrow understanding of the total flood warning process by the legislators in the 1970s has resulted in a fragmented approach to flood warning that has not been conducive to integration.

The Government has shown that it is aware of the need for an integrated approach to flood warning. In the parliamentary statement referred to above it was stated:

> ".... that there must be a seamless and integrated service for flood forecasting, warning and response. Weather forecast information needs to be integrated with reliable information about flood risk in particular areas .... to generate a flood forecast and, if appropriate, a flood warning. Flood warnings need to get to the people in the area at risk of flooding in time for them to respond appropriately".

The legislation needs to be amended therefore, to reflect this view and there needs to be more emphasis placed on reviewing all relevant legislation to ensure that laws that affect one organisation are compatible with laws that affect another. This is rarely achieved as the sponsoring government departments are often different and the apparent lack of cross-departmental liaison can frustrate this process.

Institutional Arrangements

This chapter has demonstrated that the institutional arrangements in England and Wales prior to 1996 were often fragmented and poorly integrated. Inter-agency procedures were frequently informal and undocumented and precise roles and responsibilities were not adequately defined and understood. Attempts at formal clarification had largely failed due to fears of legal liability and an unwillingness to recognise that the then NRA had a co-ordinating mandate. Cross functional integration was not given a high priority at this time and each institution assumed a general area of responsibility and arranged its organisational structure to suit its operational circumstances. Liaison between organisations was conducted in a rather ad-hoc fashion and often involved a limited number of agencies. A rather negative climate and culture was becoming common in many organisations involved with flood warning as resource pressures, confusion over roles and responsibilities, and fears of legal liability created real barriers to integrated and co-ordinated effort. Many authorities had become inward looking and much energy was devoted to minimising involvement and focusing resources on other statutory duties.

The introduction of new flood warning dissemination arrangements in 1996 has been a major step forward in developing a more integrated approach to flood warning in England and Wales. The Environment Agency has been given the lead role in co-ordinating flood warning matters and the Ministerial Direction places an onus on the Agency to maintain written local flood warning plans and to co-ordinate inter-agency liaison. All of these factors are positive integrative advances, but as the Easter 1998 floods exposed, there are a number of significant and fundamental weaknesses still to be addressed.

The Easter floods highlight the importance of inter-agency liaison both in planning for and responding to floods and the Bye Report acknowledges that satisfactory arrangements are in place between some organisations, but between others liaison is patchy. The Report pays particular attention to the need for strengthened links between the Agency and the Met Office, the media and navigation authorities such as British Waterways. It encourages all relevant organisations to review their emergency planning and preparation and to gain a better appreciation of command and control procedures in their partner authorities. Emphasis is also placed on the importance of testing and exercising inter-agency plans with extreme event scenarios at regular intervals, especially during periods when flooding is infrequent, recognising that this practice has not been commonplace in England and Wales and that it may require a shift in organisational culture to achieve.

Although the Agency has taken initiatives since 1996 to raise public awareness, the Bye Report states that "people in known and potential at-risk areas do not understand the roles of the Agency and the other response organisations". It is also clear that, despite some good work since 1996, there is still much confusion within organisations as to the roles and responsibilities of others, and in some cases staff are unclear as to the precise role of their own organisation. As Drabek (1986) states, if one organisation is unclear as to the role of the other then this can delay response. The problem is compounded by the fact that there is still low political commitment to flood warning and flood response in some organisations: "there were suggestions that fluvial flooding was not seen as a particular priority alongside other potential emergencies" (Bye and Horner, 1998). Even within the Agency, following strong initial commitment by senior management to the new flood warning arrangements in 1996, there has been a tendency to give higher priority and political focus to other matters, such as integrating environmental protection activities. The perception of senior managers was that the flood defence and flood warning functions were working relatively well and, as they were not subject to major structural change following transfer from the NRA, they required less management attention. Senior Management seemed unaware of the Agency's vulnerability in a major flooding incident. This is confirmed by Drabek (1986) when he states that hazard awareness among executives is often minimal and that this can impact on policy making within an organisation.

In response to the Easter 1998 floods and the Bye Report, the Minister of Agriculture, Fisheries and Food issued a statement that has important implications for integration and if adhered to should instil a more positive climate and culture for integrated flood warning arrangements,

- "flood warning is the Government's highest priority" (in flood defence)
- "there must be a seamless and integrated service of flood forecasting, warning and response"
- "all local authorities, police and fire services will be reminded of the importance of effective liaison with the Environment Agency, in ensuring that emergency plans are kept up-to-date, and for active participation in exercises".

Since the publication of the Bye Report in September 1998, the Environment Agency has taken steps to address each of the Report's recommendations and has published an Action Plan. It has established a national project team to oversee this work, the Easter Floods Action Group (EFAG), which has been given a very high profile in the organisation. It has also established a National Flood Warning Centre that is tasked with forging stronger and more nationally consistent links with partner organisations in the operational and research fields. It remains to be seen however, if the Agency sustains this level of commitment over a long-term period, both internally and within outside organisations, especially if the incidents of and focus on flooding is less than it is today.

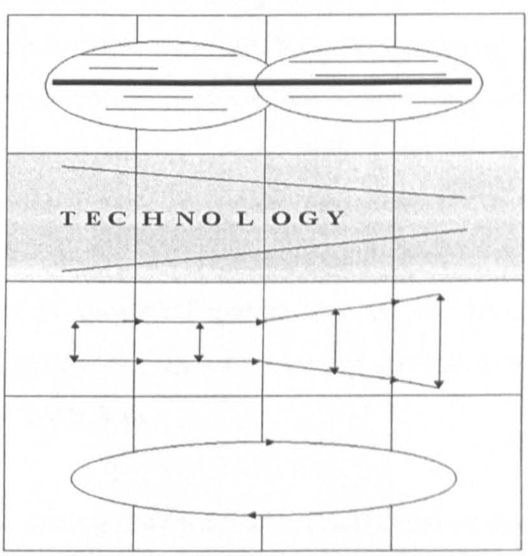
Chapter 5

Technology

5.1 Introduction

This chapter addresses the second element of the conceptual model presented in Chapter 3 (shaded area in Figure 5.1). Building on what was presented in Chapter 2, its purpose is to analyse by what means, and to what extent, the application of technology has enhanced and can further enhance the integration of flood detection, forecasting, warning and response systems (FDFWRS). Technological applications in such systems address integration problems in a variety of direct and indirect ways, and must be distinguished from those applications of technology that are mainly not about enhancing integration and are focused on other aspects. Most technological applications are intended to have a favourable impact on either integration or non-integration components of FDFWRS, but there are also examples in which it appears that technological application has had disintegrative impacts. In some cases a particular application may have both favourable and unfavourable effects on flood warning systems and the likely net effect is what must be examined.

Figure 5.1: Conceptual model of the FDFWR process



(see Chapter 3 for full details)

5.2 The nature of technological applications in FFWRS

Technology has made a significant impact in the development of FDFWRS in the last thirty years. It is possible however, to distinguish between those technological applications that have specifically enhanced the process of integration and those that have either not addressed integration or may have even worked against the development of integrated arrangements.

5.2.1 Flood detection and forecasting

The very earliest flood warning arrangements, which were non-technical and largely community-based, were in fact very integrated ones. They tended to be locally based, dependent on local knowledge, expertise and resourcefulness, reflecting the local need. The detection and forecasting was typically undertaken by individuals who lived near a river and developed a considerable expertise in the prediction of river levels and response times. Such individuals would take it upon themselves to warn their neighbours if they predicted that flooding was imminent.

The initial focus of technological application was in the measurement of hydrological parameters such as rainfall, river level and flow. Over the last 30 years a great deal of technology has been applied to increase accuracy and precision and this has transformed, for example, the simple weight and float gauge into a sophisticated micro-processor based measuring device. This thrust of technological activity however, has not been aimed at integration. Indeed, the main emphasis has been on improving the accuracy of low flow measurement for water resources purposes rather than on high flows for flood defence. The effect of this was illustrated in the Easter 1998 floods in the Cherwell catchment in Oxfordshire when all 9 river level/flow gauges, designed only to measure a 1 in 5-year flow on average, were overwhelmed by the magnitude of the event, which exceeded 1 in 100-year frequency. This resulted in duty staff underestimating the severity of the event and this perception was communicated down the warning dissemination chain resulting in an inadequate response (see Table 5.1).

Another integration issue arising from this lack of functional co-ordination is that many of the flow gauging stations are not ideally located for flood warning purposes. For example and as Table 5.2 illustrates, out of a network of 34 river gauges in the Lee and Roding catchments in the north-eastern part of the Thames Basin, 28 (82%) were installed primarily for water resources purposes. These are often to be found in downstream locations at river confluences, rather upstream of flood risk areas where they would be of most value for flood detection and forecasting. This was recorded as being a hindrance to operational activities even during flood events in the 1990s (see Appendix 1) and can be traced to poor liaison between the Water Resources and Flood Defence functions when the gauge networks were planned and installed. Better integration between functional departments in river management would help avoid such discrepancies in the future

In 1999 all river gauge stations in the Thames Region were audited to determine their measuring range and a programme of work was initiated to make the necessary improvements to extend these where practicable. As Table 5.3 illustrates, the number of gauges has increased across all river catchments in the 10-year period 1989 to 1999 by 175%, and further installations are planned in the next 5 years to give better information in flood risk areas. But the problem of accurately measuring extreme flows remains. It is estimated that to construct 15 gauges to measure in excess of the 1 in 100 year flow at critical locations in the Region could cost in excess of £20m.

In the mid-1970s river and rain gauges began to be telemetered, enabling the collection of information at a central location, at first by manual interrogation, for use in the preparation of flood forecasts. In the last 20 years the level of technology applied to telemetry has increased dramatically moving from simple trigger level monitoring devices to on-site micro-computers capable of continuous data logging and multiple alarm handling. As Table 5.3 emphasises, the development of telemetry networks in tandem with communication systems has been a highly integrative process, bringing together data across river basins over both time and space. The use of technology therefore, has allowed the integration of data gathering and the generation of flood forecasts, resulting in increased flood warning lead times at critical locations. The application of this technology has not been compatible in all cases however, and this has impacted negatively on integration. In the Thames Region for instance, different telemetry systems were installed in different parts of the catchment and as a number of these systems were incompatible, regional-wide monitoring and forecasting was not easily undertaken (see Table 5.4). Although the integration of telemetry and computer systems was achieved in the mid-1990s there were lingering problems of poor coverage and robustness in the network, especially in the west of the Region as detailed in Appendix 1, an issue that is only being fully addressed today.

Table 5.1 Status of river gauges in Cherwell catchment during the Easter 1998 flood.

River level station	Status	Level (m) and flow	Time of failure (GMT)	Time of first property flooding (GMT)
Cropredy	Telemetry failure	2.296	17.30 9/4/98	
Banbury	Gauge stuck	2.477	01.00 10/4/98	23.30 09/4/98 (Banbury)
Bodicote	Gauge stuck	1.219	19.15 9/4/98	
Heyford	Telemetry failure	0.908	00.00 to 07.45 10/4/98	
Enslow	Telemetry failure	1.583	13.30 10/4/98	16.00 10/4/98 (Kidlington)
Kings Mill	Telemetry failure	1.898	20.30 10/4/98	
Oxford	Telemetry failure	74.58 m3/sec	08.45 11/4/98	

Table 5.2: Location of river flow/level gauges in the Lee and Roding catchments.

River gauges located for water resources purposes	River gauges located for flood warning purposes
28	6

Looking beyond the Thames Region it is clear that the 8 regions of the Environment Agency still operate locally and autonomously developed telemetry systems making the cross regional availability of data difficult to achieve. The Agency is generally unable therefore, to share data in real-time amongst its operational regions and with other organisations such as the Met. Office. This is thought to hamper improvement to forecast accuracy and detection capabilities. Even within regions, different functional departments operate different gauge networks. These networks may be incompatible with each other and although the number of gauges that have been telemetered has increased there is still a substantial number that are not. This can result in forecasters not having full access to all relevant data in real-time. These are all examples of where, for mainly organisational reasons, technology that has the potential to improve integration has not been applied in an integrated way and as a consequence the benefits of that technology have not been fully realised.

Table 5.3: Outstations available to Flood Warning Staff in the Thames Region - 1989 and 1999.

River Catchment	Telemetered Raingauges		Telemetered Rivergauges	
	1989	1999	1989	1999
South London Rivers	11	17	10	23
North London Rivers	12	9	14	23
Lee	9	24	14	23
Roding	4	8	4	4
Colne	2	8	10	34
Mole	2	2	7	13
Wey/Bournes	3	6	10	20
Loddon	2	2	5	9
Thame	1	2	1	4
Cherwell/Ray (Oxon)	2	3	6	10
Kennet/Ock/Pang	6	9	10	18
Cotswolds Rivers	5	6	11	17
Fluvial Thames and minor tributaries	9	9	33	51
Total	68	105	135	249

Table 5.4: Flood warning telemetry systems in operation in the Thames Region prior to 1984

Sub-area	Telemetry System
Thames Valley (upstream of Teddington)	Churchill and Delta Technical Systems.
Lee and Roding Valleys	Dynamic Logic Autolog/Radal.
London tributaries	Dynamic Logic 32/RGA digital talk-out system.

The reliance on manual methods to collect and process data from telemetry meant that the generation of timely forecasts was only really practicable for rivers with long response times. Forecasting for short-response rivers was a far more complicated procedure and generally not attempted. In the 1980s computer systems began to be increasingly used in real-time detection and forecasting schemes and this had important implications for integration. The processing time that the computer offers enables the integration of large volumes of data that can be analysed quickly, allowing more sophisticated models to be run operationally. These advances gave the hydrologist the tools to develop monitoring and forecasting systems for any type of catchment, including those with a short response time, and the ability to issue flood warnings in such circumstances is now a feasible proposition. The introduction of computer technology therefore, can be a highly integrative process. In the Thames Region for instance a regional computer system has brought together a number of key processes, including data capture and processing, the running of forecasting systems and the dissemination of flood warning messages via linked facsimile units. But this is only a relatively recent development as in the early 1990s there were up to 16 different real-time computer systems operating in the region, most of which were stand-alone and incompatible with each other (see Table 5.5). This pattern of inconsistency is repeated between regions with a wide variation in the computer systems in operation across the Agency that can be traced back to procurement decisions by the predecessor Regional Water Authorities prior to 1989. This has resulted in the evolution of inconsistent and poorly integrated systems across the Agency that has hindered the exchange of information and the introduction of nationally compatible enhancements.

Even though the Agency has conducted much research and development into improving detection and forecasting techniques over the recent years, it has a poor track record in implementing any resultant new products into operational procedures often due to problems of system incompatibility. A wide gulf has developed between research and operational implementation illustrated by the fact that in the last 15 years the Agency and its predecessors have commissioned 16 pieces of research in this area but only 4 of these have resulted in enhanced operational systems. This highlights the fact that although computer technology offers great potential for integration, unless this technology is applied in a consistent manner this potential will not be realised.

Perhaps one of the most significant technological advances in flood detection and forecasting has been the development of weather radar. It was with the advent of the Dee Weather Radar Project in North Wales (CWPU, 1977) and the North West Radar Project in north-west England (NWRP, 1984) that the importance of radar for hydrological uses, including flood forecasting, was fully demonstrated. These projects highlighted that radar has many advantages and many of these are highly integrative:

a) radar data could be processed in real-time, transmitted from site and displayed remotely with a high level of operational reliability
b) radar could integrate measurements of areal precipitation over large areas of varying terrain and at a far lower cost than a comparable telemetering raingauge network

Table 5.5: Multi-functional real-time computer systems operating in the Thames Region in 1990 (after Kennedy and Donkin, 1990)

	Real-time computer system	Function
1	Hydrological PSTN system (west)	Regional Water Resources
2	Lee Area Telemetry	NE Area Flood Defence
3	Lower Thames Flood Level Telemetry	SE Area Flood Defence
4	Barrier Telemaster System	SE Area Flood Defence
5	Thamesmead pumping stations	SE Area Flood Defence
6	Thames Tidal Gauges	SE Area Flood Defence
7	Southend Obsermet System	SE Area Flood Defence
8	Argus Telemetry System	Multi functional
9	CASCADE Flood Warning System	Regional Flood Defence
10	River Level Warning Devices	Regional Flood Defence
11	Pinner Alarm system	Regional Flood Defence
12	Flood Warning DTS/WTS System	Regional Flood Defence
13	Trend Monitoring PSTN System	Navigation
14	Meteorburst Water Quality System	Regional Water Quality
15	Meteorburst Development System	Multi-functional
16	Weir automation Scheme	Regional Flood Defence

c) on-line hydrological forecasting using radar data was shown to be feasible and radar could be used, even in very simple models, to produce forecasts for areas for which lead times were previously insufficient

d) radar data could be used to improve the short period quantitative forecasting of precipitation which could be used in turn to improve flood forecasts

e) radar data could be used in an operational flood warning system supplementing meteorological and hydrological data from other sources.

The ability of individual radars to measure rainfall quantitatively up to 76 km and qualitatively up to 210 km provides the hydrologist with a powerful tool in detecting and monitoring flood-producing storms. When radars are then networked together the integrated product gives coverage across large river basins and even nations. Extensive radar networks are now in operation in the developed world including the NEXRAD system that gives almost total areal coverage across the USA with a network of nearly 140 radars. Despite the clear advantages that radar offers however, there is a continuing concern in some quarters of the accuracy of radar measurements. So although an operational network has been in operation in England and Wales since 1984, many hydrologists continue to use radar data only in a qualitative way, preferring to rely on raingauge networks for quantitative rainfall measurement. These concerns are being actively addressed jointly by the Met Office and the

Environment Agency through a 10-year programme of improvements and enhancements to the network in England and Wales. From 1 April 1999, each region of the Agency will receive a consistent package of radar products using the best available quality-controlled information. As Collier (1996) mentions however, the need to develop robust operational radar networks means that consideration must be given not just to the radar itself, but also to real-time computing facilities, to telecommunications and to the functions of the software producing the data. In other words all these facilities must function in an integrated way to obtain the best quality information for flood warning purposes.

The process of forecasting is potentially a highly integrated one. State-of-the-art forecasting arrangements are now operationally available incorporating computer systems that communicate via digital telephone circuits, to obtain data from dense networks of intelligent telemetry outstations and weather radars which are fed automatically into models, which generate forecasts every 15 minutes (see Table 5.6). But are these arrangements in common operational use today across England and Wales? The review into the Easter 1998 floods reveals that there is a wide variation in the technical approach to flood forecasting in the four regions of the Environment Agency that were under investigation. It was found that leading edge science is only being used in a few cases, for example the use of radar derived rainfall data and forecasts to predict flows. In others, there are "out-of-date techniques" in use that are "in need of updating or replacement" (Bye and Horner, 1998). The often held perception that sophisticated flood detection and forecasting systems are in operation across the country therefore, is not accurate. Indeed, the Agency continues to operate techniques in some regions that were first introduced some twenty years ago and described by Smith and Tobin and others in the 1970s. The evolution of inconsistent detection and forecasting systems in the Agency has been a key integration problem hindering the rolling out of state-of-the-art techniques across the country.

The installation of a fully operational and integrated flow forecasting system across the Thames Region has yet to be achieved. Although the Institute of Hydrology's Regional Flow Forecasting System was purchased in 1995 insufficient staff resources have been dedicated to its implementation. The Easter Flood Review states: "the Thames Region needs forecasting and prediction tools that are able to indicate the severity of an event at an early stage. Progress on forecasting models had been postponed as the resources were reallocated to work related to flood warning dissemination". For an integrated system to evolve it is important that technological advances are applied to all elements of the flood warning process rather than focusing on one at the expense of another.

The Easter Flood Review highlights a number of specific shortcomings with relevance to the application of technology and integration:

- telemetry networks have poor coverage in some areas and many river gauges are not positioned in the correct places. A high proportion of the gauge network was installed for water resources purposes in downstream locations. In addition, a significant number of river gauges are unable to measure flows of the magnitude that occurred at Easter when many stations were overwhelmed and failed to operate.

- technology was either not used or adequately provided to duty officers in a consistent way to enable them to detect, monitor and forecast the flood event as it developed. This resulted in a general underestimation of the severity of the event.
- flood forecasting models are not widely used operationally by the Agency, and where they are the techniques are sometimes outdated.

Another issue that has hindered the introduction of an integrated approach to flood detection and forecasting is that of the reliability and fallibility of technology and the resultant lack of confidence in its operational use. As technology was being introduced in the 1970s importance was given to continuing to supplement information with manual observations. As staff resources reduced in the 1980s and 1990s this became increasingly difficult to support and greater reliance was placed on technology. The Easter floods exposed the dangers of this reliance with weather radar underestimating the quantity of rainfall, raingauges and river gauges failing to measure the magnitude of the event, and some telemetry equipment malfunctioning altogether. All these factors conspired to give hydrologists and meteorologists a misleading picture of the severity of the event, giving rise to an under-reaction in certain areas. It is interesting to note that in the United States where the use of technology in flood detection and forecasting is highly advanced, there is still a widespread use of field observers in flooding situations (Haggett, 1997). Staff are sent to key locations to give visual confirmation of the situation on the ground especially in extreme conditions when gauge readings are not always trusted. This is a good example of the continuing need to integrate low and high technological techniques to deliver an effective service

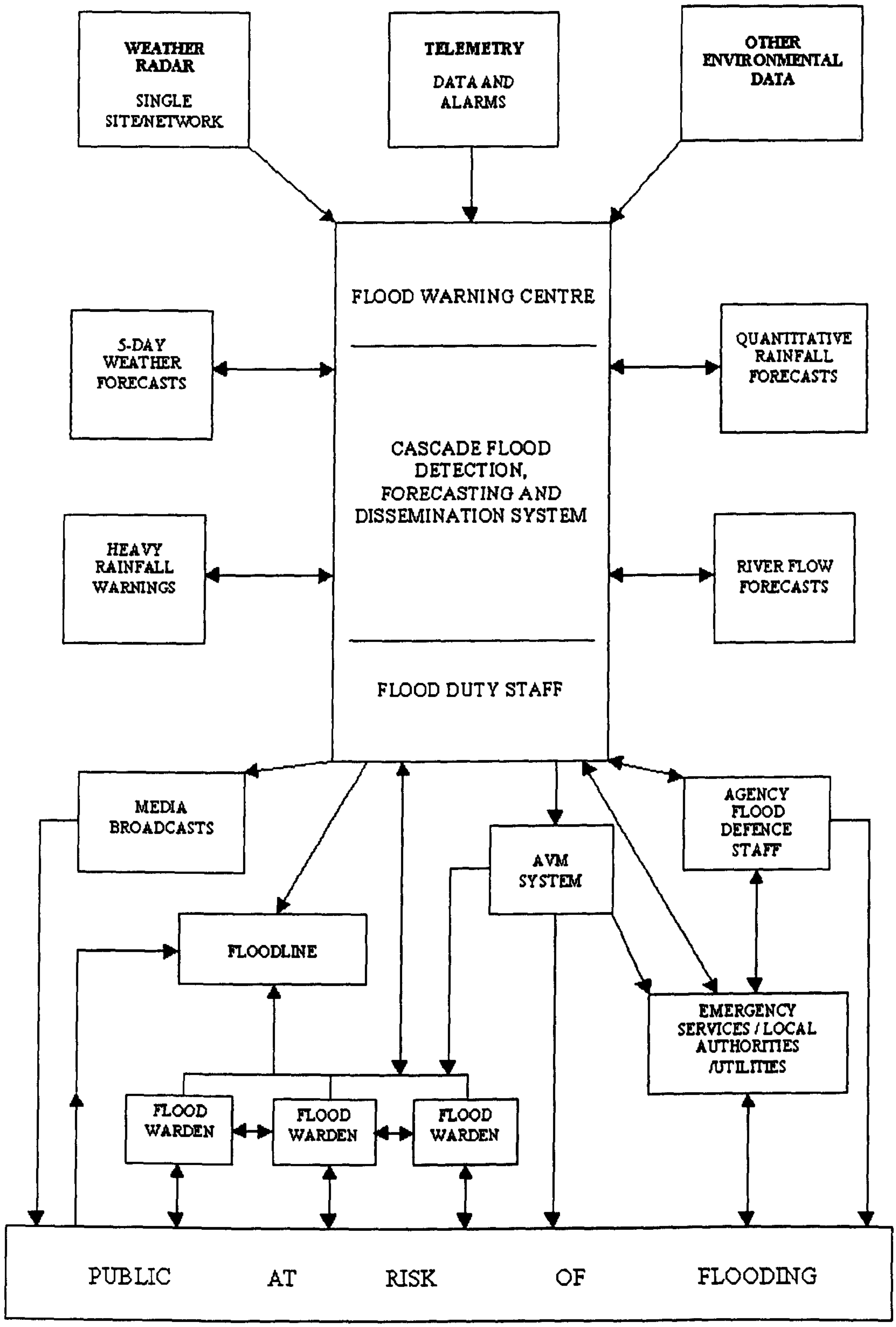
5.2.2 Flood warning dissemination and response

Perhaps the most important piece of technology in use today in flood warning systems is the telephone (see Table 5.7). The use of the public switched telephone system (PSTN) not only offers the ability to target information to those who need to receive it, but has enabled the integration of technical aspects of data collection and analysis. As Figure 5.2 illustrates, telephone networks effectively link the various components of modern FDFWR systems, from the capturing of data from telemetry networks and weather radar to the dissemination of warning information to a range of recipients. Whereas in the past, concerns about reliability and robustness of telephone networks, especially in flooding situations, limited their utility, the advent of digital exchanges, water-resistant cabling and more effective maintenance have improved performance dramatically.

One advantage that the telephone brings to flood warning dissemination is that it offers a mechanism for providing a personalised delivery of information from a remote location. Next to face-to-face contact, person-to-person dialogue is probably the highest level of integration that can be achieved. Another advantage is that most households are equipped with a telephone and all sections of society are familiar with and are able to use the equipment effectively. The provision of flood warnings manually by telephone does have some disadvantages. It can, for instance, take a significant length of time to mobilise sufficient staff resources in warning agencies and alert large numbers of people using this method.

Prior to 1996, the use of technology to improve public warning had been limited, although some techniques have been tested, such as alerting of flood wardens by telemetry devices. This "Watchdog" system was introduced in London in the 1980s and involved the automatic triggering of alarm calls when critical river levels were reached. The system was eventually replaced by a more robust, manual person-to-person approach due to problems of reliability with the technology. This proved to be popular with the warning recipients and allowed duty staff to receive feedback from wardens that was not possible with the automated system.

Figure 5.2: Thames Region's CASCADE flood warning system.



In 1996, the Agency introduced more technological methods to alert and inform the public. The automatic voice messaging (AVM) and FLOODCALL voice-bank systems are now in routine operational use across England and Wales from the Agency's 21 flood warning centres. Both systems have the potential of passing information rapidly to large numbers of people, but as reliance on these systems increases, it is important that they are operationally robust. Although technological failures have occurred at critical times resulting in some loss of confidence by recipients and operators, the use of this technology has been a positive development. Nevertheless, a number of disadvantages can be identified with specific relevance to integration:

- the AVM system needs individual contact details of each recipient. As these numbers increase the maintenance of databases becomes increasingly difficult, especially in urban areas where public mobility is greatest. If AVM warnings were offered to all residents in the 100-year flood risk area in England and Wales, over a million telephone numbers would have to be kept current

- errors in the data stored in the AVM databases and other technical problems can result in warning messages failing to be disseminated effectively (see below). Quality checks and back-up arrangements are essential to minimise the effects of such matters.

- there is some evidence to show that individuals can become over reliant on AVM warnings and stop acting on their own initiative in response to their own observations. There have been instances where farmers, who normally keep a close eye on the weather and river levels and move livestock when flooding is considered likely, have tended to rely less on their own observations once placed on the AVM system.

- the AVM, and particularly the FLOODCALL system, work most effectively if the recipient has a touch-tone telephone. There in an assumption that most recipients in flood risk areas have access to this technology, but a survey of 220 flood warning recipients in the Thames Region indicates that 22% still have dial telephones installed in their homes (see Table 5.8). This implies therefore, that nearly a quarter of the at-risk public in the Thames Region could have difficulty accessing flood warning information disseminated by the Agency using this technology, giving rise to severe integration problems if this was left unchecked.

- although the AVM and FLOODCALL systems were introduced consistently across all Agency regions in 1996, they are standalone systems and the technology has not been easily integrated with systems that are in operation in each region. In the Thames Region, for instance, the CASCADE system is used to disseminate warnings to outside authorities and the media which is also used to detect and forecast floods.

- the AVM allows the dissemination of a 60-second voice message (the need to repeat the message gives only 30 to 40 seconds of effective recording time) and FLOODCALL has just 20 "information boxes" for all rivers in the Thames Region. Both systems therefore, constrain the amount of information that can be communicated to warning recipients and as a consequence duty staff in the Agency are only able to provide general details of flooding in a given locality. The technology does not allow duty staff to communicate specific and locally relevant information demanded by the at-risk public (BMRB, 1999).

Table 5.6: Data types available as input to flow forecasting models in the Thames Region

Data type	Data origin
Rainfall accumulations	Telemetered raingauge network
River flows	Telemetered river flow gauges
River levels	Telemetered river level gauges
Radar-rainfall accumulations	Chenies radar – single site
Raingauge adjusted radar-rainfall accumulations	Chenies radar and raingauge network
Rainfall forecast accumulations (6 hours ahead)	Nimrod quantitative precipitation forecasts
Rainfall forecast accumulations (2 hours ahead)	Hyrad quantitative precipitation forecasts
Rainfall forecast accumulations (3 hours ahead)	GANDOLF thunderstorm warning system

Table 5.7: Use of telephone circuits in the Flood Warning Centre, Reading.

Function	Number of circuits	Type of circuit
Telemetry polling	25	Exchange line
Alarm handling	2	Exchange line
Weather radar data	3	Private wire
Rainfall forecast data	2	Private wire
Remote computer access	8	Exchange line
Automatic Voice Messaging Written message dissemination Remote access	12 6 2	ISDN Exchange line (fax) Exchange line
Warning dissemination to external authorities/media	12	Exchange line (fax)
Floodcall	2	Exchange line
Flood warden helpline	1	Exchange line
General public helpline	1	Exchange line
Information exchange	3	Exchange line (fax)
General FW Centre lines	8	Exchange line
Written message dissemination	2	Telex line

Table 5.8: Type of Telephone in use by Flood Warning Recipients in the Thames Region

Operating Area	Pulse	% of those responding	Tone	% of those responding	No response
West	3	23%	10	77%	7
North East	14	19%	59	81%	47
South East	14	25%	42	75%	24
Total	**31**	**22%**	**111**	**78%**	**78**

The Easter 1998 Flood Review assesses the use of these systems in flood warning dissemination and makes the following comments which have relevance to integration (Bye and Horner, 1998):

> "an error in the pre-programming of the AVM system resulted in amber and red alerts failing to be communicated".
>
> "although expressing preference for person to person telephone contact, the AVM and FLOODCALL services are generally accepted by members of the public as appropriate existing or potential dissemination methods".
>
> "for people who are unfamiliar with modern telephone based information systems, FLOODCALL is confusing and this inhibits its effectiveness as a warning mechanism. In one region, under 50% of calls made by the public connected to the message box and the majority of callers did not, therefore, obtain any information".
>
> "consideration should be given to augmenting, or in due course replacing, the AVM system with one which offers the flexibility to issue warnings to any area identified as at risk during the forecasting phase".

> "Thames Region do not use the AVM system for dissemination of warnings to people at risk. Methods achieving direct personal contact are preferred and independent surveys commissioned by the Agency have revealed that a personal form of service is favoured by most recipients"

These comments highlight problems associated with reliability, accessibility, familiarity and flexibility. For technology to enhance the development of an integrated FDFWR system it needs to be robust, user friendly, accessible and non-confining. The most successful solutions may be those that bring together high-tech systems with more low-tech, personalised approaches.

Because organisations in receipt of flood warning messages, such as the local authorities, emergency services and utility companies, require written confirmation for reasons of security and ease of onward transmission, the telex and facsimile have been utilised for this purpose. The technology that supports facsimile and telex systems advanced significantly in the late 1980s/early 1990s as terminal equipment became more compact and cheaper to procure, multi-polling became possible and the integration of hardware into computer controlled systems became operationally feasible.

A number of Flood Warning Centres introduced these more sophisticated faxing and telexing systems into operational procedures, often borrowing and adapting the technology that had been developed for other purposes. In the Thames Region, for example, the TEXTEL system, that was developed and marketed by a firm of travel agents, was adapted to issue telex and facsimile messages via a host computer. This allowed dissemination systems to be integrated with those dealing with detection and forecasting. For the first time warning messages could be issued from the same computer terminal that was used to monitor telemetry gauges and weather radar, whether in the Flood Warning Centre or at duty officers' homes. This speeded-up and simplified warning procedures considerably, allowing up to 180 organisations to receive direct flood warning notices within a 15 minute period via 12 linked facsimile units.

Although the introduction of these and other techniques represent a positive development for integration on the one hand, they can create integration problems on the other. By their very nature, technological solutions mean that messages are sent impersonally and there is often no guarantee that they are received and acted upon by the appropriate individuals. This contrasts with a person-to-person communication interface where message transmission is more personal and direct. There have been instances, for example, when warning messages have been sent by facsimile to local authority offices but have not been discovered for several hours because the offices were not staffed at the time of receipt. In this context technology can give rise to a discontinuity in communication and have a negative impact on integration.

Since the 1970s the police have used their own information transmission media to disseminate warnings from their central headquarters to local police stations and thence to local police officers on the beat. Initially, the main medium was the police's own radio networks supported by telex messages. The police have constantly updated their internal communications systems to meet the needs of their core functions and most forces have progressively introduced state-of-the-art systems that have resulted in the efficient and reliable routing of flood warning messages both internally and to other emergency services. The Metropolitan Police at New Scotland Yard, for instance, are able to re-transmit warning notices received from the Environment Agency to the appropriate local police station, which are staffed on a 24 hour basis, within seconds of receipt. The police's internal communications system is therefore, both highly sophisticated and very well integrated.

In marked contrast to the procedures outlined above, less sophisticated techniques are generally used by the police at a local level to disseminate warnings to others. Local authority staff, for instance, normally operate a duty officer standby arrangement whereby the local police station makes contact by telephone using a duty roster provided. These arrangements have not changed to any great degree over the last thirty years, although some of the local authorities now offer a 24-hour contact point, some equipped with facsimile machines. Public warning arrangements had also evolved little between the 1960s and 1996, with local police touring risk areas and alerting residents using a range of techniques including, vehicle-based loudhailer, sirens, door-to-door knocking and direct telephone call, each of which has advantages and disadvantages. Although these approaches, involving warning dissemination by word of mouth and on a face-to-face basis, are often portrayed as being antiquated and "low-tech", they are often highly integrated and personalised when targeted correctly, and can contrast sharply with the more impersonal AVM technology referred to above.

In practice, warning mechanisms such as loudhailers and sirens can be unduly indiscriminate with whole streets or communities being alerted when in reality the risk may be relevant to only a few properties. There is a danger that loudhailers can be over-used to the extent that they cause unnecessary alarm. The Environment Agency now offers such a service in some areas, but greater care is needed to target the delivery of warnings more effectively. Research carried out in London (GLC, 1979) shows that the audibility of sirens is not great under certain conditions and that they are also misunderstood. In Operation Floodcall undertaken in London in 1978, 77% of those targeted by a siren warning failed to hear the alert, and 12 of the 82 sirens sounded failed to operate at all. Both warning mechanisms, therefore, although reaching a wide audience, run a high-risk of misinterpretation. The exception is in coastal areas where flooding is likely to be widespread affecting whole communities who often clearly understand the risk they face. Some of these schemes are in decline however, due to problems of responsibility for upkeep and repair of the hardware. It is interesting to note however, that in response to flooding in Northampton during Easter 1998 and after public consultation, a siren system was installed in the city. Nevertheless, the first test of this system resulted in a high proportion of people failing to hear the sirens even though they were given advanced notice of the test.

The use of the media to disseminate public flood warning information has featured to a greater extent since 1996. The Agency has secured agreements for the transmission of warning messages with a number of media outlets, including local radio stations, television text services, travel bureaux and the Met Office for inclusion in weather forecasts. Messages are forwarded to all these outlets by facsimile in an agreed, nationally consistent format. A number of shortcomings can be identified with these arrangements that have relevance to integration:

- many local radio stations have a limited budget and usually operate with a single facsimile machine for incoming information. There is a high probability therefore, that either the line will be busy or in the sheer volume of traffic a flood warning message may be overlooked and not acted upon.
- national media outlets, such as Teletext, employ a news agency to receive and collate information before disseminating summaries for public consumption. In situations of widespread flooding across several regions, many of the Agency's 21 Flood Warning Centres may be sending information simultaneously. The volume of information is likely to be large and this needs to be rapidly assimilated and prioritised. For example, in the Thames Region alone a catchment-wide flood could generate up to 400 individual warning messages (127 reaches and 3 warning stages).

There are dangers therefore, that a single news agency will get easily overwhelmed and block or distort the dissemination process.

- the amount of information that can be communicated via individual media outlets is usually small. On Teletext for instance, each warning message is restricted to a few words only. In addition, the agreements that the Agency has secured with the media do not give any guarantee that a warning message will get broadcast at all.

- to be effective, the public needs to have access to the technology that provides the media information and a clear understanding of the public's listening and viewing habits is required. A smaller survey of 21 flood wardens in the Thames Region provides some useful insights in this context. Unsurprisingly, all wardens owned a television, but 67% had access to the text services (so that 23% of wardens did not have access to one of the Agency's warning outlets) and only 1% had invested in cable television. Nearly all respondents (95%) listened to the radio at sometime during the day, however 67% indicated that they regularly listened to just 1 radio station, whereas 14% listened to 2 stations and a further 14% to 3 stations. By conducting surveys such as this the Agency will be able to better assess the needs of the public and their ability to access flood warning information.

Table 5.9: Media access amongst Flood Wardens in Thames Region

Media outlet	Yes	%	No	%
Television	21	100	0	0
Television Text	14	67	7	33
Cable	1	5	20	95
Radio	20	95	1	5
1 station only	14	67		
2 stations	3	14		
3 stations	3	14		
4 stations	0	0		

5.3 Analysis of the impact on integration of current technologies.

To be able to assess the impact on integration of current technologies in common use in FDFWR systems it is necessary to develop an appropriate analytical framework. To meet this need a simple methodology is proposed in which each technology is assessed in turn and categorised into low, medium and high impact. As discussed in Section 5.2, some technologies can have a positive impact on integration, whilst others can impact negatively, this makes it necessary therefore, to analyse the full spectrum of impacts from highly negative to highly positive. It is recognised that this process can be very judgmental and that different practitioners would make different assessments, but it is nevertheless considered to be of value.

Table 5.10 sets out the results of this analysis in which 13 technologies currently in operational use in FDFWR systems are assessed it turn with reference to 4 integration impact areas per technology. It is clear that there is not only variation between each technology in terms of their impact, but that each individual technology can have different impacts depending on the integration impact area under consideration. For example, the introduction of telemetry systems is judged to have had a medium-positive impact on integration in terms of data collation and reliability, but a low-negative impact due to inconsistent application and poor spatial coverage, making its overall impact positive. If a crude scoring regime is applied to all technologies and all impact areas, then it can be seen that on balance the introduction of technological solutions has had a positive impact on the integration of FDFWR systems (see Table 5.10).

5.4 Technological applications to enhance integrated FFWRS

Technology is continually changing and the rate of change is accelerating dramatically. This section will examine how technology is likely to impact on integrated flood warning systems in England and Wales in the future, including those technologies that have been developed but not widely implemented and those that are still in the research phase.

Over the last 30 years there has been a tendency to use technology to meet a specific need or provide a solution to a particular problem, such as a river level gauge to measure and assess the rate of rise in a watercourse. There are signs that this detached approach, which can lead to fragmentation, is changing and that technology is starting to be used more to consolidate. This is most apparent in flood detection and forecasting systems where increasingly powerful computer systems, communications and data base technology are allowing advances of this kind to be implemented operationally.

The detection and forecasting system in operation in the Thames Region for example, is becoming increasingly sophisticated. Moore (1993) states that the CASCADE flood forecasting system is arguably the most advanced in the Agency in its deployment of weather radar for instance. Much work has been undertaken in recent years to link together the formerly disparate telemetry systems and integrate them with weather radar and satellite data to form a regional flood detection scheme allowing operational access to any individual outstation via one computer system. The incorporation of local radar calibration (which operationally adjusts the radar data with data from 105 raingauges) and forecasting systems, including rainfall forecasts from the Nimrod, Hyrad and GANDOLF systems, and a range of processing and display tools, makes it very versatile. More work is needed however, to develop an automated flood forecasting capability and improve the interfacing of the detection and forecasting subsystems. The real-time measurement of rainfall and river flow could be used to improve the quality of flow predictions further through state-updating or error prediction. Plans are in place to improve these aspects, but as Moore (1993) comments, "whilst CASCADE can make model predictions for specific catchments, developments have not yet been made to co-ordinate the construction of forecasts down the river network".

This step has been taken with the Regional Flow Forecasting System (RFFS) developed by the Institute of Hydrology (Moore, 1993). The system is an example of a generic flow forecasting system capable of integrating the task of flood forecast construction for both simple and complex river networks and is likely to be the forerunner of a new approach in operational forecasting in England and Wales. The system has been developed to invoke and manage the co-ordination of data acquisition needed for forecast construction and the ordered execution of models working from the headwaters of a catchment to the sea. It tackles a possibly complex overall forecasting problem through division into a number of simpler sub-problems or "model components". A model component is typically made up of a number of model algorithms, for example for snowmelt modelling, rainfall-runoff modelling or real-time updating. Such an integrated flow prediction system is capable of forecasting at hundreds of locations over a region and incorporating flexible decision-support tools for flood warning and river control. The first implementation of RFFS was to provide forecasts at some 150 locations within the 13,500 km^2 region of Yorkshire and operated on a trial basis in 1992/3. The system is also to be installed in the Thames Region in the near future but such systems have yet to be implemented widely across the Agency. This integrated approach is supported by the Easter 1998 Flood Review that recommends that modelling should be rationalised and

Table 5.10: Impact assessment of technology in current use in FDFWR systems.

Technology	Integration Impact area	Negative Impact			Neutral Impact	Positive Impact		
		High	Medium	Low		Low	Medium	High
River level/flow measurement	1. Collation of data					X		
	2. Consistently applied		X					
	3. Accuracy in floods		X					
	4. Spatial coverage		X					
Telemetry	1. Collation of data						X	
	2. Consistently applied			X				
	3. Reliability						X	
	4. Spatial coverage			X				
Computer systems	1. Collation of data							X
	2. Collation of systems			X				
	3. Consistently applied			X				
	4. Reliability					X		
Weather radar	1. Collation of data						X	
	2. Spatial coverage							X
	3. Accuracy in floods		X					
	4. Consistently applied					X		
Modelling systems	1. Collation of data						X	
	2. Consistently applied		X					
	3. Accuracy in floods			X				
	4. Spatial coverage		X					
Telephone networks	1. User-friendliness							X
	2. Reliability						X	
	3. Personalised delivery						X	
	4. Multiple recipients					X		
AVM/ Floodcall	1. User-friendliness			X				
	2. Reliability			X				
	3. Personalised delivery			X				
	4. Multiple recipients							X
Facsimile	1. User-friendliness					X		
	2. Reliability					X		
	3. Personalised delivery			X				
	4. Multiple recipients						X	
Teletext	1. User-friendliness					X		
	2. Accessibility			X				
	3. Locally specific			X				
	4. Multiple recipients						X	
Local Radio	1. User-friendliness						X	
	2. Accessibility						X	
	3. Locally specific						X	
	4. Multiple recipients						X	
Loudhailer	1. User-friendliness				X			
	2. Accessibility			X				
	3. Locally specific					X		
	4. Multiple recipients					X		
Sirens	1. User-friendliness		X					
	2. Accessibility					X		
	3. Locally specific			X				
	4. Multiple recipients						X	
Face-to-face	1. User-friendliness							X
	2. Accessibility							X
	3. Locally specific							X
	4. Multiple recipients							
TOTAL SCORE	High=3, medium=2, low=1, neutral =0	0	-14	-13	0	10	26	21

founded on a small number of state-of-the-art techniques relevant to the range of basic catchment characteristics found across the country (Bye and Horner, 1998).

Forecasting in the Thames Region has tended to concentrate on rainfall prediction and rainfall/runoff modelling. Improvements in the forecasting subsystem to enable predictions to be made of the precise areas and properties liable to flood for an event of a given magnitude, would be an important step forward. To achieve this however, links would need to be established between model predictions and a database of property information maintained on a river reach basis. This in turn would require the development and deployment of real-time hydraulic models that could predict out-of-bank flows and flood extents for individual flood events. This would allow targeted flood warnings to be issued to those properties identified by the forecasting system. Realistically, models of this type are unlikely to be introduced operationally in the short term, but this approach does offer the possibility of greater integration between the forecasting and dissemination elements of a FDFWR system.

A further step in this process would include the use of Digital Terrain Models (DTM) and Geographical Information Systems (GIS) facilitating the simulation of the extent of a flood event ahead of its actual rise. Software could be developed to construct computer generated maps to indicate the locations of rivers, streets, utilities, property boundaries, and contours and flood routes. Once survey data of significant features are obtained, such as low points on roads or the threshold levels of buildings, it would be possible to use such systems to obtain an impression of the likely extent and consequences of an impending flood when the forecast level is reached. It is important to ensure however, that duty staff are not presented with more information that they can assimilate and act upon at peak times. To minimise these effects, technology should be used to streamline presentation and aid in assimilation

Message dissemination systems are increasingly becoming computer-based and in some instances, as with the CASCADE system, are being operated on the same computers that operate the detection and forecasting systems. This integration process gives the ability of accessing all components via one computer terminal that may be situated at the flood warning centre or at a remote location. Flood warning messages can be distributed rapidly between organisations via banks of computer controlled facsimile machines. In the future, the use of electronic mail through local and wide area communication networks and the internet offer alternative means of disseminating information and examples of how greater integration can be achieved with emerging communications technology.

Public warning has traditionally relied on methods such as sirens and door-to-door knocking, but here too technology offers scope for improvement. Advanced automatic voice messaging systems are being developed to alert large numbers of people in short time periods of impending danger. British Telecom for example, is developing the Tallis system that telephones those living in an affected area and delivers an alert message (British Telecom, 1997). A digitised map of the British Isles linked to a database of every telephone number in the country is central to the warning system. Operators can highlight the area likely to be affected on a computer screen and the system will then begin telephoning all the numbers within the delineated boundary and deliver the warning message. The message is fed into the system as text and the computer converts it to speech. It is capable of telephoning 10,000 numbers in an hour, logging responses and listing those it could not reach. At present, 93 per cent of homes have a telephone, but the system takes account of those without. The database includes information about homes without a telephone and their neighbour's warning message can be tailored to include instructions on when to warn them about the danger. The hard of hearing can have vibrating/flashing systems to alert them to a telephone call and receive warning messages via text-phone units. The system can also be configured to ensure that those who are likely to be flooded first are called first, working outward to those at least risk. To be fully integrated however, there is a need for such systems to be both user-friendly and user-accessible as the more impersonal the warning message the less the recipient is likely to believe it and take effective action.

The full potential of the internet and email have yet to be fully exploited for flood warning purposes in the UK. The internet is extensively used in the United States and is not only seen as a important mechanism for the rapid acquisition and dissemination of hydrological data, but also for disseminating warning information (Haggett, 1997). The internet and email have the potential to facilitate interaction between organisations, allowing the pooling of appropriate data in both the planning phase and during actual floods. The fact that such information can also be accessed by the public is an important consideration for integration and as the number of people linked to the internet increases in the UK (estimated to be nine million), this will be an increasingly significant mechanism for disseminating information in future years. It should be recognised however, that sections of the population will always be excluded from this technology for reasons of income, infirmity or other special needs. Recent public surveys for example, have indicated that the elderly tend to occupy flood plains more than other areas (BMRB, 1998, 1999), a section of the community that may have difficulty relating to technology such as the internet and email.

Much of the technology being used to improve flood warning dissemination in the United States centres on the use of the media. For instance, emergency mangers have the ability to override cable television on all channels to turn screens blank and give 30-second audio messages or scrolled text messages. This is seen as a very powerful tool in emergency situations and managers have full editorial control, an arrangement that is written into the licenses of the cable operators. Digital technology is being adopted to broadcast warning messages over the radio networks in the United States. The NOAA Weather Radio has more than 425 stations in 50 states and the goal of the National Weather Service is to expand the reach of weather radio broadcasts to 95% of the U.S. population (U.S. Department of Commerce, 1997). Radio sets turn on automatically and/or sound a *tone alarm* when severe weather announcements or emergency information are broadcast. The hearing and visually impaired can also receive these warnings by connecting weather radios to other attention-getting devices, such as strobe lights, pagers, bed-shakers, personal computers and text printers. There have been investigations made on the viability of using technology to activate television sets remotely and relay warning messages, however there have been civil rights concerns regarding the implementation of such a facility.

As computer systems increase in power and decrease in price the prospect of integrating systems further becomes possible. Expert and decision support systems offer a mechanism for achieving this. Such systems are often complex and require significant computer resources to operate in real-time, a facility that has not been available until relatively recently. The GANDOLF thunderstorm forecasting system, developed jointly by the Met. Office and the Environment Agency, illustrates how such a decision support procedure can start to evolve. It utilises meteorological data from various sources and produces new forecasts every ten minutes. Such extensive data processing could not be achieved even a few years ago due to the large amount of computing resources that are required to operate the system. GANDOLF attempts to tackle the problem facing the hydrologist of determining which rainfall forecasting technique to use quantitatively to predict river flow. GANDOLF establishes a procedure that will automatically select the most appropriate forecast scheme through the identification of the weather type together with a measure of the degree to which convective development is occurring (Pierce et al, in press). The GANDOLF system is designed to be integrated into the Environment Agency's flow forecasting systems but the main problem to date has been one of operational implementation across the Agency's regions. Although the system has been successfully introduced in the Thames Region, due to incompatible systems this has not been achieved across all regions. There is much scope for furthering the use of expert and decision support systems in operational flood warning and this has the potential for being very integrative. As computer technology advances the complexity of these systems will increase to encompass not only detection and forecasting but the dissemination and response elements as well. This potential will not be realised however, until the incompatibility issue is addressed.

In the home, technology may be used in the future to integrate various functions including communication with the outside world. Berg (1995) talks about the "Smart House" which denotes the extensive application of information technology to the dwelling of the future. Such a dwelling could receive information from a range of sources via telephone, cable, and even satellite into an integrated central control unit. This would facilitate the receipt of flood warning information and possibly data direct from detection and forecasting systems. As discussed in Section 5.2, although this development would obviously be advantageous for certain sections of society, it would not be accessible to all. Berg (1995) also raises the implications of such arrangements on gender. Technology is traditionally a masculine domain whereas the home is traditionally a female domain. Berg puts forward evidence that men have dominated the design, installation and use of technology and consequently this might result in women becoming excluded from its utility in the home.

Technological development is a highly dynamic process and it is difficult to know precisely how it will impact on flood warning systems over the next ten years. It is possible to identify a number of specific enhancements however, that could be developed and introduced during this period that will go some way to further improve the integration process. These enhancements are set out in Table 5.11. It is of course highly feasible that many of these technological developments will be introduced into operational flood warning procedures over the next two decades. It must be acknowledged however, that access to new technological developments will continue to be distributed unevenly, and in the case of the underprivileged members of society this will be limited. This is an important integration issue.

Thomas (1995) makes the point that technological developments, far from creating a more egalitarian world, will bring about a society that is more unequal as well as socially fragmented. He believes that technological developments tend to confirm or reinforce existing inequalities, and to create new inequalities. As the pace of change accelerates, the gap between those who have access to the new technology and those who do not will widen and this will have implications for the future development of integrated flood warning systems if reliance on technological solutions becomes too great. In short, sections of society will progressively become excluded from the benefits of a technology-driven flood warning service.

5.5 Assessment of the impact on integration of future technologies

In this section the analysis undertaken in Section 5.3 is repeated for future technologies likely to impact on FDFWR systems. Eight technologies are considered with four integration impact areas per technology. Table 5.12 illustrates that although it is still judged that variation will still exist between and amongst technologies, the overall assessment is that the potential impact is very positive for integration. It is vital however, that these technologies are implemented in an integrated way and that current practices are not perpetuated. As discussed in Section 5.2, many technologies in operational use today have a high potential impact for integration but in practice this is not realised due to poor implementation policies.

5.6 Issues arising from the assessment of technology usage in flood warning systems

Through the analysis presented in this chapter, of the current and potential use of technologies in FDFWR systems, it is possible to identify a number of key issues that have particular relevance to integration and these will be summarised here. It is useful to draw on the integrative factors identified in Chapter 2 and added to in this chapter, to assess further the degree to which technology has influenced integration.

Technology has resulted in the decline of informal, community-based arrangements.

Prior to the first introduction of official flood warning procedures in England and Wales in the 1960s any warning arrangements that were in place were largely local in scale, non-technical and community-based, with a high degree of local community ownership. These arrangements were highly integrated. The evolution of technology in detection and forecasting and the establishment of formal co-operative arrangements between agencies to facilitate the exchange of information, resulted in the decline of the old community-based self-help systems. The recent application of technology to flood warning dissemination has tended to fuel the culture of reliance that has gradually developed over the last 30 years. Many recipients of flood warnings seem content to sit back and wait for the Environment Agency to issue alerts, but are also quick to apportion blame when things go wrong. As Rowe and Thompson (1996) state,

> "there is a danger that technology becomes one's controller rather than one's servant. Just as working skills are transferred to machines, so the human activities of waking up, ascertaining the weather, remembering commitments, making decisions, etc. are taken from us and we cease to think for ourselves".

Technology should be applied evenly within and across the elements of flood warning systems.

Evidence has been presented in this chapter to indicate that technology has not been applied evenly across the four elements of flood warning systems and indeed there are inconsistencies in its application within the same element. In areas where flooding is relatively frequent, for example, there has been an early and persistent preoccupation with developing techniques to first detect and then forecast floods, and these have become more and more sophisticated over the years. In areas where flood risk is low however, investment in state-of-the-art technology has not been forthcoming and either more rudimentary arrangements are more typical or no systems have been put in place at all. The Agency has commissioned extensive research and development into flood forecasting and warning over a number of years. The results of such research however, often involving technological solutions, have not been routinely introduced into the development of operational practices. This has meant that leading-edge systems are not universally in place across the Agency's eight regions and this has lead to the evolution of inconsistent and poorly integrated practices across England and Wales. These fragmented arrangements are brought sharply into focus when widespread and extreme floods occur such as during Easter 1998. Another complication is that the Agency's

Table 5.11: Technological developments likely to improve the integration of flood warning systems

Detection Systems	Once all required detection systems are accessible on a common computer system, one system could automatically initiate the operation of another when certain criteria are met, e.g. heavy rainfall measured by weather radar could trigger telemetry polling.
	Operationally linked detection systems can be used to improve data accuracy, e.g. weather radar data adjusted with telemetry information.
	An alarm or exception condition from a detection system could act as a trigger to the activation of flow forecasting systems.
	Exception conditions generated from a detection system or an activated forecasting procedure could in turn activate instructions for duty officers with respect to warning dissemination.
	Computer systems belonging to different agencies could be linked so that a flood forecasting agency's telemetry data could be made available to the met. service to improve the rainfall forecasts provided to the flood forecaster.
	Detection and forecasting computers could be accessible by the public either directly or via the internet. The public would be able to obtain real-time data covering their local river that could link into informal warning or self-help procedures. Such access would need to be supported by a public education programme.
	Closed-circuit television cameras located at key flood warning gauges could transmit information over the internet. Filming of actual floods and of gauges to check their operation would aid detection and allow staff in control centres to determine whether the gauge has been vandalised or may be blocked with debris.
Forecasting Systems	Forecast models could be operationally linked to the data output from a number of detection systems allowing the generation of alternative forecasts, e.g. using raingauges or radar data or a combination of the two.
	Measured river flow data could be used to automatically correct flow forecasts in real-time thereby improving the forecast for the next time step.
	Different forecasting models could be linked operationally e.g. meteorological forecasting to hydrological forecasting models, rainfall forecasts to rainfall/runoff forecasts to flood level forecasts.
	Linked forecasting systems could in turn be coupled to flood risk maps and property level databases held on a geographical information system (GIS) and to Digital Terrain Models (DTM).
	Flood forecasts could be made available to the public via the media. The use of experts to communicate this information on radio and television broadcasts using graphics.
Dissemination Systems	Flood warning message dissemination systems could be operationally linked to detection and forecasting systems, running on a common computer facility.
	Public warning mechanisms could be triggered by detection systems, e.g. sirens or pagers could be automatically activated by a telemetered river level gauge.
	Forecasting systems, linked to property databases, could feed into automatic voice messaging systems resulting in targeted warnings to at-risk householders.
	Linked computer systems between the forecasting agency and media outlets, such as local radio, television text and travel services, could facilitate the rapid dissemination of broadcast warning messages.
	Computer links into flood wardens' homes could present a means of disseminating warning messages (possibly automatically triggered by a detection/forecasting system), but could also facilitate the two-way exchange of information allowing the warden to notify the forecaster of local flooding incidents or river blockages.
Response Systems	Flood warning information systems could be used to advise the public of the status of flood warnings and how best to respond. Auto-routing facilities, based on the telephone exchange the caller is dialling from, can select the appropriate information for the local area.
	Automatic voice messaging systems can detect whether flood warning messages have been received and acknowledged, if not alternative arrangements can be made to improve the response to the warning.
	Warning messages could be formatted flexibly to allow the automatic inclusion of advice about the most appropriate behavioural response for the impending situation, as defined by the detection/forecasting system, e.g. a flash flood would require a different response to a slow winter flood.
	"Fax-back" systems could give the at-risk public a facility to obtain up-to-date advice on what action to take in a flood situation. The current status of flood warnings and even river level information could be acquired by this method.
	The internet and cable technology could be harnessed to issue "live" information and advice to flood plain inhabitants. Warnings could be disseminated by these routes.

Table 5.12: Potential impact assessment of future technology.

Technology	Integration Impact area	Negative Impact			Neutral Impact	Positive Impact		
		High	Medium	Low		Low	Medium	High
CCTV at gauged points	1. Collation of data					X		
	2. Confirmation						X	
	3. Accessibility of data					X		
	4. Spatial coverage			X				
Linked computer systems	1. Collation of data							X
	2. Data accessibility							X
	3. Organisational interaction						X	
	4. Spatial coverage						X	
Linked forecast modelling systems	1. Accuracy in floods						X	
	2. Spatial coverage						X	
	3. Universal forecasting							X
	4. Targeted forecasts							X
Expert systems	1. Consistency of service						X	
	2. Confirmation						X	
	3. Informed decision making					X		
	4. Locally specific service			X				
Internet	1. Universally accessible					X		
	2. Locally specific					X		
	3. Rapid dissemination of information							X
	4. Multiple users						X	
Auto-activated warning broadcasts	1. Universally accessible						X	
	2. Multiple recipients						X	
	3. User friendliness						X	
	4. Locally specific						X	
Advanced messaging systems	1. Universally accessible						X	
	2. Multiple recipients							X
	3. User friendliness					X		
	4. Personalised delivery					X		
Interactive information systems	1. Universally accessible				X			
	2. Locally specific					X		
	3. User friendliness					X		
	4. Multiple users						X	
TOTAL SCORE	High=3, medium=2, low=1, neutral =0			-2	0	9	28	18

predecessors tended to introduce independent technological systems that have been updated and enhanced separately from each other in the Agency's regions. This inconsistent approach becomes self-perpetuating as manufacturers deliberately adopt incompatible protocols to tie users into their systems. The transfer of data and techniques between regions is made difficult which further inhibits the introduction of new products on a consistent basis thereby hindering integration.

Concerns over the reliability and fallibility of technology can result in loss of confidence and integration problems

Ever since technology was first adopted in flood warning systems there has been concern about its reliability and fallibility especially in times of storm and flood. This can be traced from the use of the earliest river gauges, through to the use of telephone communications, computer systems, weather radar, forecasting models and AVM systems. In the 1970s there was greater emphasis placed on using technology in parallel with manual techniques to record river levels for instance. As staff resources were cut back in the 1980s and 1990s this dual approach became less feasible and reliance on technological approaches increased. It is interesting to note however, that in the United States where the use of technology is highly advanced, there is still a perceived need to provide visual confirmation of measurements especially in extreme conditions when gauge readings tend not to be trusted. Indeed, the Easter Floods Review recommends flood forecasting operating procedures should ensure that, "in addition to using model predictions, close attention is paid to monitored flood levels" (Bye and Horner, 1998).

In flood events in England and Wales the performance of technology has been variable. Following the failure of the warning system in London in 1977 for example, although some technological malfunctions occurred, this did not contribute significantly to the failure of the total warning system. Poor integration between organisations was found to be a more important issue. Confidence in technology emerged as a major problem however, and unless systems had a proven operational track record there was a reluctance to trust and rely upon them – an issue that is still relevant today, re-emerging with the introduction of the AVM system in 1996. During the Easter Floods in 1998 problems with weather radar under-recording, poor measurement of river levels and rainfall, and failures of telemetry units all conspired to give duty staff an imprecise appreciation of the scale of the event that adversely affected response and the level of warnings issued. Conversely, there have been instances when the technology has been correctly measuring an extreme condition, but the duty officer has failed to believe in its accuracy. A lack of confidence therefore, can act as a blocking mechanism for action resulting in a delayed response and, in the extreme case, in no action at all. To overcome this problem, it is important to build into any integrated operational system the means to obtain confirmation from alternative sources, especially in severe events, to minimise periods of uncertainty.

Public access to technology can be variable and can lead to problems of integration.

Access to technology is not universal and there is evidence to show that a sizeable section of society is being or will be excluded from using technology-based systems. In many areas at risk of flooding members of the public do not have access to or may be unfamiliar with the technology needed to receive flood warning information. As Huby (1998) comments, the effects of flooding fall most heavily on the more vulnerable groups in society who often have limited access to or experience of technology. Communities in rural areas, in the ethnic minorities, and in inner-cities have been specifically cited in the literature as falling into this category, and there is also some evidence to indicate that women can be disadvantaged in this respect. As discussed in Chapter 2, for integrated systems to work there must be a free flow of and ready access to information. If information is provided solely by technological means on the assumption that it is accessible to all, then this criterion will not be met for certain sections of society. In the Easter 1998 Floods, for instance, the majority of callers to the FLOODCALL service in one region failed to obtain any information from the system. For technology to deliver an integrated service it must be user-friendly and user-accessible, be capable of delivering locally specific information and be supplemented by more traditional and personalised approaches to meet the needs of the diverse public. As pressure increases on organisations such as the Environment Agency to deliver warning information to an increasing number of people, the temptation to use technological solutions is likely to increase as staff resources decrease. This could well lead to a fragmented flood warning service with the prospect of societal inequalities widening further as the pace of technological change accelerates. The importance of engaging local communities to ascertain their needs and ability to receive information is paramount in ensuring an integrated system.

Differing attitudes to technology can block its utility especially when it is perceived not to be user-friendly.

Just as some sections of society become excluded from technology for financial reasons, there are others that exclude themselves due to fear, suspicion or even "hostility towards the tyranny of technocratic power" (Lyon, 1988). The elderly for example, can often feel uncomfortable with technology and view it in a negative way, whereas others may refuse to use technology on a point of principle. Within organisations, certain staff can find computer systems difficult to deal with and will tend to rely on older arrangements that are tried and tested. In extreme cases they may have enough influence to be able to block the introduction of new technology and force the continued reliance on out-dated techniques. This again can lead to fragmentation and inconsistencies in the delivery of the service. The fear and suspicion of technology both in organisations and in communities may be overcome through better training and awareness.

There is anecdotal evidence that when the public is alerted by an AVM call they seek to confirm the message before acting. The assumption by some that the recipients of such alerts would respond without question is not borne out in practice. The FLOODCALL service, that was introduced to provide warning confirmation, does not appear to be satisfying that need in some instances. There appears to be a continuing desire for person-to-person telephone contact i.e. people want to speak to someone to confirm the warning message and obtain locally specific information before responding. Greater attention is needed therefore, to the development of more user-friendly information systems and if this still does not satisfy the public's needs it should be supplemented by person-to-person contact.

The application of technology can result in organisational change giving rise to tensions that are not conducive to integration.

With the introduction of new technology tensions can arise between departments within an organisation that may work against integration. This is most common between the operating department, provider of the service to the customer, and the Information Technology Department, provider of the necessary technology to the operating department. Conflicts can arise over the control of systems, the level and priority of maintenance, and the development of strategies. One common complaint of operating departments is that the IT department does not have the responsibility of service delivery and hence puts less emphasis on ensuring reliability and robustness. Conflicts such as this can result in mistrust and inefficiency that are not conducive to integration. It is common for IT staff to develop a view that "users" lack competence, are unable to articulate their requirements and that only IT people "know best". Operational staff, on the other hand, are often suspicious of their IT colleagues and feel that they work to their own agenda and are generally not supportive (Rowe and Thompson, 1996). This lack of trust results in barriers being raised between departments, which works against a policy of integration within an organisation. Although it would be an exaggeration to suggest that such inter-departmental conflict was widespread, it is certainly common within organisations such as the Environment Agency and the Met Office where operating departments have staff with a high technical capability.

The issue of "hi-tech" solutions versus "low-tech" solutions.

There is a growing concern amongst some practitioners that there is too much reliance on technological solutions in flood warning systems today. As Penning Rowsell (1986) stresses, there is a need to review the technology of flood warning systems in light of local experience and to integrate the appropriate forecast technology with the character of the dissemination system and the likely levels of public response.

> "It may be more appropriate to base forecasts on low technology and concentrate resources on efficient dissemination and response, rather than producing super-accurate forecasts which are either too late or which, when they reach those intended to respond, are in a form which cannot be understood or used" (Penning-Rowsell, 1986).

The driving force has often been the desire to introduce the best technology available rather than considering what is adequate to meet the target level of service for the public at risk in a given locality. It is important therefore, to tailor the methods used to the needs of the local community. An example from Appendix 1 is when letters were distributed to residents at Maidenhead by the NRA, warning them of flooding from the Thames in January 1994 and again in 1995. This "low-tech" approach was effective, personalised and well targeted, and possible because of the long warning lead times and a detailed knowledge of properties at risk in the town.

On a recent visit to the United States by the author a number of relevant comments were made in relation to this issue by workers in both the operational and academic areas:

- "there is no correlation between the fanciest systems and efficiency"
- "more complicated does not always mean better"
- ""high tech" should be balanced with "high touch", often local knowledge is the key"
- "the guys that sit on the bench and watch the river all day long have a better idea of how the river responds than forecasters in an office 50 miles away, this knowledge should be tapped"
- "we are becoming over reliant on technology - what if it fails?"
- "technology must reach down to the end-user (the public at risk) for lives to be saved".

In the past engineers and hydrologists have seen flood warning as simply a technological or mechanical process. There is now a growing recognition that the key to a successful warning system may not always lie in "high-tech" approaches to the exchange of information between senders and recipients. This will be explored in more detail in Chapters 6 and 7 of this thesis.

"Quick-fix" technological solutions can be politically expedient but can hinder integration.

There is a temptation to use technology as a "quick fix" to meet public demand following failures of flood warning arrangements. Such an approach can raise public expectations but may not be sustainable in the long-term. A good example of this is at Leamington, Warwickshire where the public warning system failed during the Easter floods in 1998. The Environment Agency responded to considerable public and political pressure by placing all those affected on the AVM system, over 400 properties in the 150 year flood risk area. This decision places a considerable workload on the Agency in the upkeep of contact databases for a city that floods infrequently. But more importantly for integration, it also points to the need for a similar level of service to be provided in other towns and cities that face the same level of risk but may not have flooded recently.

Senior management in the Agency regards the AVM system as the primary method for disseminating flood warning messages to the public. They place considerable pressure on staff to increase the numbers of recipients on these systems so as to demonstrate that the Agency is extending the warning service. Little regard is given however, to the quality of that service and as to whether it meets the varying needs of the public.

The need for redundancy in technologies

In an integrated flood warning system there is a need for redundancy in technological systems. This not only provides a means of backup in the case of failure, but it also acts to reinforce and support. In detection systems for instance, the measurement of rainfall using both radar and raingauges enables mutual backup and support. It also gives the opportunity for both data streams to be combined to increase accuracy through the use of raingauge adjusted radar images. Warning systems are most effective when information is disseminated from a single source using multiple channels. By operating several technologies side-by-side the warning message is reinforced, the need for confirmation is met, and alternative channels are available in the event of one failing.

Balancing the favourable and unfavourable impacts of technology

Technology can be divided into three broad categories, basic, intermediate and state-of-the-art. It is common in operational flood warning systems for different levels of technology to sit side-by-side and in some cases the resultant arrangement can work well, but in others not. In some circumstances the most basic technology can give the most favourable impact, such as an official manually checking a gauge board and directly warning the local public. In others, state-of-the-art technology can give unfavourable results because of teething problems, being operationally untested in certain circumstances and because of user unfamiliarity. An example would be the use of email to disseminate information. Email offers rapid communication, the ability to transfer large amounts of information and the ability to contact large numbers of recipients simultaneously. Unlike the telephone however, it is not personalised, it is not universally understood, and it does not facilitate easy confirmation and interpretation of the warning message.

Often it is conventional, intermediate technology that is not state-of-the-art that is the most reliable because it is tried and tested. In certain circumstances it is the combination of intermediate and low technologies that gives the best results. An example would be the use of well understood and simple river flow forecasting models combined with observations of experienced field staff.

5.7 Summary and conclusions

It is clear from this analysis that technology has brought mixed benefits to flood warning integration. However, it is not only the technology itself that can influence this process, but also the way in which it is applied. In other words, technology and the application of technology can improve some integration problems whilst at the same time worsen others. Table 5.13 summarises some of the positive and negative impacts that technology can have on the integration of FDFWR systems. The key words for integration in this context are: rapid gathering, capturing, storing, consolidating, simultaneous operation, exchange, interaction, tried and tested and accessible. In contrast, the key words for the more unfavourable impacts are: uneven application, inconsistency, incompatibility, unreliability, fallibility, over-reliance, dependency, suspicion, exclusion and tension. An impact analysis, as presented in Section 5.2, offers a simple mechanism for measuring the impact that each technology may have on integration, be it positive or negative. This approach can be used when introducing a new technology to FDFWR systems to identify the more negative impacts, allowing steps to be taken to minimise their effects.

The desire to introduce the **best** technology available has often taken preference over the need to adopt the **most appropriate** level of technology to ensure the total warning system meets the needs of the target audience at a reasonable cost. Technological alternatives should be assessed as a balance between the potential reduction in flood damage from an improved quality of prediction or a more rapid dissemination system, the cost of technology needed to gain improvement, and the needs of the community at risk of flooding.

In the future, ever more advanced forms of technology will impact on FDFWR systems and if implemented correctly could influence integration in a very positive way. Computer-controlled communication systems, GIS, remote sensing, electronic decision support systems, and risk-analysis techniques are certain to advance substantially over the next two decades and show great promise for supporting the development of integrated flood warning arrangements. For example, the "joined up" use of remote sensing, instant communications, GIS-based models and information systems, combined with the increased availability and use of technology in the home and in mobile form offers some exciting prospects. It may soon be possible for people in flood risk areas, for instance, to monitor the evolution of a flood on their television screens. This could be in the form of continuously updated "live" and forecast flood extent maps, supplemented by locally specific on-line advice on the appropriate action to take in the prevailing circumstances.

Table 5.13: Summary of the impacts of technology on the integration of FDFWR systems

Favourable impacts	Unfavourable impacts
Gathering data rapidly from spatially diverse points	Uneven application to solve single issues
Capturing and storing information over time	Inconsistently applied between functions and within the same function
Ability to consolidate information from a range of disciplines, enabling the formulation of multi-functional plans.	Incompatible technology hampers the interchange of information and systems within and between organisations.
Simultaneous operation of multiple key processes	Low user confidence due to unreliability, fallibility and inaccuracy
Several technologies working side-by-side can reinforce and support	Can discourage self-help and encourage over-reliance and dependency
Can facilitate the rapid exchange of information between large numbers of individuals and organisations	Can engender fear and suspicion if level of user-friendliness is low and technology is not tried and tested
Can stimulate organisational interaction	Public access may be variable leading to exclusion
On-line data processing and analysis can facilitate forecasting for all catchment types	Can result in organisation change and inter-departmental tension
Tried and tested technology can have a high level of reliability and high user confidence	Temptation to use technology as a "quick-fix" irrespective of the quality of service it offers
Some technologies are universally accessible e.g. telephone, television and radio	Public perception that technology can be used to control nature and make people safe

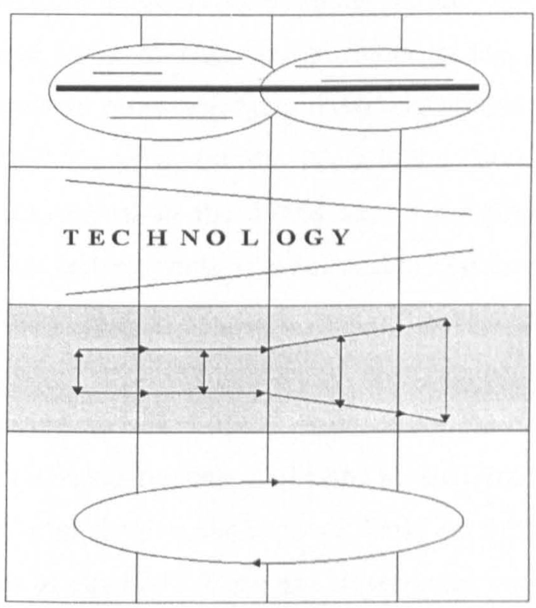
Chapter 6

Human Interaction, Expertise and Training

6.1 Introduction

Whereas Chapter 5 dealt with the technical mechanisms for receiving, analysing and delivering information, this chapter focuses on the human aspects of interpreting and acting on that information; the third element of the conceptual model presented in Chapter 3 (shaded area in Figure 6.1). The impact of differing approaches amongst the professionals or "experts" involved in flood warning is analysed as is the importance of multidisciplinary working to integration. Perception differences between the senders of information and the receivers of that information are discussed in some depth and the need for consistency and understanding is explored. The relevance of social networks to integration is then assessed, both in local communities and in organisations, as is the importance of the role of the individual. The chapter concludes with an analysis of learning and training strategies both for individuals in communities and organisations, and for the organisations themselves and how this can benefit integration.

Figure 6.1: Conceptual model of the FDFWR process



(see Chapter 3 for full details)

6.2 Integration of multidisciplinary professions

Foster (1980) highlights the fact that warning is a complex process involving the interaction of physical, technological, and social systems, the operation of which must be carefully co-ordinated if the desired result (an effective integrated system) is to be achieved. Penning Rowsell et al (1982), see difficulties in the provision of an effective warning system because of differences in the beliefs, attitudes and language of the "experts" in each of the physical, technological and social sciences. They point to possible problems faced by the recipients of warnings in grasping the nature and meaning of the advice provided by each. They cite the training of hydrologists and meteorologists that can encourage an often uncritical concern for data for its own sake. They see that this, and the emphasis on the products of technology to "solve" problems, may give rise to tensions with other professionals, such as social scientists, leading to communication difficulties. For an integrated system to evolve therefore, it is important that experts across these disciplines interact effectively.

In the forecasting and warning agencies in England and Wales flood warning has been dominated, until relatively recently, by a small number of professions. As the range of professional involvement has gradually increased over the years, instances of conflict have arisen and this can be shown to have a negative impact on total system integration. Even within the area of physical science for instance, tensions developed between civil engineers and environmental scientists/physical geographers in the late 1970s/early 1980s. The engineers, who occupied senior management positions in the forecasting agencies, often imposed bars to promotional progress unless retraining programmes in engineering were followed. It took almost ten years for the latter to be "accepted" by the former. As computer technology developed in the 1980s strains developed between the physical scientists and information technologists. It is not uncommon for technological strategies to be driven by the technologists as opposed to the "users" and this can result in the implementation of systems that do not adequately meet the business needs. More recently still, the new warning dissemination duties acquired by the Environment Agency have resulted in staff with a social science and public and media relations background becoming actively and legitimately involved in the process. Early on in the project however, some fundamental differences of emphasis developed between the social and physical scientists in the area of public awareness and community involvement in flood warning arrangements.

A way of addressing the issue within organisations is to introduce multidisciplinary team working practices. This approach has been followed in the Thames Region and Table 6.1 illustrates how the distribution of staff resources in the Regional Flood Warning Group has varied since 1985. The team's size has trebled during the past 15 years from being one focused on hydrological matters to being far more multidisciplinary. Despite this and as Table 6.2 indicates, the senior management within Thames Region (Flood Defence function and above) is still dominated by civil engineers and scientists.

The relationships between professionals involved in flood warning and flood response in different organisations is variable. For example, hydrologists and engineers in the Agency and staff in the emergency services and local authorities generally enjoy good working relationships, although some difficulties can arise due to differences in training and perception. The police and emergency planners in local authorities operate under a command and control and mechanistic regime and tend to place less emphasis on local interpretation and judgement than the hydrologist. They also have difficulty relating to the approaches recommended by the social scientists for similar reasons as the physical scientist. A similar mistrust is reflected in MAFF's grant-aid policy in support of the Environment Agency. The engineers at MAFF are comfortable with providing financial support for the installation of telemetry systems to enhance the flood detection capabilities, but are suspicious of the value of funding a national public awareness campaign.

Perhaps the most sharply contrasting professional communities that are often required to interact in emergencies are those in the media and emergency management. As Drabek (1986) states, many media reporters have no scientific background and they are generally unfamiliar with technical subjects and have limited scientific knowledge. They have difficulty understanding the information that is presented to them by "experts" who need to recognise this and translate their concepts into terms that can be easily used within a news format. To avoid conflict Burkhart (1991) suggests that close social contacts need to be established between the two communities and that the media are involved in the planning stage so that they understand the issues. In fact both communities need to gain knowledge of their respective procedures, behaviour patterns and individual personnel. As Burkhart stresses, "there is a need to reach across boundary lines of professional and organisational groups" in order to accomplish better working relationships. This is an important integration point.

There are examples however, where inter-professional relationships have grown in an increasingly positive way giving rise to a more integrated approach to system development and operation. The relationship between hydrologists and meteorologists in the UK falls into this category, and good working partnerships have resulted in the successful development of the weather radar network and short period rainfall forecasting systems which underpin many flood warning systems. This situation is not typical however, and in many other countries tensions exist between the two professions. Another example would be the relationships between physical scientists and engineers in the operational and research arenas that have notably improved in recent years and this can be partly attributed to government policy and economics. The fact that universities and research bodies are now obliged to seek funding through outside contracts has forced a more focused research programme to meet the specific needs of the operational scientist in areas such as flood forecasting.

Table 6.1: Distribution of staff resources in the Thames Region's Regional Flood Warning Group – 1985 to 1999.

Staff posts	1985	1990	1995	1999
Flood Warning Manager	Nil	1	1	1
Flood Warning/River Control Hydrologist	4	5	5	4
Flood Warning Technologist	Nil	1	1	3
Flood Warning Information Officer	Nil	Nil	1	1
Flood Warning Liaison Officer	Nil	Nil	1	5
Public Relations Officer	0.3	0.3	0.3	0.75
Out of hours duty officers:				
Hydrologist	3	4	4	3
Technical support	1	1	1.5	3
Information officer	nil	nil	2	1
Dissemination officer	nil	nil	0.5	1

Table 6.2: Disciplinary background of senior management in the Thames Region 1985-1999

Senior management posts	Engineer	Scientist	Accountant	Social Scientist
Regional General Manager	1	1	1	-
Regional Water Manager	1	1	-	-
Regional Engineering Manager	1	-	-	-
Regional Flood Defence Manager	2	-	-	-

To summarise therefore, the following approaches to multidisciplinary working can offer improvements to ways in which the different professions inter-act which can impact positively on the degree of integration in flood warning systems.

- Inter-professional rivalry is both normal and natural and attempts should be made to minimise possible conflict through regular contact thereby developing a common awareness of respective positions. The cultivation of good social networks can help in this process. These can be established formally, by forming committees and working groups, or more informally, through ad-hoc meetings to discuss matters of mutual interest and concern. The importance of social networks within organisations is discussed further in Section 6.4.

- Within organisations, multidisciplinary teams offer a useful mechanism for integrating staff from different professions to focus on a common issue such as flood warning. This approach has been adopted in the Thames Region with technologists, hydrologists, a planner, an engineer, and a public awareness/information scientist making up the regional flood warning team. This could be enhanced further with the recruitment of a professional social scientist into the team. The opportunity for multi-tasking across professions within teams then becomes possible, facilitating integration to an even greater degree.

- Drabek (1986) sees co-ordination between professions in different organisations as being important. One way of achieving this during flood emergencies is through the establishment of multi-agency emergency management centres. This can reduce potential conflict and suspicion between professional communities that are likely to arise if different groups work in isolation from each other.

6.3 Perception and cognition

For an integrated system to develop successfully there must not only be effective interaction between the "experts", but also greater mutual understanding between the experts or senders of warning information and the recipients of that information, the at-risk public. Ways of achieving this will be explored in detail in this section.

The warning message is an important element of an integrated system and forms a bridge between the appraisal of flood characteristics and the making of decisions about protective behaviour (Keys, 1997) (see Section 7.3). The literature indicates that warning messages emanating from warning agencies are rarely acted upon immediately by the recipient and that peoples' reaction is dependent to a large degree on their perception of the risk they face (Quarantelli, 1983; Burkart 1991; Mileti and Sorensen 1988). This perception is often formed after reference to other warning information received, to past experiences and is dependent on whether the warning is considered to be real and related to the environment in which the recipient lives (Janis and Mann, 1977; Drabek, 1986; Parker and Handmer, 1997). The challenge to designers of integrated warning systems is to ensure that the information that is disseminated leads a diverse at-risk public to "correct cognitions and perceptions" (as defined by Mileti and Sorensen, 1988:322). Parker and Handmer (1997) state that forecasting agencies in the UK often simply assume that their forecasts are conveyed to those at risk, that local needs are met and that appropriate adaptive behaviour ensues. They contend that it is common for these organisations to have little idea about the social and individual processes at work amongst recipients. Clearly, this position is not conducive to the development of a seamless and integrated relationship between these two communities.

6.3.1 Perceptions of the sender

The role of the sender of a warning message is to influence the behaviour of the recipient and to enhance the actions that would take place naturally without a warning being present (Edworthy and Adams, 1996). The message content may depend on the sender's local circumstances and frame of reference however, and may be influenced by a number of factors. These include the confidence a warning official has in the scientific information that is presented, on the ability to interpret that information, and to take the appropriate action, which includes the use of the appropriate technology (Williams, 1964). It should not be assumed that every duty officer in a warning agency reacts in the same way to the environmental and other information that is presented to him or her. In other words there is much scope for inconsistency and confusion and this has implications for integration.

These and other factors have been analysed and their influence on the perception of the sender and hence performance of the warning system has been tested in a survey of seven Flood Duty Officers who are responsible for delivering the flood warning service in the Thames Region:

- Imprecise or "uncertain" environmental information may be presented in which the sender may have low confidence. If extreme conditions are indicated but the information is not believed, the sender may hesitate and seek confirmation before acting. The sender may experience denial and convince him/herself that such conditions are unlikely to develop. Bennett (1997) terms this phenomenon as a "perceptual defence mechanism" that causes an individual to dismiss unpleasant information and focus towards other (more agreeable) conditions. As illustrated in Table 6.3, most duty officers questioned in the Thames Region indicated that in this circumstance their initial reaction would be to seek confirmation, two said that they would delay action until the situation become clearer.
- The sender's "situational perception" may be influenced by the lack of confirmation that a certain condition is taking place. In such circumstances, warning dissemination may be delayed or blocked until the situation becomes clearer. An example is provided by duty officers during the Easter 1998 floods in the Cherwell catchment who interpreted information as indicating that the flood was less significant than it actually was. This perception was communicated down the dissemination chain resulting in a

less than adequate response. In the Thames Region survey only two of the seven duty officers said they would act immediately on the receipt of uncertain information, but in one case it was his second preference (see Table 6.3). One duty officer indicated he would act immediately in some instances, but seek confirmation in others.

Table 6.3: Actions by Thames Region duty officers on receipt of "uncertain" information.

	Flood Duty Officers						
	A	B	C	D	E	F	G
Dismiss the information and take no further action							
Act immediately on the information presented		2	1				
Delay action until the situation becomes clearer	1			1			
Proactively seek confirmation from another source and only act when certain	2	1	1	1	1	1	1
1= first preference, 2 = second preference							

- Drabek (1986) states that public officials responsible for issuing warnings are likely to delay until they are reasonably satisfied that the danger will actually develop. He suggests that officials will be concerned about what false alarms will do to their credibility and future effectiveness; they may be concerned with the legal problems associated with erroneous predictions. Table 6.3 shows that only one duty officer questioned would act immediately on receipt of uncertain information (but not in all cases), most duty officers would not act unless they were certain of the accuracy of the information presented to them. One commented, "I would need to be convinced of the absolute accuracy of the information".

- On the basis of past experience flooding might not be expected to occur at a given locality. This is often the case when flood defences have been constructed and a flood exceeds the design capacity. The sender's perception is that flooding is unlikely to occur at such localities and will tend to focus on areas where the perceived risk of flooding is higher. An example is afforded by the response to the flooding that occurred in Northampton at Easter 1998. Arrangements for warning the public were not in place because the risk was perceived to be low due to the presence of 100-year defences and the Environment Agency's policy to use its limited resources to warn areas at greater risk (Bye and Horner, 1998).

- The intuition of the duty officer may be at odds with the environmental information that is being presented via the detection system and he/she may "sense" that flooding will not take place on a given occasion. An example would be if rainfall measurements indicated that certain flood producing intensities were occurring, but the duty officer's own perceptions, based on experience and general observations, may indicate that the situation is less severe. All duty officers interviewed in the Thames Region however, indicated that in such circumstances they would seek confirmation from another source and would only take action when they were more certain. No duty officer said that he would act on his own intuition if it was at odds with the information presented to him (see Table 6.4).

Table 6.4: An assessment of the intuition of duty officers in the Thames Region.

	Flood Duty Officers						
	A	B	C	D	E	F	G
Dismiss your feelings and only act on factual information	2		1	2			
Go with your intuition if its at odds with the information presented to you							
Delay action until the situation becomes clearer							
Proactively seek confirmation from another source and only act when certain	1	1	1	1	1	1	1
1= first preference, 2 = second preference							

- Communication breakdowns may occur between colleagues due to the fact that they perceive the same information in entirely different ways. As Bennett (1997) suggests, there is a possibility that in such circumstances one duty officer may attempt to "project" his or her own feelings to others. The danger here is that incorrect perceptions may prevail. The consensus amongst duty officers in the Thames Region is that it would depend upon how the other person's judgement was rated and as to whether that person was perceived as having greater experience. If there was disagreement most would seek the advice of a third party if time was available.

- In an integrated system a sender should ensure that the content of his/her warning message will be received, understood and believed by those at risk, and that appropriate action to reduce loss will ensue. Table 6.5 indicates that these concerns are not uppermost in the minds of flood duty officers when they are issuing flood warnings. Six of the seven duty officers indicated that their main concern would be to get warnings out on time, two officers indicated that they would also be concerned about procedural activities being adequately covered, but only one officer indicated that he would be concerned about the recipient receiving the warning. Another officer mentioned however, that a change in emphasis was required moving towards a greater appreciation of the needs of the recipient.

Table 6.5: Issues that concern duty officers in the Thames Region when issuing flood warnings.

	Flood Duty Officers						
	A	B	C	D	E	F	G
Getting the warning out on time	1		1	1	1	1	1
Remembering to cover all activities set out in the procedures		1					
Getting the location of the warning correct			1		1		
Concern about issuing a false warning/ future credibility							
Ensuring that the warning gets to the recipient				1			
Ensuring that recipients understand the message and act appropriately							
1 = first preference							

It is possible therefore, for individual senders of flood warning messages to have varying perceptions of the flood hazard and of the action that they and receivers of their warnings should take to respond to that hazard. Such differences can be attributed to a number of different factors including the individuals' personality, level of confidence, age, sex, level of experience, and status in the organisation in which he or she works. Duty officers who are young and with a limited amount of experience will have quite different perceptions to their older, more experienced counterparts. There will also be marked differences in how such individuals are perceived by others, both inside and outside their organisation. This will include perceptions of their credibility and their legitimacy. The young, female duty officer for instance, sometimes has difficulty in being taken seriously by more experienced male colleagues and some members of the public.

Variations in perception by and of senders of warning messages pose a problem for the forecasting and warning agencies as they can lead to an inconsistent level of service to their customers. Such variations can also have a detrimental effect on total warning system integration in that in certain circumstances the warning process can become distorted, confused or even blocked at this vital interface. The decision to issue a warning may not be made at the critical time for a range of perceptual reasons. Williams (1964) mentions the phenomenon of the psychological inability to accept the possibility of a completely devastating disaster. He also raises the issue of blame. If the warner does not warn and death and destruction occur, will he or she be blamed? Conversely, if he or she does warn and nothing materialises will there be criticism for upsetting people unnecessarily? This dilemma may influence a duty officer's decision to warn. One duty officer in the Thames Region commented that if he were criticised for unnecessarily issuing a flood warning, he would delay issuing a warning the next time until he was more certain. This highlights the need for clear decision rules and other measures that will facilitate decision making and integration at this important stage in the warning process.

A number of measures can be suggested to minimise the possible inconsistencies brought about by differences in sender perception, to improve the function of the warning, and hence the integration of the total warning process. These include:

- Regular staff meetings, training sessions, and multi-agency exercises that will give opportunities to discuss issues, obtain feedback, and receive consistent instruction and advise on what action to take in given circumstances. This will be explored in more detail in Section 6.6.

- The use of expert systems can help encapsulate the knowledge and expertise of the most experienced staff to support the decision making of less skilled staff. Work shadowing will also help in this regard.

- Consistency of the warning messages from different sources has been found to be an important factor in increasing public belief in the veracity of the warning (Burkart, 1991). Convincing the public that they are in danger however, is a serious challenge and involves the careful communication of risk. This will be addressed more comprehensively in Chapter 7 of this thesis.

- A better understanding of the social and individual processes at work among warning recipients will help ensure that the sender meets their needs more fully. This will be explored more fully in the next section of this Chapter.

Duty officers in the Thames Region were asked to rank the measures likely to reduce inconsistencies between them and the information they perceived that the recipients of their warnings would most require. Table 6.6 shows that the introduction of standardised procedures, formal training sessions and regular informal meetings were thought to be the most effective measures to reduce inconsistencies. The more integrative measures such as multi-agency exercises and better understanding of the needs of the recipient were not rated highly. The results presented in Table 6.7 are more encouraging however, as factors such as the timing and severity of flooding, and provision of behavioural information in public warning messages, match public requirements as determined through public perception surveys (see Table 6.10).

Table 6.6: Measures to reduce inconsistency between flood duty officers.

	Flood Duty Officers							Average
	A	B	C	D	E	F	G	
Regular informal meetings	4	3	6	1	2	5	3	3
Informal training sessions	3	4	4	4	1	3	4	2
Multi-agency exercises	6	6	7	8	3	7	8	7
Use of expert systems	7	5	3	3	7	2	6	5
Better understanding of recipients needs	8	2	5	7	6	6	5	6
Standardised actions	1	1	1	2	8	1	1	1
Consistent instruction	2	8	2	5	4	4	2	4
Work shadowing	5	7	8	6	5	8	7	8
1=best 8=least								

Table 6.7: Duty officers' perceptions of the information required by warning recipients.

	Flood Duty Officers							Average
	A	B	C	D	E	F	G	
Time of onset of flooding	1	2	1	1	2	2	3	1
How long flooding will last	7	3	6	7	7	5	8	7
Information on what to do	4	6	3	3	4	6	5	3
How severe will flooding be	2	5	2	6	1	3	1	2
Depth of flooding	2	4	8	8	3	3	7	4
Where to get sandbags	6	1	4	5	5	8	9	5
Is the warning real	9	9	9	9	9	1	2	9
Is evacuation necessary	8	8	5	2	6	9	4	6
Where to go for help	5	7	7	3	8	7	6	8
1=best 8=least								

6.3.2 Perceptions of the recipient

Mileti (1994) poses two fundamental questions in relation to this issue that have implications for integration:

1. Why can different perceptions of risk arise among the members of a public who all receive the same flood warning message?

2. Why can public response to a flood warning differ between individuals who receive the same information about how to respond?

Mileti and Sorensen (1988) contend that people go through a sequential process when they receive a warning where various aspects of the decision confronting them are considered before acting. They have attempted to encapsulate these actions in a model that is presented in Table 6.8. It is through greater understanding of these processes that the designers of integrated flood warning systems can achieve greater effectiveness.

Table 6.8: The general warning-response sequential process model (Mileti and Sorensen, 1988).

<table>
<tr><td rowspan="2">ATTRIBUTES</td><td rowspan="2">NOTIFICATION</td><td colspan="2">OUTCOME</td></tr>
<tr><td>PSYCHOLOGICAL</td><td>BEHAVIOUR</td></tr>
<tr><td>Sender Characteristics
Receiver Characteristics</td><td>Hear</td><td>Understand
Believe
Personalise</td><td>Respond</td></tr>
<tr><td colspan="4">← Information Seeking and Confirmation →</td></tr>
</table>

Mileti and Sorensen see the process as being initiated by notification, or hearing an initial warning. This leads to various psychological and behavioural outcomes. The process is shaped by sender (those issuing the warning) and receiver (those hearing the warning) factors. Mediating the process are information-seeking and confirmation activities. As people go through this sequential process their decisions at each stage are based largely on their perceptions of the risk of flooding and the options they have to respond to that risk. Why these perceptions vary becomes apparent when each of the stages in the process is examined in turn. But it is important to recognise that in an integrated system not only should information flow freely between those who issue a warning and those who receive it, but that it is understood and acted upon in a consistent way.

The first stage of public warning response is **hearing** the warning message. Mileti and Sorensen (1988) stress that it cannot be assumed that just because a warning is broadcast people will hear it. People may fail to hear a warning for a number of reasons, including selective listening or a physical constraint to hearing. The failure to hear a warning can preclude or delay response so it is important to disseminate warnings using multiple warning channels to ensure the greatest number of people hear and remember that they have heard a warning message (Quarantelli, 1983, Drabek, 1986, Mileti, 1994). This is an important integration point. During Easter 1998 for instance, flood warnings for the Cherwell catchment in Oxfordshire were only issued via local radio, and although people in risk areas heard the warnings they did not think they applied to them. It can be argued that if warnings were disseminated via a number of channels they may have been taken more seriously, resulting in more appropriate action to minimise losses. There is still a tendency by some in the Environment Agency however, to focus on a small number of warning methods over which they have complete control such as the AVM and FLOODCALL systems. To achieve the desired level of service in an integrated system, it is important that these methods are used within a multi-channel strategy. The source of the warning has also been shown to have an impact on public response. As Burkart (1991) suggests, peoples' confidence in the source of the warning varies and this affects the level of seriousness given to particular warning messages. This is particularly relevant in England and Wales because, as Table 6.9 indicates, the public awareness of the flood warning responsibility of the Environment Agency, although increasing, is still low. It is also clear that people are more likely to hear a warning if they are part of a social network (Mileti and Sorensen, 1988, Parker and Handmer, 1997), if they are in tune with their environmental surroundings, and have experienced a flood in the past (Mileti 1994, Quarantelli, 1983, Drabek, 1986). The relevance of social networks will be explored in more detail in Section 6.4.

Once heard, the warning must be **understood** and given meaning (Mileti and Sorensen, 1988). It is common however, for the initial reaction to a warning to be one of disbelief and a failure to take action, especially when it is unexpected and the level of awareness is low (Burkart 1991, Drabek, 1986). Few recipients of warnings develop an immediate sense of severe personal risk, and a common reaction is "it can't happen to me". Quarantelli

(1980) comments that people in low-risk areas in particular simply do not believe they are at risk and they often deny this even in the face of warnings to the contrary. This phenomenon was noted in Kidlington, Oxfordshire during the Easter 1998 floods when people ignored warnings and told the emergency services just before they flooded that " it never floods here". The meaning attached to a particular flood warning can vary among people therefore, and this may or may not conform to what was intended by the sender of the information. In an integrated system it is important that the recipients of a warning respond effectively and they are more likely to respond if they **believe** that the warning is real, that the contents of the message are accurate, and that it applies to them. Mileti (1994) argues that believability is influenced by many factors associated with the method and contents of the warning message. People are also more likely to respond to a warning if it is **personalised** in some way, if they do not feel that they are the targets of the warning they may well ignore it.

Table 6.9: Spontaneous awareness of responsibility for issuing flood warnings by the at-risk population (after BMRB, 1999).

	1999	1998	1997
Unweighted base:	1106	1138	855
Weighted base:	1106	1138	855
	%	%	%
Environment Agency	24	15	8
Local authority	21	25	29
National Rivers Authority	12	10	17
Local water company	10	14	16
Police	4	7	9
DoE/DETR	2	1	-
Fire Brigade	1	2	2
Don't know	33	33	33

A number of factors are identified in the literature that are likely to maximise the probability that warnings will be understood, believed and personalised. Several researchers for instance, consider that the more effective warnings are those that are specific about the area to be affected, the time of maximum risk, the characteristics of the hazard, and on the action that should be taken (Quarantelli 1980, Mileti 1994, Mileti and Sorensen 1988). This is confirmed by the results of recent nation-wide surveys commissioned by the Environment Agency and presented in Table 6.10. They indicate that the time of flooding, instructions on what to do and the severity of flooding are the most commonly mentioned pieces of information required (BMRB, 1998,1999). Despite these findings, information of this type is not routinely disseminated to the public in the Agency's flood warning messages. Warning messages put out on the AVM and FLOODCALL systems for instance, do not provide behavioural advice nor specific information on timing and depth of flooding (see Table 6.12). Although the Environment Agency has taken great strides since 1996 to improve the information it supplies, the format of the basic flood warning message it issues to the public is still largely factual and uniform. Keys (1997) stresses the need to recognise that the community is not a single mass of people and that different groups will need different information and different presentations of it. The Agency has yet to come to terms with the fact that these differences exist and then how to meet the different needs.

Table 6.10: Information required by the public in flood warning messages (BMRB, 1998/1999)

	1999	1998
Unweighted base:	1106	855
Weighted base:	1106	855
	%	%
Time of flooding/when to expect it	23	26
Instructions on what to do	19	18
How severe flooding will be	13	16
Which areas are likely to be flooded	10	14
Height of the flood	10	11
Where to evacuate to/which roads to use	8	10
Whether should evacuate	5	7
Whether sandbags are their way/where to get them from	8	7
Where to go for help/what help is available	9	6
How long flooding will last	7	6
Preliminary warning/24 hours notice	11	5
Whether serious risk or just an alert	-	2
Other	1	6
Don't know	11	9
None	-	11

Edworthy and Adams (1996) emphasise the need to consider the **alerting function** of a warning and the fact that different signals or "icons" produce different levels of arousal. Certain key words or symbols can be used to trigger certain reactions and speed-up public response. Colours such as "red" and words such as "deadly" or "lethal" for example, can be used to signify the highest level of danger. The Agency and its predecessors have used a colour-coded system (YELLOW, AMBER, and RED) to communicate increasing flood severity for many years. Surveys have shown however, a strong perception among the public that the colours relate to increasing levels of certainty that a flood will hit a certain area i.e. a traffic light system. This is a classic example of the recipients of flood warnings attaching a different meaning to the warning message to that intended by the sender (see Tables 6.13 and 6.14).

Many researchers point to the importance of **confirmation** in establishing warning belief. Most people will engage in some form of confirmation after receiving a warning and before taking any protective action, and this is often with relatives and friends rather than via official sources (Burkart, 1991; Drabek, 1986). This involves gathering further information so that the level of personal risk can be assessed. Drabek (1986) estimates that as many as 80% of warning recipients will engage in this type of behaviour and that when confirmation is received, perception of risk is likely to be higher. This activity is commonly observed in the Thames Region, and a recent example would be when flood warnings were issued for the Pinn catchment in north-west London on 2 June 1999. Flood wardens were alerted in the early hours and their first response was to observe local river levels and liaise amongst themselves before taking any protective action. Drabek states that people are more likely to believe a warning if the environment supports the threat message. If others around them seem to be behaving as if they believe the warning, then they are more likely to do so as well. There is evidence to show however, that the more warning messages that are received by an individual, the fewer the attempts at warning confirmation (Drabek, 1986). This reinforces the need for a multi-sourced warning strategy that will cut the need for confirmatory behaviour and speed up response. Burkart (1991) points to the importance of the media as an independent source of surveillance information, which may be used to confirm a warning. In summary he states "an environment in which the citizen can easily confirm an initial warning through alternative sources is one that fosters the development of a warning belief".

Even when warnings meet all these standards, response by the public is still dependent upon the different perceptions that each individual brings to an emergency situation, and which almost predispose them to different actions. Factors that can influence the way people react include age, sex, level of education, pre-knowledge about a particular hazard, experience of a particular hazard, proximity to risk area, length of residence, and stress. Drabek (1986) notes for example, that people of low socio-economic status tend to disregard official warnings more than the middle classes, that women are more likely to interpret warnings positively than men, that old people are less likely to respond effectively as younger people, and that ethnic groups assign little credit to official warning sources. He also notes that families tend to respond more effectively if they are together and that emergency planners should work to unite families to avoid delay. Other people are constrained from responding to a warning message for a number of reasons. They may lack the resources to act, or be particularly stressed, or be elderly, handicapped and infirm, or belong to an ethnic group and not understand the meaning of the message. Table 6.11 indicates that on average one-fifth of households in flood risk areas in England and Wales may have an occupant with a long-standing illness/disability/infirmity. As Quarentelli (1983) notes, some people may refuse to respond because they fear looting of their property, which is often unfounded, or for undue concern over the safety of a loved one or a pet. Such behaviour may appear irrational to those issuing flood warning messages.

Table 6.11: Long-standing disability/illness and non-English speakers across the eight regions of the Environment Agency in England and Wales (BMRB, 1998).

	T	A	M	NE	NW	S	W	SW
Unweighted base: Weighted base:	139 57 %	142 194 %	62 11 %	117 22 %	99 24 %	268 675 %	94 24 %	55 5 %
Presence of h/hold member with long-standing illness/disability/infirmity	13	17	11	19	20	19	19	22
English not first language	1	2	-	-	2	-	9	-

Past experience of flood events greatly enhances the probability of people taking effective action when they are warned. Those who have been flooded before generally react quicker than those who have not, once they have accepted the likelihood of danger (Drabek, 1986, Perry and Green, 1982, Quarantelli, 1983). People have a tendency however, to believe that history will repeat itself and it is often difficult to persuade people that a new disaster will be different from the earlier one. Drabek (1986) comments that judgements on probable impact of a flood are often made on the basis of the last one that affected the area. An example of this would be where individuals go to the expense of raising electricity sockets or the floors of their premises above the level of the last flood only to find that the next flood is deeper. Past effectiveness of warning systems is also important for timely response. If warnings are issued but flooding does not materialise however, then this might neutralise future warnings and dampen subsequent vigilant tendencies. There is a desire not to react in a way that looks foolish and to be seen to be overreacting and typically people adopt a "wait and see" approach following receipt of a warning. There is evidence to show however, that if people have developed a personal or family emergency plan they are more likely to heed warnings and respond more effectively (Drabek, 1986). This is something that is actively promoted in the United States for example, to try and persuade people to be prepared for hazards that may affect their area (NOAA, 1997).

It is clear therefore, that "receiver characteristics" can vary widely among members of the public in any one warning circumstance, as well as between different events. The goal for designers of integrated warning systems is to maximise the sender characteristics and provide convincing and reasonable warning information to the public, whilst at the same time minimising the negative impacts of receiver characteristics. The interface between the sender and receiver of warning information is an important one in an integrated system and to make this interface work effectively, greater understanding of the perceptions and likely response of the warning recipient is essential. Warning recipients will respond more effectively if the sender's messages are believable and understandable and their content can be confirmed via alternative sources. To date, this area has received little attention in the establishment of flood warning arrangements in England and Wales. Small regard has been given to the content and format of public warning information and the varying needs and responses of recipients have not been comprehended nor adequately cater for.

6.4 The relevance of social networks to system integration

These will be examined under two main headings; within communities and within organisations.

6.4.1 Community networks

As has been shown in Section 6.3, the interpretation of and reaction to a warning is not a simple or automatic process; it is a complex and usually highly social process. The literature records that recipients of warnings do not normally respond and interpret messages individually, they react instead with other people who may or may not be physically present or directly involved (Quarentelli, 1983; Williams, 1964). It is clear that people who are part of large and well-established social networks are more likely to receive warnings, to confirm warnings, as well as understand, believe, and personalise them, and engage in response (Mileti, 1994; Burkart, 1991). Networks are relevant to integration as they can facilitate the same or a similar message being disseminated to most of the community. Networks allow people to turn to others to interpret information and to increase the options for response, and studies have shown that when people get separated from their network they have a lower probability of responding appropriately (Burkart, 1991). They have the characteristic of binding the community together and providing mutually supportive assistance. For fast responding situations local community networks are the most effective in rapidly passing messages and giving immediate assistance, but all networks take time to start functioning. When lead times are very short people tend to rely more heavily on official warning sources (Burkart, 1991).

Table 6.12 Example of a FLOODCALL message

THIS STATEMENT WAS PREPARED ON Monday 17 March **AT** 1200 HOURS
THERE ARE CURRENTLY THE FOLLOWING FLOOD WARNINGS IN FORCE: **AN AMBER WARNING FOR THE RIVER** Pang and Sulham Brook **BETWEEN** Hampstead Norreys **AND** Pangbourne **INCLUDING** Stanford Dingley **THIS MEANS:** **AMBER – FLOODING TO ISOLATED PROPERTIES, ROADS AND LARGE AREAS OF FARMLAND, PARKS AND GARDENS**
WEATHER PROSPECTS There is a band of heavy rain steadily moving across the region from the west. This rain will persist throughout the afternoon, total rainfall could exceed 40-50mm with as much as 10mm in an hour in places.
RIVER AND FLOODING FORECAST The prolonged wet period has resulted in river levels rising. The forecast rainfall is likely to result in many watercourses overtoppng their banks and flooding large areas of floodplain. **THIS FORECAST WAS ISSUED AT 1200 HOURS ON MONDAY 17 MARCH AND WILL BE UPDATED AS THE SITUATION CHANGES.**

Table 6.13 Awareness of colour-coded warning system across the Environment Agency's regions (BMRB, 1998/1999).

	SW	M	W	NW	NE	S	A	T	**Total**
1999	83%	82%	-	-	-	50%	71%	50%	**55%**
1998	84%	77%	61%	48%	48%	40%	33%	33%	**40%**
1997	63%	59%	80%	36%	28%	37%	43%	39%	**42%**

Table 6.14: The interpretation of colour-coded warnings across all Environment Agency regions (BMRB, 1998/1999)

	1999	1998
Unweighted base:	652	542
Weighted base:	606	453
	%	%
YELLOW		
Low risk/only slight risk	32	27
Possibility/chance of flooding	23	19
Be prepared/stand by	7	11
Be alert/be aware	8	10
Medium to high risk	5	5
Flooding is imminent	4	5
Risk of high tides	2	5
Other	2	1
Don't know	22	24
RED		
Flooding is imminent/about to happen	22	27
High risk/flooding is certain/100% sure	16	26
Serious/severe/major flooding	16	18
Danger	8	11
Flood is happening now/has started	12	9
Need to prepare/move valuables	6	9
Evacuate now	6	7
Possible evacuation	6	2
Listen for further information	-	2
Get sandbags	-	1
Other	-	-
Don't know	-	-

There is evidence presented in the literature that indicates that social networks are an important mechanism for disseminating **unofficial** warnings during times of flood (Parker and Handmer, 1997). Drabek (1986) emphasises the importance of informal systems and notes that they often keep functioning when official systems fail, a fact that is often not appreciated by the operators of official schemes. In the 1990 Thames river floods at Maidenhead for example, Tunstall (1992) reports that over 40 per cent of flood plain occupants who were eventually flooded sought to warn others in their community once they had informally detected the flood risk. Such networks have also been found to be important in raising public awareness of the flood risk. Tunstall (1992) found that over 30 per cent of householders in Maidenhead first found out about their flood risk after moving into the area through conversation with neighbours. The issue facing the operators of official warning systems is how to ensure that a competitive environment does not develop between the two systems. Australian research suggests that official and unofficial systems can coexist peacefully, and can often function to reinforce each other (Handmer, 1991). Research in the Thames catchment (Tunstall, 1992; Hyde, 1992) supports this finding as recipients of unofficial flood warning messages were found to display a high degree of willingness to participate in an official scheme. People indicated that they were prepared to pass on flood warnings by telephone to neighbours and friends, and significant numbers were willing to work as voluntary flood wardens. Parker and Handmer (1997) state that where they exist, flood wardens can help integrate official and unofficial flood warning schemes and appear to be associated with high levels of warning system satisfaction.

So how can social networks within recipient communities be best used to improve the dissemination, interpretation and response to warnings, and ultimately the integration of warning systems? Mileti and Sorensen (1988) believe that because different people belong to different social networks, warning messages should be disseminated over the full range of communication channels to maximise the number who hear a warning. Parker and Handmer (1997) suggest that a more targeted approach is needed, to attempt to meet the needs of a community through dialogue and the provision of personalised information. They state that where the flood warning agency has sought the views and assistance of local communities, and subsequently constructed partnership arrangements, the flood warning systems appear to be more robust and effective. In the Thames Region an example of where this approach has been successfully introduced is in the Pinn catchment in north-west London. A residents association, The Pinner Association, has established a comprehensive warning network involving over 250 residents as detailed in Figure 6.3.

> "After the Great Flood in 1977, the Pinner Association decided immediate action was needed but, as the authorities with any responsibility were unwilling or unable to act, the Association agreed to co-ordinate local efforts. These took two main courses. The first was to reduce the risk of flooding by applying pressures at all levels, from local authority and responsible government agencies up to Parliament via our local MPs. The second was to set up a Flood Warning Scheme so that those likely to be affected would have notice of imminent flooding" (Wise, 1999).

The Agency is able to activate this community-established network by a single telephone call to the co-ordinator and receives feedback from warden observations on the ground. The network has been successfully activated on many occasions, the last being on 2 June 1999 when procedures worked particularly well. This is a good example of how an official warning system can successfully integrate with a community-led scheme to provide an effective local dissemination network. In fact the Pinner Association wrote to the Agency stating that they felt that the arrangement was "an example of how a Government agency can work closely with a local association to the benefit of all parties" (see Appendix 5).

6.4.2 Social networks within organisations

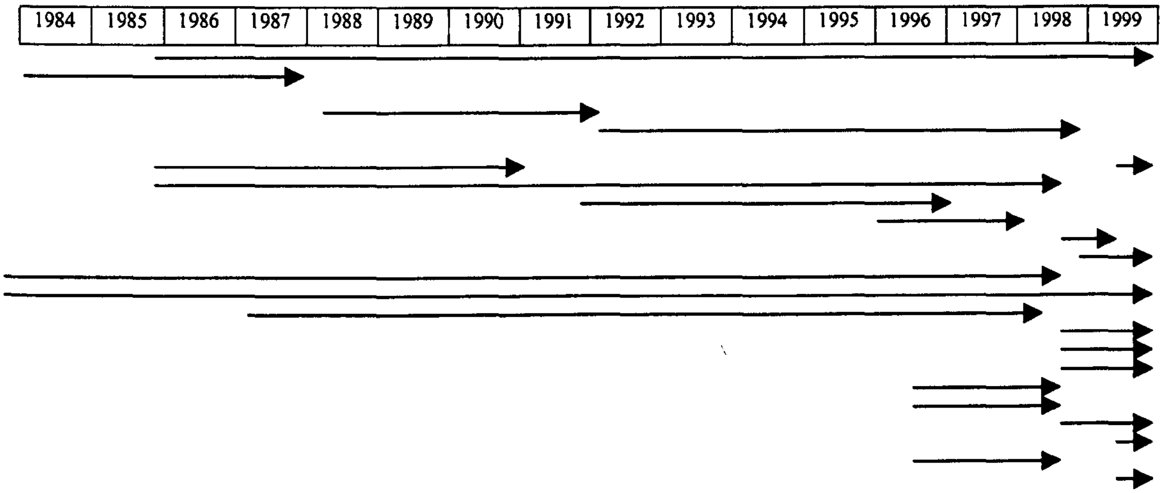
Parker and Handmer (1997) state that social networks are central to the functioning of warning systems within organisations. There is little in the research literature however, that examines in any detail the impact of such networks on the functioning of flood warning systems. The author's experience within the Environment Agency would suggest that social networks of relevance operate at two levels; within the operational framework, and in the area of system planning and development.

The staff engaged in full-time flood forecasting and warning activities in the Agency is small, around 60 across all eight regions in England and Wales (although numbers have recently increased in response to the Easter 1998 Flood Review). Because of the specialist nature of the work, staff have tended to remain in post for long periods (until very recently - see Figure 6.2) and close working relationships have been established across regional boundaries. Close relationships also develop with staff in other organisations, such as the emergency services and local authorities, with which the flood warning staff come into regular contact. This can often lead to more efficient working during flood emergencies, cementing integration within and between organisations. This is not always the case however, and in some instances team working can engender "tribalistic" attitudes between groups. In the Environment Agency for example, tensions have been known to develop between staff operating in Area and Regional teams. In an integrated system it is important that staff work together with a common focus, that there is free flow of information, and that roles and responsibilities are clearly defined to avoid conflict. In the Thames Region a formal operating agreement has been introduced in 1999 between the Regional Flood Warning Centre and the three operating Areas that clearly sets out roles and responsibilities of each group.

Prior to 1989, systems for detecting and forecasting floods and disseminating warnings were largely developed separately by 10 autonomous regional water authorities in England and Wales. There was typically little contact between the staff managing these functions in these independent organisations. The formation of a national organisation resulted in more contact between staff in the newly formed regions and the interchange of ideas. The Flood Warning Dissemination Project in 1996 for instance, became a catalyst for greater liaison between practitioners in the Agency' regions, strengthened by the organisation's desire for greater national consistency. Formal project groups have now been established to oversee the development of a whole range of activities in the flood warning field. Underpinning these groups is a strong informal network formed by practitioners in what is still a small national community. This network has facilitated the exchange of ideas and the identification and adoption of best practice, and extends outside the Agency and includes workers in other organisations such as the Met Office, research bodies and universities. The number of individuals is still relatively small and close relationships develop that help with the identification of system development needs and possible solutions. As way of illustration, Table 6.15 sets out the personal networks in which the Thames Region's Flood Warning Manager participates and the frequency of communication.

For social networks to develop and to be maintained however, a degree of organisational stability is required. Re-structuring and organisational change has been particularly prevalent in the Agency and in other organisations in recent years and this has had an impact on the functioning of social networks. Figure 6.2 illustrates the staff movements in the Flood Warning Group in the Thames Region alone between 1984 and 1999. A marked change can be seen in 1996 when previously infrequent staff movement is replaced by a rapid turnover that coincides with significant organisational change. Loss of knowledge and expertise due to early retirement, redeployment and departure of staff often accompany such reorganisations, and the Thames Region was no exception. In addition, the morale of the staff remaining has inevitably declined in a climate of uncertainty and change. Social networks that have been established with the Agency and with staff in other agencies have shown signs of breaking down and this has a potentially negative impact on integration. Indeed in the Easter Floods in 1998 there was evidence that the loss in continuity of staffing and expertise, and poor liaison between organisations weakened the effective response to the incident (Bye and Horner, 1998).

Figure 6.2 Staff movements in Flood Warning Group, Thames Region 1984-1999



6.5 The power of the individual

Mitchell (1990) states that integration, co-operation, and co-ordination depend to a significant extent upon the willingness of individuals to make them happen. People who are inclined to co-operate and are enthusiastic can often make a poor system work well. Conversely, a well-designed system may falter if individuals are determined not to make it work. As O'Riordan (1976) observes, decision-making often has little to do with organisation, statutory guidelines and co-ordinating arrangements. Rather, it has much more to do with "the outcome of the determination, vision, indifference, antagonisms and bloody-mindedness of particular individuals who are in positions of influence". Thus, the combination of organisational culture, personalities, and individuals' attitudes can pose a major obstacle to integration, or conversely can facilitate its introduction.

Looking specifically at flood warning systems, who are the key individuals who can make or break a policy of integration? It is possible to identify two main types; those in organisations who design systems and deliver the operational service; and those in communities who receive and act on warning messages. In the former, the individuals who manage and design flood warning systems are highly influential, as it is they who interpret and implement the policy of the organisation (see Table 6.16). Their enthusiasm towards a policy, such as integration, will determine how effectively it is implemented operationally. If individual managers are convinced that such a policy has little merit, then the chances of

Figure 6.3: Pinner Association Warning Network

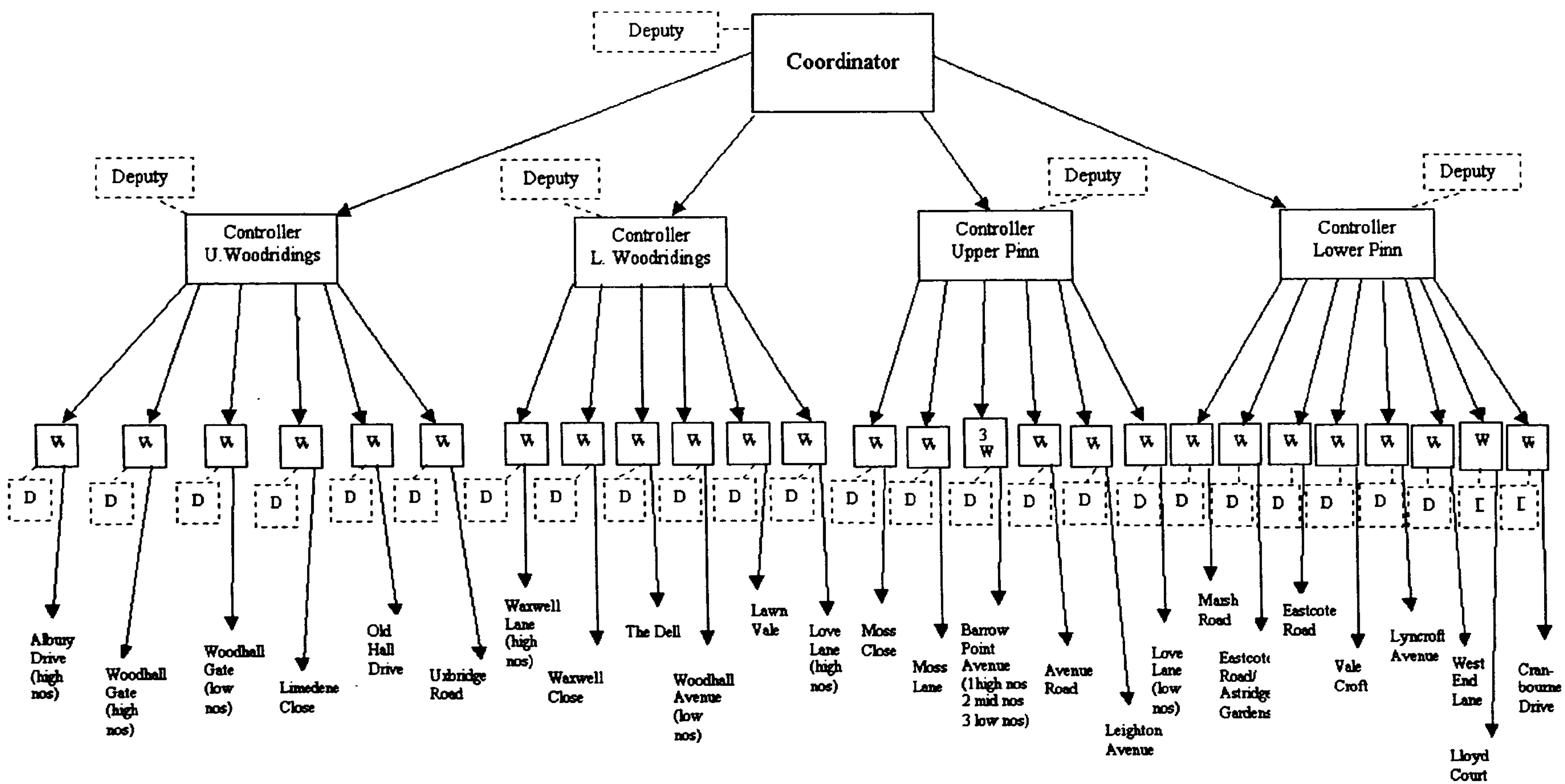


Table 6.15: Social Networks in Organisations. Flood Warning Manager, Environment Agency, Thames Region.

INTERNAL TO THE ENVIRONMENT AGENCY	Frequency of Communication
Regional/Area	
Regional Water Department	Daily
Regional Water Department Management Team.	Ad-hoc
Flood Warning Team.	Daily
Regional Flood Defence Teams.	Weekly
Regional Water Resources Teams.	Monthly
Area Flood Defence and Water Resources Teams.	Daily
Flood Duty Officers Team.	Daily
Regional Flood Action Group.	Quarterly
Regional Flood Defence Committee	Ad-hoc
Central Information Services.	Weekly
Regional Telemetry.	Monthly
Public Relations Group.	Monthly
Research and Development.	Quarterly
NATIONAL	
National Flood Warning Implementation Team.	Quarterly
National Weather Radar Team.	Quarterly
Weather Services Team.	6-monthly
National Flood Defence Team.	Ad-hoc
Flood Defence Managers Group.	Ad-hoc
Easter Floods Action Group.	Monthly
Sub-groups spawned by any of the above	Ad-hoc
EXTERNAL TO THE ENVIRONMENT AGENCY	
Met Office:	
London Weather Centre.	6-monthly
National Weather Radar Committee.	6-monthly
National Weather Radar Operational Working Group.	6-monthly
Commercial Services.	Ad-hoc
Institute of Hydrology:	
Flood Forecasting Group.	Ad-hoc
Local Authorities, Emergency Services, Utilities:	
County FW Planning Groups (12).	Annually
London FW Planning Groups (5).	Annually
Flood Warning Seminars (3).	Annually
Middlesex University:	
Flood Hazard Research Centre.	Ad-hoc
Other:	
Inter-Agency Committee on the Hydrological Applications of Weather Radar.	6-monthly
Chartered Institution of Water and Environmental Management.	6-monthly
British Hydrological Society.	6-monthly

implementation are low unless organisational pressure is placed on that individual to comply. This is unlikely to occur unless the policy has a very high priority within the organisation and a strong political message in support of the policy is communicated from the top management. It is common for some individuals to react negatively especially if they perceive themselves as becoming losers through loss of authority, shrunken empires and reduced leverage or influence. In such situations, lip service may be given in support of integration, but in practice low-risk strategies such as delay, systematic misinformation and minor sabotage will be used to hinder its implementation (Mitchell, 1990). The Environment Agency for example, has experienced difficulty in implementing a policy of consistency and integration throughout each of its eight regions and twenty-six areas. There are still many individual members of staff still wishing to work in ways that have been locally formulated to meet, in their eyes, the local needs of their customers.

In emergency situations, decision making in organisations increases, especially in the lower ranks, and individual autonomy increases (Drabek, 1986). Key individuals can often trigger the response of organisations and it is important that these individuals are properly empowered to take appropriate action. Within the Environment Agency decision making on the issue of flood warnings rests with professional flood duty officers who have an intimate knowledge of the flood-producing characteristics of the river catchments concerned. There is no doubt that these individuals have great influence over system integration as they operate at the interface of the detection, forecasting and dissemination phases of the warning process. Many integrative processes take place in their heads as they assimilate, evaluate and process information and generate other information in the form of warning messages. Although the Agency tries to even out the level of service offered by such staff through training and the issue of standard procedures, differences in the intuition, experience, value judgements and response of individuals are inevitable (see Tables 6.4 and 6.6). The process of integration will be assisted by the creation of the right environment for officers to operate in, free from the fear of criticism or blame if things go wrong.

Prior to the Easter Floods in 1998 there were signs within the Agency that flood duty staff were not being fully valued. There was an increasing trend to reduce staff numbers on standby rosters and reduce payments and other terms and conditions. A continuation of this policy would have resulted in loss of motivation and a reduction in the level of service offered to the public. An example is provided in the Thames Region during the establishment of a Regional Flood Warning Centre at Reading in the Thames Region in 1998 involving the closure of the centre in Hertfordshire. The decision was taken despite an awareness of the high business risk and potential loss of a large number of experienced individuals. As Table 6.17 illustrates, 9 experienced duty officers were lost to the flood warning service out of an original team of 11 representing 83 person-years of experience.

In many response agencies in England and Wales the enthusiasm of key individuals, such as emergency planning officers or local commanders, can determine how effectively a given organisation responds to flooding incidents and flood warnings. In the Thames Region, for instance, the policy of some district councils to operate flood warden schemes and provide and deliver sandbags to the public at risk, can be traced to the dedication and interest of one or two individuals. The same can be said of the Metropolitan Police in London where differing levels of commitment between local commanders' results in different levels of response across the capital. The response of the organisation at a local level seems to hinge on whether such individuals have an interest in flood response or not.

Within communities there are usually individuals who are especially sensitive to certain kinds of environmental changes, who are more capable than the population in general in detecting and interpreting signs of danger from a certain source such as a river (Williams, 1964). These more sensitive or capable people often take it upon themselves to warn others, and as a consequence informal communication processes and networks emerge for interpreting and disseminating information about changes in the environment. Parker and Handmer (1997) refer to such individuals as "local gurus" who are prepared to serve or lead the community, which might include organising networks, stimulating contact between people, facilitating the flow of information and providing reassurance. Research in the Thames catchment has shown that there is a untapped resource of individuals willing to participate in disseminating flood warnings and act as voluntary flood wardens (Tunstall, 1992; Hyde, 1992). In many instances flood warden networks have been established by local communities acting on their own initiative where there is no (or an inadequate) official flood warning system. Parker and Handmer (1997) state that where they exist, flood wardens are a potentially important integrating link between official and unofficial systems. Flood warning systems that are designed to incorporate the expertise of these individuals are likely to be highly effective (see Figure 6.3).

Table 6.16: Individual staff posts with influence over flood warning systems in the Environment Agency

Agency Structure	Staff position
Head Office	Director of Operations Director of Water Management Head of Flood Defence Flood Defence Officer National Flood Warning Campaign Manager Head of Media
Regional Office	Regional General Manager Regional Water Manager Flood Defence Manager Flood Warning Manager Regional Flood Warning Team members Flood Duty Officers
Area Office	Area Manager Flood Defence and Water Resources Manager Flood Warning/Operations Team Leader Area Flood Warning Team members Flood Duty Officers
National Groups	Flood Defence Managers Group Flood Warning Implementation Team (Flood Warning Managers) Public Awareness Group (Public Relations staff) Easter Floods Action Group (Expert group)

Table 6.17: Staff movements following the closure of the Waltham Cross Flood Warning Centre in 1998

Position prior to 1998	Position after 1998	Years working in flood warning	Continuing role in flood warning
Flood Warning Manager	Flood Warning Manager	23	Yes
Senior Flood Warning Technologist	Software Company	11	No
Flood Warning Planning Officer	Flood Warning Technologist	2	Yes
Flood Warning Liaison Officer	Environment Protection Officer	2	No
Flood Warning Hydrologist	Water Resources Hydrologist	2	No
Flood Warning Information Officer	Millennium Project Officer	2	No
Administration Officer	Retired	5	No
Flood Duty Officers (X5)	Removed from the FW roster	60 (combined)	No

Within forecasting and response agencies individuals, such as those referred to above, are not always fully appreciated and valued. There has been, for instance, a general reluctance to acknowledge the expertise and potential role of "local gurus" in at-risk communities. A rather arrogant "we know best" attitude has tended to prevail in these organisations and this continues to be the case today. There is a perception in some quarters that members of the public cannot be trusted to deliver warning messages to their friends and neighbours. The new flood warning dissemination arrangements introduced by the Environment Agency for example, were not designed to make provision for such individuals. The AVM and FLOODCALL services are mechanisms for passing information in one direction only, from the Agency to the at-risk public, they do not cater for the inter-change of information with key individuals in the community. In the Midlands and Welsh regions of the Agency for instance, a policy decision has been taken to abandon flood warden schemes and focus warning dissemination solely on the use of the AVM system. In the Thames Region however, a different policy has been adopted. Not only are "local gurus" being actively sought out to participate in official warning arrangements often acting as flood wardens, but links are being established between them and staff in the flood warning centres to encourage the interchange of information during flood events. This is seen to be an effective way of disseminating flood warning information to the at-risk public whilst at the same time benefiting from feedback from the "local experts".

6.6 Learning and training

Bennett (1997) defines learning as the absorption of knowledge and the acquisition of skills and/or fresh attitudes. He sees training as being utilitarian and intended to improve the skills that individuals use in their daily lives. Both are important for integration. Foster (1980) for example, sees all decision-making processes such as flood warning as learning cycles that can be continually modified with reference to recent experience to improve their adequacy and efficiency. Williams (1964), identifies prior training and practice and the presence of trained, organised leadership as adding to the effectiveness of the total warning process.

The importance of learning and training to system integration can be analysed under the headings of the individual, both inside organisations and in communities, and organisations themselves.

6.6.1 Individuals within organisations

Foster (1980) recognises that the operation of the warning system itself should be carefully recorded if the total system is to be improved. This can be achieved through debriefing sessions after events. Discussions should be held between the key individuals involved, to record in detail any problems experienced and the reasons for them, such material is very useful in the training of personnel. He goes on to state that regular testing and exercising of systems is important to determine how effective they are, and this is especially valuable where staff lack direct experience or where the frequency of events is low. As disaster-warning networks are essentially learning systems, they generally improve with use. Exercises should not be confined to the testing of the technology on which the system is based, important though this is. The performance of the personnel should also be monitored with a view to improving efficiency; this may identify points of weakness in the warning system that can be modified as a result.

Detection and forecasting systems are increasingly complex and technology-based. Personnel within forecasting agencies need regular training on the operation of such systems and on the interpretation of the information presented for the total system to function effectively. This is particularly relevant where flooding events are infrequent and duty rosters are large. In such cases an individual duty officer may only have to manage a flood event once every few years, but will be expected to operate systems effectively at very short notice. The importance of a continual programme of training coupled with regular exercises cannot be over-emphasised in these circumstances. Table 6.18 gives details of the Agency's training programme for flood duty staff and it is clear there is variation from region to region that could result in differing levels of service across England and Wales.

Table 6.18: Training programme for flood warning staff in each of the Agency's regions (after Bailey, 1999).

Region	Training programme
Anglian	Formalised – training on new developments as weekly duty rosters change. Special training day held annually.
Midlands	Not formalised – training confined to new technical systems.
North East	Formalised – half day training as weekly duty rosters change.
North West	Formalised – meetings of duty officers every three months, briefing on new developments as weekly duty rosters change.
Southern	Not formalised – duty officers trained on new developments.
South West	Formalised – half day training for duty staff every six weeks.
Thames	Formalised – monthly meetings of duty staff including a formal training session.
Wales	Formalised – training sessions every three months.

The evaluation of incoming environmental information is not a simple process, as it requires value judgements based on experience. There are various techniques available for passing on this experience and knowledge to others including the use of expert systems, forecasting models, comprehensive written procedures, job shadowing etc. Problems arise however, when unforeseen circumstances occur and the experienced officer has to use his or her initiative to make the right decisions. Such expertise is acquired over a long period of time and cannot be passed on easily.

Bye and Horner (1998) noted that during the Easter 1998 Floods the number of staff within the Environment Agency with the necessary expertise was limited. They cite examples of the use of computer packages where data had been wrongly analysed for instance. They expressed concerns about the scarcity of senior staff with advanced academic training within the Agency and the often-poor supervision of less experienced staff. They made the following recommendations for improvement:

- Centralising flood warning and flood defence technical specialisms regionally or nationally in order to improve efficiency, effectiveness and national consistency by developing excellence through the concentration of specialist resources.
- Ensuring that flood warning and emergency response activities are led at all times and at all stages during the period of flood emergency by senior staff experienced in the function and trained in crisis management.

- More effective training of duty officers including the interpretation of meteorological information and radar data and the use of forecasting models.
- Greater attention should be given to the human and social aspects of warning message construction, dissemination and the encouragement of greater response. More emphasis should be placed on evaluating the experiences of flooding victims.

6.6.2 Individuals within communities

Williams (1964) recognises the value of instructing or training people in risk areas in hazard recognition and emergency procedures. He sees that experience is the great teacher but where this is absent he suggests a network of trained leaders or wardens as being an effective way of improving awareness. The implementation of such an approach will strengthen integration and encourage individuals to become part of the total warning process.

Although pre-disaster education is seen as an effective way of raising awareness and instructing individuals on how to recognise and respond to danger situations, there is need for public awareness campaigns to be targeted. Those campaigns that are broadly based and non-focused have been shown to be ineffective (Drabek, 1986). People are often confused about the risks to which they are exposed (they tend to underestimate the events that will affect them), what warning messages mean and the roles and responsibilities of organisations. Drabek (1986) indicates that hazard awareness is significantly increased for individuals who receive information leaflets. In a study in Denver Colorado, he shows that a higher proportion of leaflet recipients took mitigating action than those who did not receive a leaflet. The effects of this tails off however, as after one year only 37% of those supplied with a leaflet remembered receiving one. This compares with public surveys in England and Wales where average recognition was only 26% in 1999, in Thames Region however, a much higher figure of 51% was recorded (BMRB, 1999) (see Table 6.19).

Table 6.19: Prompted awareness of local leaflets (BMRB, 1999)

Thames Region			**National Average**		
1997	**1998**	**1999**	**1997**	**1998**	**1999**
34%	43%	51%	33%	33%	26%

Attention is drawn in the literature to the problem caused by events of severe magnitude which are well outside the range of historical experience of communities at risk and agencies involved in flood response (Emergency Management Australia, 1999). It is important to ensure that communities recognise the potential for flooding which is worse than they have experienced in the past. There is a tendency for people to believe that flood defences constructed to keep out, say, a 1% flood will protect them from all flooding. This was clearly illustrated during the Easter 1998 Floods in Northampton where 100-year flood defences were overtopped, and at Kidlington where the pre-event perception of the public and Agency staff was that the risk areas were not extensive and included only a few properties.

The introduction of public awareness and information campaigns by the Environment Agency in England and Wales is discussed in some detail in Chapter 7. The question of training individual members of at-risk communities, such as flood wardens, to raise their level of understanding of the risk and ultimately their ability to respond, has been debated at some length within the Agency. It has been concluded that to offer such training will place the Agency (and the wardens) at greater risk of litigation as the wardens could be viewed as acting as agents of the organisation. Accordingly, instructions have been issued to all Agency regions not to offer any training to individuals such as wardens, not to provide them with equipment or any recompense for they work they carry out. Such a policy could limit the effectiveness of such schemes and hence reinforce already held prejudices against community–based arrangements within organisations such as the Environment Agency.

6.6.3 Organisations

Bennett (1997) states that the term "learning organisation" is sometimes applied to companies that attempt to facilitate the introduction of new systems through the continuous training and development of their employees. This can result in the very essence of the organisation totally altering from time to time to avoid the development of rigid and out-of-date plans and procedures. Organisational learning involves the collation of all freshly discovered solutions to problems that are then passed into the organisation's "managerial memory" allowing it to react more effectively to future events. A consequence of this is that decision-making procedures are continually modified and adapted in the light of experience, which is a positive process for integration.

The Agency has recently adopted a "learning" policy that it termed the "next steps process". This was introduced during its first year of its operation in an attempt to integrate the former predecessor authorities, to drive cultural change through the organisation and to establish a unique identity for the new authority. The policy was framed around five main themes: environmental awareness, organisational commitment, customer focus, team working and staff development. This was applied to all aspects of the Agency's work including flood warning, and an intensive staff training programme was established. The effects of the establishment of this integrated management structure were not wholly positive, and it can be argued that the policy was damaging to the performance of certain functions such as Flood Defence. There is evidence that staff morale was adversely affected in the process resulting in loss of knowledge and expertise in many key areas including flood forecasting and warning.

There are more positive examples of organisational learning in relation to the Environment Agency however, with particular relevance to flood warning. These include the commissioning of outside bodies such as Middlesex University to assess the performance of flood warning systems, the holding of annual seminars and liaison meetings with local authorities and emergency services, to receive feedback on the operation of the service, and the conducting of annual awareness surveys to gauge the public's view of the flood warning service. All these mechanisms have been used to identify shortcomings that have been used to adapt policies and strategies in the flood warning. But probably the best example of organisational learning in recent years is the commissioning by the Agency of an independent assessment of its performance during the Easter Floods of 1998. This review made 55 recommendations for change and resulted in a major shift in how the Agency manages flood events and organises the Flood Defence function within England and Wales (Bye and Horner, 1998). An organisation that is willing to learn from its mistakes, improve its performance and acquire new skills is likely to be highly integrative.

6.7 Summary and conclusions

Flood warning is essentially a social process involving a wide range of players with varying levels of knowledge and expertise, all with different perceptions and modes of interaction. For an integrated process to evolve the key players (including the at-risk public) need to communicate effectively, to minimise their differences in beliefs, attitudes and language, and be open to the acquisition of new skills. This chapter highlights a number of key issues that can facilitate the development of an integrated approach in the area of human interaction, expertise and training.

1. **The development of multidisciplinary working practices.**

   For many years flood warning has been dominated by a small number of professions and as a result there has been a preoccupation with a narrow range of issues. Tensions have arisen when other professionals have become actively and legitimately involved in the process. This has tended to have a negative impact on integration. To overcome inter-professional rivalry there is need to develop a common awareness of respective positions and to cultivate good social networks, both formal and informal. Within organisations multidisciplinary team working offers a useful mechanism for integrating professionals to focus on a common issue such as flood warning. During flood emergencies the establishment of multi-agency emergency centres where all relevant professional communities are present can reduce potential conflict and suspicion between them.

2. **Variations in the perception of the senders of flood warning information need to be minimised.**

   The role of the sender of warning information is to try and influence the behaviour of the recipient of that information, adding value to what would normally take place without the warning. It has been shown here that senders have varying perceptions of the flood hazard and of the action that they and receivers of their warnings should take to respond to that hazard. This can lead to inconsistencies in the level of service and ultimately will have a detrimental effect on total warning system integration. A number of measures have been suggested to minimise these inconsistencies and hence facilitate integration including regular staff meetings, training sessions, multi-agency exercises, the use of expert systems and work shadowing of more experienced staff. But importantly there is a need for a comprehensive and common understanding of the social and individual processes at work among warning recipients to ensure that their needs are more fully met and appropriate response to a warning ensues.

3. **The varying needs, perceptions and decision-making processes of the receivers of flood warning information should be understood and if necessary modified.**

The success of a warning depends on getting an appropriate message to the right people and for that warning message to result in an appropriate reaction. This chapter shows that the way in which people respond depends to a large degree on their background experiences and situation. In an integrated system information should flow freely between those who issue warnings and those who receive them, and for that information to be understood and believed and acted upon in a consistent way. It should not be assumed that recipients react directly they receive a warning message, but rather go through a sequential process to consider the relevance and applicability of that message to their particular circumstances. Designers of integrated warning systems need to pay more attention to the social and behavioural aspects of risk communication. There is a need to move away from simple procedures that attempt to deliver a standard warning message to a (perceived) uniform community assuming it will reach its intended target and result in effective response.

4. **The need for confirmation should be recognised and designed into all stages of the flood warning process.**

At every stage of the warning process most people will engage in some form of confirmatory behaviour after receiving information and before taking appropriate action. The seeking of confirmation can delay action and if not obtained can result in the entire process becoming blocked, thereby having a negative impact on integration. The greater the number of information sources the fewer the attempts at warning confirmation, the greater the belief in that information and the greater the likelihood of appropriate action. In an integrated system confirmatory mechanisms should be built in to each stage of the process to avoid delay and improve efficiency.

5. **The use and cultivation of informal contacts and social networks should be encouraged both in communities and organisations.**

Flood warning is a highly social process both in communities and in and between organisations. It is clear that social networks are central to the functioning of warning systems and that people from whatever background rarely function individually. Such networks have a significant role in the interpretation and confirmation of information for instance, and where they are in operation effective response is more likely. When people get separated from their social network there is evidence that they have a lower probability of responding appropriately and this can introduce delay and inaction. These findings appear to have equal weight both in communities and in organisations.

As evidenced in the Mimmshall Brook catchment (Chapter 8), social networks are an important community mechanism for disseminating unofficial warnings in times of flood. There is evidence to show that they help raise public awareness of flood risk and are often more robust that official schemes. In an integrated system it is desirable that official and unofficial schemes coexist and reinforce each other. Flood warden schemes can help in the integration process and where warning agencies have sought the views and assistance of local communities the flood warning systems appear to be more robust and effective.

6. **The role of the individual at all stages in the flood warning process should be recognised and encouraged.**

Individuals can have a significant impact on whether a policy of integration is successfully implemented. It is important that individuals are empowered and develop an affinity with relevant strategies such as one of integration. In many authorities for instance, the enthusiasm of key individuals can determine how effectively a given organisation responds to a given event. If these staff become disenfranchised for any reason they can, through various means, hinder the operation of an integrated approach to flood warning.

Within communities there are individuals who are more capable of detecting and interpreting signs of danger. These "local gurus" are often prepared to serve or lead the community in the interpretation and dissemination of information about changes in the environment and can perform an integrating role between agencies and the communities in which they live. These individuals are not always fully appreciated and trusted by forecasting and response agencies and there can be a general reluctance to acknowledge their expertise and potential role. In an integrated system these "local experts" would be brought into the warning process and supported to ensure their long-term involvement.

7. **Individual education and organisational learning strategies should be adopted.**

The importance of learning and training strategies for individuals in both organisations and communities, and for organisations themselves cannot be overestimated if a policy of integration is to succeed. Within organisations, individuals should receive regular training in all elements of the flood warning service, including the operation of the detection and forecasting systems, but also covering the social and human aspects of warning dissemination and response. The operation of the flood warning service should be carefully recorded, detailed debriefing sessions are recommended after events, and arrangements and procedures should be regularly exercised.

In communities, especially where experience of flooding is low, pre-disaster education is seen as a mechanism to raise public awareness and instruct individuals on how to recognise and respond to danger situations. These campaigns need to be well targeted and focused on local issues to be effective. Even communities that have experienced flooding need to be regularly reminded of the risk and the potential for floods to be worse than they have experienced in the past.

Organisations need to adopt learning strategies to ensure the continuous training and development of their employees. Organisations need to be flexible enough to be able to modify their structures and decision-making procedures in the light of experience and freshly discovered solutions to particular problems and issues. In an integrated system a participating organisation should be able to adjust itself to avoid being encumbered with rigid and out-dated plans, procedures and policies.

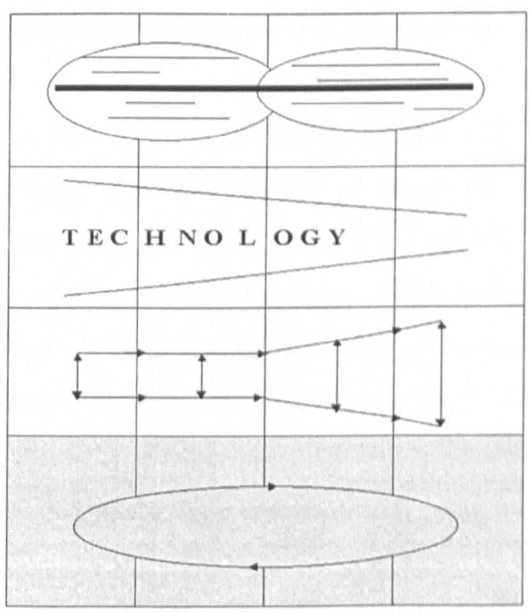
Chapter 7

Information and Knowledge

7.1 Introduction

This chapter examines the importance of the fourth component of the conceptual model (presented in Chapter 3) to flood warning integration, namely information and knowledge (shaded area in Figure 7.1). Particular attention is given to how information and knowledge flow through flood warning systems, how they are used and interpreted, and how they influence the consolidation of system components to make the whole more effective. A series of key issues are identified as having particular relevance to integration and these are critically assessed. This all takes place under the back-drop of the "information society" where the amount of information available to the public is growing exponentially, where the demand for information is increasing, as is the requirement for openness especially from public bodies such as the Environment Agency.

Figure 7.1: Conceptual model of the FDFWR process



(see Chapter 3 for full details)

7.2 The importance of information and knowledge to integration

The significance of information and knowledge in warning systems is well recorded in the literature and there is a general consensus amongst authors (Williams 1964, Foster, 1980, Mileti, 1994). In essence, and as diagrammatically represented in the model figure above, integrated warning systems should be viewed as a circular communication process, around which information and knowledge should flow, rather than a simple linear communication chain. This can be conceptualised as a means of getting information about an impending emergency, communicating that information to those who need it, and facilitating correct decisions and timely responses by people in danger (Mileti, 1994). It is vital however, that within such systems information is continually re-evaluated and modified in light of experience

A number of key issues can be identified that affect how information and knowledge flow from one system component to another around this idealised path, and as a consequence influence the degree of integration that is achievable.

7.3 The key issues affecting integration

7.3.1 Characteristics of the initial environmental information

The environment produces the initial information that must be collated, assessed and analysed to determine whether danger is present and in an integrated system the "environment-detection" linkage is an important structural characteristic (Mileti, 1994). However, the type of incident affects the opportunity to collect environmental information. Gradually rising river floods for instance, differ from flash floods in the length of time available to collect and process data and predict the occurrence of impact (see Table 7.1). Thus the environment, at the outset, affects the functioning of the warning system by influencing the characteristics of the initial information, and this has implications for system integration.

The type of incident will influence not only the type of information the hydrologist needs for detection and forecasting, but also that required by the at-risk public to ensure effective response. In the case of a fast responding flood, the hydrologist will rely heavily on information provided by the meteorologist such as short-period rainfall forecasts and frequently updated predictions of storm development (see Table 7.2). The accuracy of the information on which predictions are made is likely to be low and uncertainty will be high. Despite this, the public requires targeted information that is sufficiently accurate, timely and reliable to stimulate appropriate response. Because in many instances the detection and forecasting systems are unable to offer this kind of information, many areas that suffer from rapidly responding river flooding are not provided with an official flood warning service. It may be that the only system that is functioning effectively in these circumstances is an unofficial warning arrangement within the at-risk community itself and this system may indeed alert the forecasting agency rather than the other way around. Integration of official and unofficial arrangements would be beneficial in such circumstances.

Table 7.1 Lag-times for selected rivers in the Thames Region

River/location	Basin Area (km^2)	Average lag-time (hrs)
Kyd Brook at Kyd Brook Close	1.8	0.75-1.00
Mimmshall Brook at Warrengate Road	53	5
Wandle at Connolly's Mill	176	8-9
Mole at Royal Mills	485	30-36
Thames at Kingston	10,000	100-900

For floods that develop more gradually, hydrologists become more self-sufficient, relying more on information from local detection networks and flow prediction models under their direct control (see Table 7.2). The promptness of the information and frequency of updates is less critical and it is likely to be of a higher accuracy and more certain. Warning information for the public in these circumstances can be more comprehensive and detailed and can be repeated and updated at regular intervals. A slow speed of onset does not necessarily lead to more effective warnings however, as too long a period of forewarning, unaccompanied by any obvious signs of mounting danger, may result in an apathetic public reaction. A person is more likely to believe a warning if his or her physical environment supports the warning messages (Drabek, 1986).

The collection of environmental information is dependent on the size and integrity of the detection system. In an integrated system this should be designed to allow the adequate monitoring and recognition of an impending threat and where response to that threat must be rapid, information should be relayed automatically to a central processing centre. Sufficient coverage often does not exist resulting in incomplete information and inadequate warnings. Another issue is the functionality of detection equipment that may be affected by the impact of the hazard itself, unrelated technical problems or sabotage. In the Easter 1998 floods in the Cherwell catchment for instance, none of the nine river gauges "was without problems" and some failed altogether (Bye and Horner, 1998). Within an integrated system every detection network should be supported by an independent back-up system or at the very least sufficient redundancy should be built-in to a system to make it operationally robust. This back-up system should also include the relay of information from those on the ground whether they be officials or knowledgeable members of the public (see Table 7.3).

Table 7.2: Environmental information requirements for fast and slow developing flood events

	Fast Responding	**Slow Responding**
Detection	Trigger point exceedance Significant rainfall accumulations Rapidly rising river levels Storm development	Upstream river levels Catchment wetness Rainfall accumulations
Forecasting	Frequently updated rainfall forecasts (15 minutes)	Flow forecasts Daily rainfall predictions
Dissemination	Targeted information on areas at most risk - rapidly delivered	Detailed and locally specific information, repeated and updated
Response	Signs of immediate danger	Signs of mounting danger

In an integrated system, forecasting systems should also be tailored to the type of event. Complex flow forecasting models that require much data and time to produce a prediction are clearly not appropriate in flash flooding situations. In such circumstances there is much reliance on quantitative rainfall forecasting and the rapid interpretation of information by an experienced flood forecaster. Similarly, dissemination systems must be tuned to the type of risk; long dissemination chains are inappropriate for fast responding catchments, where technological solutions may be the only way of alerting large numbers of people in a short period of time. The need for robustness and redundancy are equally important here as well.

The length of warning about the onset of a hazard is a function of knowledge (Foster, 1980). As knowledge of environmental processes increases, the ability to predict and warn of their effects increases. The individual's knowledge of environmental processes is an important factor in an integrated system, be it that of the forecaster, local emergency manager or member of the public. An experienced flood forecaster will be in tune with local conditions, will be able to assimilate large amounts of environmental information and, based on knowledge that has built up often over many years, will be able to make predictions and issue warnings with some precision. Experienced local emergency managers may well be influenced by environmental conditions, prompting them to bypass the official detection system and warning those at risk directly. Similarly, local people living in flood risk areas can be very sensitive to environmental conditions, especially if they have experienced flooding before, and may act to alert their friends, neighbours and even the authorities based on their intuition and knowledge.

Table 7.3: Sources of environmental information in the Thames Region

Environmental information	Sources of information
Rainfall measurements	Telemetered raingauge network (105 gauges) – built in redundancy. London Weather Radar - high resolution National Radar Network London Weather Centre Staff observations (on-site)
River level information	Telemetered river gauges (250 gauges) – built in redundancy Flow forecasting models Staff observations (on-site) Flood wardens observations (via dedicated telephone line) Observations of the general public, media, etc
Catchment wetness	Met Offices MORECS system Environment Agency's Water Resources model Observations of catchment response to rainfall Staff observations (on-site)

The media may act as an independent source of surveillance information of the environment (Burkart, 1991). Information presented by the media may play the same role as the direct observation of a natural condition during an emergency. The media often do not totally rely on information provided from official sources, and can add to this information by tracking and monitoring the situation themselves. In certain circumstances they will use their own judgement more and go and look for themselves, using environmental cues to evaluate the severity of the hazard.

The characteristics of the initial environmental information, therefore, can heavily influence the way in which information and knowledge flow through a warning system, and can impact on the degree of integration achieved. The following points should be taken into account when developing an integrated approach to flood warning:

- Time is a critical factor and the speed of storm development and catchment response affects the time available to prepare a forecast and the medium chosen for disseminating a warning.
- Not only does the detection and forecasting system need to be tailored to the type of environmental condition that gives rise to flooding, but the dissemination of messages and response to warnings must be geared to stimulating an effective response. If not, warnings will be issued too late and remedial action will not be taken.
- There is a general reluctance to base flood warnings on uncertain information and for this reason many small river catchments in urban areas across England and Wales are not provided with an official warning service. In an integrated system uncertain information should be communicated to those at risk but in a way that is easily assimilated and understood. Uncertainty is explored more fully in Section 7.3.7.
- As discussed in Chapter 6, the knowledge of environmental processes held by key individuals is an important resource and should be recognised and managed. The assimilation, interpretation and decision-making processes that take place inside an experienced flood forecaster's head, for example, have important implications for integration. This will be analysed further in Section 7.3.2.
- The media often play a role in monitoring and reporting on environmental processes, but if they fail to get adequate advice they often attempt to evaluate environmental information using their own judgement. This can result in ill-informed assessments being made and communicated to the wider public. In an integrated system the forecasting agency should engage the media and give access to regularly updated information throughout a flooding incident.

7.3.2 Interpretation of environmental information

When the organisation responsible for issuing warnings receives environmental information from whatever source, these data have to be collated and evaluated. Decisions have to be made on the reliability of the information and what danger, if any, it implies to certain places at specific times. This evaluation is not a simple process, it requires value judgements based on experience and knowledge (Foster, 1980). In some cases the evaluation can be aided by the use of models that allow simulations by using incoming information, such as rainfall or river flow. As stated previously, early in a flood event predictions are often based on uncertain information. In an integrated system, it is important that there is close liaison between "expert" groups to ensure that such information is interpreted and acted upon consistently. In the Thames Region for example, a close working relationship between the Agency's forecasters and those at the London Weather Centre is paramount, along with the free interchange of information. The Agency for instance, provides free access to its raingauge information and this has been demonstrated to result in the production of more accurate rainfall forecasts and warnings from the London Weather Centre in return. When the Agency went one step further however, and offered access to its high-resolution weather radar displays and local rainfall forecasting system to provide added value, this was turned down. The Met. Office did not want to be seen to be reliant upon rainfall forecasting products supplied by a hydrological agency even though individual meteorologists were keen to have access to the information. This is a good example of professional demarcation obstructing the free flow of information between organisations and hence inhibiting integration.

Another common problem is that of inconsistency of incoming information. When faced with conflicting information the individual is likely to accept as more valid that which is least threatening. For this reason, evaluating groups faced with data inconsistencies tend to underestimate threats and in some cases contradictory data can delay the issue of warnings and this has implications for integration (Drabek, 1986). It is common for the receiver of information to seek confirmation from other data sources before acting, especially if an extreme condition is detected. There are circumstances however, where only one source of data is available and when extreme conditions are being accurately measured there is a danger that the information is not believed nor acted upon, especially when that data source has been known to be incorrect in the past. An example would be the "Folkestone Storm" in 1995 when rainfall totals in excess of 100mm/hr were accurately recorded by radar but were not believed by operational staff who felt the radar was overestimating. Interestingly, the automatic rainfall forecasting system Nimrod, also assumed the radar was overestimating the true rainfall and incorrectly reduced the rainfall intensity, which had the effect of confirming the false perception gained by the operational staff.

A further integration point, is the need for organisations responsible for interpreting environmental information to clearly understand the aim and objective of the service they are providing. It is necessary to determine the precise locations that will benefit from their predictions, the criteria on which local warnings should be based, and the time and information needed for those being warned to take the necessary protective action. In short, it is important for integration that predictions should be made with the end user, the public at risk, in mind. Until recently this approach has not always been taken and in some instances the production of a flood forecast was seen as an end in itself, with little or no consideration given to the requirements of the end user.

In some European countries, notably Germany and Holland, a policy of open public access to environmental information is practised. This is achieved by giving either direct access to data from measuring stations via multiple access telephone lines, or by broadcasting hydrological information via various media outlets, including dedicated environmental television channels. In England and Wales, this level of public participation is not encouraged and this policy potentially obstructs the free flow of information, working against integration. The only direct exposure to environmental data is via the television weather forecasts where weather radar, for example, has been given public exposure in recent years. Unlike in other European countries, it is assumed that the public will either not understand hydrological information or will be uninterested due to the relative infrequency of flooding.

In summary, a number of issues can be identified with specific relevance to integration:

- The evaluation of environmental data is not an easy process and on occasions incoming information may be inconsistent, conflicting, highly uncertain or incomplete. During flood emergencies it is possible for an "information fog" to form making it difficult to determine how the event is developing. In such circumstances, the experience and knowledge of the forecaster is paramount in helping to form a view of the level of risk and the type of warning needed. This situation can be eased by the interchange of information between forecasting groups (such as hydrologists and meteorologists), through close team working where issues such as conflicting information can be discussed, and the ability to confirm the accuracy of incoming information by some means. This might include receiving feedback from people on the ground including knowledgeable members of the public. These are all-important points for integration and the need for confirmation will be addressed further in Section 7.3.7.

- It is vital for the forecasting agency to take into account the needs of the end-user, the public at risk, when interpreting environmental information and not produce forecasts just for their own sake. In an integrated system the public need will influence the type of information collected, how it is interpreted, and the emphasis placed upon it. Giving greater public access to hydrological information will help with interpretation and understanding.

- The involvement of the public in the interpretation of environmental information should be explored further and where informal systems exist, steps should be taken to integrate them into official warning arrangements rather than trying to compete with them. Informal warning systems are examined in more detail in Section 7.3.6.

7.3.3 Interpretation of forecast and warning information by the response agencies

Once the prediction agency interprets the environmental information and produces a forecast it will communicate that risk information with other agencies responsible for local emergency management. These agencies will want to interpret this information themselves in terms of potential losses (i.e. loss to life and property) and scale their response to the risk accordingly (Mileti, 1994). There is a need for clear linkage between agencies in an integrated system and because the local emergency management agencies may need assistance with interpreting warning messages, communication between personnel during emergencies is vital. It is possible however, for the environment to in effect bypass the detection system and to directly influence managers in local agencies, and this eventuality should be recognised and planned for. This often happens in urban areas such as London, where heavy rainfall may alert local managers before formal flood warnings are received.

Keys (1997) raises the issue of adding value or giving meaning to flood predictions. To do this effectively, he argues, local knowledge must be added to the prediction. In Australia this has been tackled by the state emergency services through "flood intelligence systems" which are records of flood information for the area for which predictions are made. This would include gauge heights at which flood waters are likely to begin to encroach upon farmland, low points on roads, houses, industrial and commercial premises, community institutions and utilities. It is useful to have indications of the heights at which flood defences could be overtopped or when communities become isolated, as well as the heights at which significant decisions must be made, such as evacuation. In an integrated system, local agencies should develop an understanding of the characteristics of flooding in their own areas and have the ability to record information to extend that knowledge. In many instances the formal development of flood information is absent or rudimentary, and a vital ingredient for high-quality communication is often lacking. Gathering flood information not only helps build expertise about the characteristics of floods in local areas, but also assists in the development of the appropriate flood warning messages for the public, an important integration point.

In England and Wales, the Environment Agency and its predecessors have taken the lead role in the collation of flood information. In some areas, teams of trained staff visit flooded areas both during and after flood events and gather detailed information on flood depths and extents, and the numbers of properties affected. This information is often collated into flood reports and maps and in some cases the data are stored on geographical information systems. In the Thames Region, data are used to set trigger levels at river gauging stations, to improve flood detection, and to generate reach-based flood information that is supplied to local authorities and police forces as an aid to flood warning dissemination. This is good integrative practice. Unlike in Australia however, local authorities are not generally active in this area and are unable or unwilling to collect detailed flood information. Without good quality information and knowledge of the nature and effects of floods in their area however, local emergency managers may be hampered in their ability to respond effectively when floods strike.

The Environment Agency's lead role in flood warning matters puts an onus on the organisation to ensure that other agencies involved in the process have access to the correct information and know how to interpret it effectively in the event of a flood emergency. In the Thames Region, this has been addressed over many years through the hosting of annual seminars with representatives from local authorities and the emergency services (see Chapter 4 for details). This gives the Agency a forum to liaise with and educate other organisations on the relevance of flood warning information and how it can be used in flood events to improve response. In addition, county/metropolitan area-based flood warning planning groups, that were established in 1996, allow local issues surrounding all elements of the flood warning service to be discussed in more detail, the establishment of closer working relationships, and for improvements to be made in the flow of information between agencies.

The main issues of relevance to integration can be summarised as follows:

- The response agencies will want to interpret, confirm and even by-pass the official flood warning information that is sent to them by the forecasting agency. In an integrated system these requirements should be planned for and managed.

- It is relevant to attempt to add value to flood predictions by incorporating local information. This has the effect of not only building local expertise and knowledge, but also improving the quality and meaning of warning messages to the public.

- Systems should be put in place to collate and archive local flood information by all relevant organisations and to introduce feedback loops to improve detection, such as modifying trigger levels at river measuring points.

- A role of the forecasting agency is to facilitate the provision and interpretation of flood forecasting information to and by the response agencies to improve overall response.

- Improved liaison between agencies ensures an improved flow of information during flood emergencies and at other times, and shared access to local knowledge. The removal of barriers to this free flow of information and knowledge is a positive integration action.

7.3.4 The design of public warning messages

One of the most important factors in determining the effectiveness of a warning system is the warning message itself, and it is the content and style of the warning message that shapes the extent to which an endangered public engages in protective actions (Mileti, 1994). A warning message converts technical information on a flood prediction and interpretative material on the meaning of that prediction into a message for those at risk (Emergency Management Australia, 1999). The message is an important element in an integrated system as it represents the critical link between flood prediction and interpretation on the one hand, and effective response on the other.

There is general agreement in the literature concerning how a flood warning message should be constructed and the information it should contain (Keys, 1997, Burkart, 1991, Mileti, 1994, Emergency Management Australia, 1999, Edworthy and Adams, 1996, Drabek, 1986). Table 7.4 summarises the main findings and these can be viewed collectively as the principal attributes required of an "integrated warning message". It will be of interest to ascertain how closely the warning messages issued by the Environment Agency comply with this ideal.

As discussed in Chapter 6, flood warning messages issued by the Environment Agency and its predecessors have been based around a three phase colour coded system, YELLOW, AMBER and RED, which is designed to indicate the likely severity of the flood in a simple form. Post event surveys indicate however, that there is much confusion amongst recipients of colour-coded warnings and they are often misinterpreted (BMRB, 1998, 1999) (see Tables 6.13 and 6.14). During the Easter 1998 floods a number of interpretations were recorded:

> "Red for danger. High priority"
> "Amber: possible risk of flooding"
> "Amber is flooding the road and red is flooding of the property"
> "Amber did not seem that bad" (After, BMRB, 1998)

The Bye Report concluded that the public was not well served by the system and that an alternative, more customer focused approach was required.

> "Colour coded warnings appear to be misunderstood by nearly all who receive them. This is because the colours are spontaneously linked with the escalating probability of flooding actually occurring and not with the extent definitions to which the colours relate. The interests of the public are not well served by warnings given on a colour-coded basis" (Bye and Horner, 1998).

Table 7.4: The attributes of an "integrated" flood warning message

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 relate to and 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 a message should be identified • 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, arouse 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 is 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 in improving message quality

(After: Keys, 1997, Burkart, 1991, Mileti, 1994, Emergency Management Australia, 1999, Edworthy and Adams, 1996, Drabek, 1986)

In response to these criticisms, the Environment Agency embarked on an extensive consultation programme with customer groups and partners during the 12-month period commencing September 1998. A national group within the Agency was tasked with collating the findings of this consultation programme and formulating and defining an alternative system.

It was concluded that a three-staged warning system was the most appropriate and this is supported by "best practice" overseas. This progressively alerts people who may be at risk of flooding of the degree of danger to life and property so that they may progress through a series of actions that will lead to effective response. These is a need however, for a fourth stage which can be described as the "all clear" when all flood watches and warnings have been cancelled. It was also recognised, that at each stage it is necessary for certain actions to be taken and these need to be specified (Parker, 1999; Haggett, 2000).

The terms and definitions of the existing colour-coded system and the proposed staged system are set out in Table 7.5. It is clear that the new definitions use more vivid language, are more action orientated and convey more of a sense of urgency than the old rather staid definitions, and this is a positive development.

Table 7.6 presents an assessment of how each of the integration attributes identified in Table 7.4 are met by the existing colour-coded system and the proposed staged approach. Although the analysis is based on a subjective assessment by the author, it is clear that the new system is scoring far higher against the integration attributes when compared to the existing colour-coded system. This is a clear indication that the Environment Agency is moving in a positive direction in this area with respect to integration.

In summary, a number of key issues can be identified relating to the design of flood warning messages and integration:

- It should be recognised that the warning message in itself is an important element of an integrated system as it links flood prediction and interpretation with effective response.
- There is a high degree of consensus amongst researchers on the type of information that the ideal warning message should contain to engender recipient response. Using findings

from the literature it has been possible to summarise the key attributes of an "integrated flood warning message" and these have been used to assess how closely current and proposed arrangements meet the ideal.

Table 7.5: Definitions of warning codes and stages used and proposed by the Environment Agency (after Haggett, 2000)

	Warning code/stage	Definition
Existing system	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 the sea.
	RED	A warning of serious flooding affecting many properties, roads and large areas of farmland.
Proposed system	FLOOD WATCH	Flooding is possible in the designated area. Be aware. Be prepared. Watch out!
	FLOOD WARNING	Flooding of homes, businesses and main roads is expected in the designated area. Act now!
	SEVERE FLOOD WARNING	Severe flooding is expected in the designated area. There is imminent danger to life and property. Act now!
	ALL CLEAR	There are no flood watches or warnings in force in the designated area.

- In an integrated system, steps should be taken to ascertain whether the public understand the content of warning messages and act on them effectively. The need for feedback and modification is underlined. For example, there is some indication that although the public in risk areas think they understand the meaning of the colour coded system, they are misinterpreting the intended meaning. In recent surveys (BMRB, 1997, 1998, 1999), RED is commonly thought to signify that flooding was happening now, AMBER that flooding is imminent, and YELLOW that flooding may occur in the future, but is less likely.

- To be effective, flood warning messages need to contain factual information about the flood hazard but also advice on what to do. Information needs to be locally specific, appropriate to the recipient group and updated regularly.

- Further work is needed to address the requirements of special needs groups within at-risk communities, including ethnic groups, the disabled, and the old and infirm. Reliance on one warning message format delivered via one mechanism is certain to be inadequate. There is a need therefore, to proactively identify key facilities (such as hospitals and retirement homes) and special needs groups that are located in flood risk areas and provide appropriate and targeted warning messages. It is recognised however, that the dissemination of a range of warning messages can be onerous where lead times are short.

Table 7.6: Analysis of the colour-coded and staged warning systems with reference to integration

Attribute	Colour-coded system	Score	Proposed staged system	Score
Factual information	Storm and flood information made available, but not always specific and relevant to the individual and local conditions	2	Greater emphasis planned for the provision of locally relevant information.	3
Acton advice	Little behavioural information given	1	Action guidelines planned for each warning stage and each recipient group	3
Source of message	Source of message not always clear, messages not given authority	1	Improvements planned, but more work required especially with the full range of media outlets	2
Consistency	Messages not consistent between regions	1	Messages to be consistent within and across regions	3
Clarity	Colour-codes not fully understood, messages not attention grabbing	1	Messages to be in plain English and more action orientated	3
Tone	Messages largely factual but neutral in terms of arousing emotional interest	1	Messages to encourage social interaction, specific individual action, but vivid language needed in severe events.	2
Alerting function	Colours used to emphasise risk, but wording does not motivate or arouse	1	Signal words and icons used to emphasise risk and action, more work needed on conveying sense of urgency	2
Target audience	Homogenous messages generally used for all recipient groups	1	Messages to be targeted for different recipient groups	3
Message construction	Message templates not consistently produced for different recipients, no mechanism for conveying uncertain information	1	Range of consistent message templates to be produced, "Flood Watch" will allow uncertain information to be communicated.	3
Professional skills	No specialist guidance sought	1	Guidance sought from communication specialists	3
Scoring: 1=low, 2=medium, 3=high				

- Consideration should be given to the provision of a mechanism for communicating uncertain information to flood warning recipients. Care is needed however, to ensure that the recipient understands the level of uncertainty and what action is appropriate when such information is disseminated. The FLOOD WATCH stage proposed by the Environment Agency is a positive development in this regard (Haggett, 2000).

7.3.5 Communication of warning information

For a warning message to be effective it must be communicated appropriately to those who need to take action. Mileti (1994) sees the instigation of comprehensive and multiple channels of communication to the public as a key element of an integrated warning system. Foster (1980) believes that no warning system will function effectively if its messages are ignored, disbelieved, or lead to inappropriate action. To avoid such pitfalls he stresses, warning messages must be designed and transmitted with the greatest of care. Drabek (1986) states "the more often people obtain information the more they trust the warning and the more they prepare".

A number of authors have documented how warning information should be conveyed effectively to those expected to respond. There is agreement that mere dissemination is not enough: it must be done in a manner which is both timely and designed to obtain the appropriate response (Emergency Management Australia, 1999). An integrated system requires warning information to be disseminated at different stages, for different target audiences, using different dissemination methods.

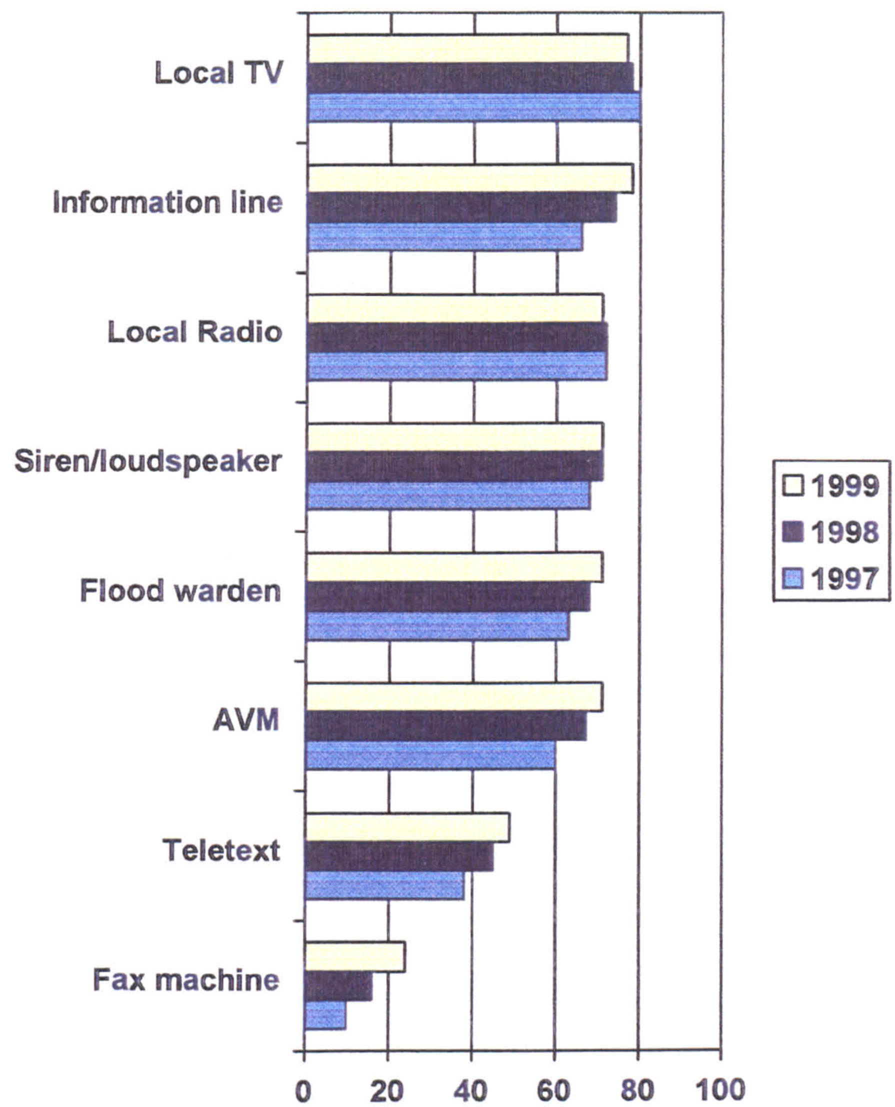
Table 7.7 summarises the advantages and disadvantages of different warning dissemination strategies that can be utilised in an integrated system. This emphasises the fact that no single method is perfect and that a range of dissemination methods is required that compliment and reinforce each other. Surveys carried out in flood risk areas across England and Wales indicate that the warning methods residents find most helpful are media related, in particular local television (78%) and local radio (72%) (see Figure 7.2). A 24-hour information line and sirens were each thought to be helpful by at least seven in ten respondents. Most other warning methods were seen as helpful by at least half the sample, with the exception of Teletext and warning by fax machine (although 58% of businesses thought faxed warnings are helpful) (BMRB, 1999).

Table 7.7: The advantages and disadvantages of different warning dissemination strategies

Strategy	Advantages	Disadvantages
Use of multiple warning channels	• Use of a range of dissemination channels helps communicate complex and widespread impacts especially in severe events • Different channels can be used in different circumstances, dictated by onset time, likely severity, nature of community, etc. • The more that different channels are used, the more people who hear and remember they have heard a warning • Allows messages to be repeated - recipients more likely to believe • General and specific channels should be used together and be seen as complementary	• Use of multiple channels increases the chances of error and the possibility of information being added to or subtracted from the message and changing its meaning • Each dissemination channel must convey the same information and must be updated simultaneously to avoid confusion and loss of credibility.
Use of the media	• The media offer an essentially free channel for public information • In many cases the media offers the only rapid way of disseminating information to large and diverse audiences • Both the broadcast and print media offer an avenue for raising public awareness of the flood hazard both during incidents and at other times. • People find television a personalised way of receiving information • People tend to believe warning messages if they are delivered by "experts" such as weather forecasters • Media and official warnings act as an impetus for social networks to function and relay information to others.	• In urban areas many broadcast channels exist and individuals have different listening habits • Individuals change their listening/viewing habits during the day. Few people are tuned-in through the night • There may be a delay in getting information broadcast on radio and television. Local radio is not able to respond quickly enough to broadcast flood warnings for fast responding rivers • There is no way of knowing if the message has been heard, understood and believed by the recipient • The media may be ineffective in engendering a sense of risk and have only mixed credibility with the public • To be effective the media must be sent concise and specific messages that are updated frequently • The media may not always pay attention to the warning message and act upon it.
Use of specific or direct warning methods	• They are likely to be more persuasive than media warnings • People are more likely to hear, understand and believe a message that is delivered to them personally • Personalised delivery allows the provision of additional, confirmatory information • Enable targeted warnings to be provided to householders, businesses or other clearly identifiable individuals, groups or organisations. • There is evidence to show that warnings are most effective if they come from a credible and authoritative source	• Direct warnings can require a significant resource to deliver • The use of technology can depersonalise warning arrangements
Use of non-specific warning methods	• Sirens and alarms are simple to operate where warning times are short • Different auditory warning sounds can be used to convey different levels of urgency • Auditory warnings can alert the visually impaired • The public's' ears are always open to auditory stimulus regardless of what they are doing	• Such methods are ineffective by themselves • Unless the public is educated about their significance they may be ignored • Many people fail to hear warnings

(After: Mileti, 1994, Foster, 1980, Williams, 1964, Drabek, 1986, Keys, 1977, Burkart, 1991, Emergency Management Australia, 1999, Edworthy and Adams, 1996).

Figure 7.2: Perceived helpfulness of warning methods: 1997, 1998 and 1999 (after BMRB, 1999)



(base: all respondents % of "very" or "quite helpful)

Table 7.8 presents an assessment of how closely the warning dissemination strategies adopted and proposed by the Environment Agency comply with the ideal arrangements. It is clear that although a number of advances were made in 1996 which were all positive integrative steps, more work is needed to fully implement a multi-channelled dissemination strategy across England and Wales. The Environment Agency plans to address many of the identified shortcomings through the introduction of a new warning system in September 2000. This should result in the use of a wider range of warning methods, better relations with various media outlets, the use of warning icons and consistent warning message templates, the provision of regular information updates, and more targeted and personalised warning messages. At the time of writing however, the system is in the planning stage and it remains to be seen if the laudable proposals find their way into operational practice from September 2000.

In summary, a number of key issues can be identified relating to the communication of flood warning information and integration:

- In an integrated system the targeting of warnings for different audiences in the flood plain is essential, but this issue has not been fully addressed in England and Wales. There is still a tendency to view the at-risk public as a single mass of people and that their needs can be adequately met by a standardised message format (delivered in English and Welsh), disseminated via a limited number of channels. For example, in urban areas, such as London, ethnic groups do not necessarily seek information from the traditional media outlets, nor speak English and alternative arrangements should be sought to reach them. With the assistance of the local authorities, the range of communities and ways in which information could be disseminated to them, such as ethnic radio stations, should be identified. Specific arrangements should also be made for the elderly, the infirm, and other special needs groups where these can be identified. It should also be recognised that there is a sizeable section of the community that for one reason or another do not have access to technology and may become excluded from warning information that is disseminated by technological means. As discussed in Chapter 5, this is a key issue for integration. Post-event surveys are required to ascertain if the chosen dissemination channels are effective in getting information across to the public: to determine whether the target audience is hearing, understanding and acting on the information provided. This will influence the number and type of channels used in the future, how frequently information is transmitted and repeated, and the way in which messages are formatted and delivered (see Figure 7.2).

Table 7.8: Effectiveness of existing and proposed warning dissemination strategies in England and Wales.

Strategy	Existing system	Score	Proposed system	Score
Use of multiple warning channels	• A number of warning channels established since 1996 - Agency regions given a choice of 4 broadcast methods and 4 direct methods • Tendency in some regions to focus on a limited number of methods for reasons of control and convenience	2	• Plans to extend the number of warning channels • Mix of methods to be used that will vary from location to location • Facility to be introduced for issuing information updates at each warning stage	3
Use of the media	• A number of local radio stations used to disseminate warnings but not the full range, other media outlets not fully exploited e.g. internet, local television, weather forecasts, text services • Media not fully engaged in the dissemination process - sense of urgency not always given to the broadcasting of warning messages	2	• Intention to engage the media more to ensure that warning messages are acted upon with greater urgency • Plans to secure national broadcasting agreements with BBC and Independent companies • Plans to extend the range of media outlets that disseminate warning messages, including the internet • Plan to use warning icons to strengthen warning messages on the visual media. • Consistent warning messages templates to be introduced	3
Use of specific or direct warning methods	• About 5% of at-risk public provided with direct warning service, but tendency to over-rely on a single technological warning method i.e. the Automatic Voice Messaging system • Rejection in some regions of more community-based methods such as flood wardens	2	• Intention to place greater emphasis on the delivery of personalised warning methods • Improved flood risk information will allow greater targeting of high risk/high impact areas for direct warnings • The use of the sub-brand and information service "Floodline" is likely to make the source of warning messages clearer and more authoritative • Consistent warning messages templates to be introduced	3
Use of non-specific warning methods	• Use limited to small number of coastal and urban areas • Inconsistent procedures across England and Wales	1	• Consistent warning messages templates to be introduced • No immediate plans to make the use of these methods more consistent and widespread	2
Scoring: 1=low, 2=medium, 3=high				

- It is also important to determine whether the public believes the warning messages when they are transmitted. In the past, the authority of the police ensured that the public took the information provided seriously. As Burkart (1991) notes, when the police are the warning source, most people are convinced that the flood threat is real. Today, the Environment Agency has more of a problem because awareness of the Agency is relatively low; in a recent survey (BMRB, 1997) only 8% of respondents were aware that the organisation was connected with responsibility for issuing flood warning. This has since increased to 24% (BMRB, 1999). Most people associate flood warning responsibility with either the local authority (21%), the local water company (10%) and even the National Rivers Authority (12%) (the Agency's predecessor authority). When flood warnings are transmitted under the name of the Agency therefore, there is a danger that they may have limited impact. The situation may be improved if well-respected and authoritative individuals, such as established weather forecasters, were employed to deliver warning messages. The Agency is attempting to adopt this approach by passing warning information to Met. Office forecasters for transmission on local and national radio and television weather forecast bulletins. It is clear however, that further work is need to fully integrate the presentation of warning information (meteorological and hydrological) to the public via this route.

- In an integrated flood warning scheme warning messages should be disseminated via multiple channels as this has been shown to increase warning effectiveness. In practice this means that warning agencies need to become reliant on dissemination channels that are outside their direct control, such as the media, flood wardens and other community channels. If trust is not placed in these warning methods they will fall in to disuse and warning agencies will become over-reliant on a small number of warning mechanisms that they can control directly, such as the AVM and FLOODCALL services operated by the Environment Agency. There are worrying signs that the latter approach is gaining favour in some quarters in the Agency with the added danger that technological solutions may be given too high a profile. This would have a negative impact on integration.

7.3.6 Official and informal warning information

It is important to recognise that in many areas especially where flooding is frequent, an "informal" prediction and warning system may exist in addition to "official" warning arrangements. Such systems are usually made up of local residents who are part of well-established social networks and friendship and neighbour groups. These people have learnt to live with floods and as a consequence may have developed their own flood warning arrangements based on their observations and understanding of hydrological processes. There is also evidence to show that informal arrangements exist in flood response organisations such as local authorities, emergency services, the media and even within the forecasting agencies themselves. Parker and Handmer (1997) consider that the designers of official systems often neglect the presence and potential of unofficial systems for enhancing warning effectiveness.

In the research literature it is recognised that informal warning systems form an important part of an integrated warning system. Regardless of the wishes of officials, they will play a role in the dissemination, interpretation and response to warnings, drawing on local knowledge and personal networks (Mileti, 1994; Parker and Handmer, 1997). In some countries, notably Australia, practitioners are actively encouraged to seek advice from local residents who operate unofficial systems, share information and incorporate these data into the prediction process. It is argued that such a strategy helps integrate the informal system into the formal one and minimises the undesirable effects of competing predictions during flood events (Emergency Management Australia, 1999). By integrating local arrangements with the formal prediction system it helps give the local people some sense of ownership of the overall process. The media can also be providers of unofficial information especially if that from formal channels is insufficient or absent. This underlines the need for forecasting agencies to work closely with the media during flood events and at other times to ensure the effective interchange of information and knowledge (Burkart, 1991; Drabek, 1986). It should be recognised however, that informal warning systems can be a source of misinformation, and this can be damaging as well as constructive. For example, information may be received and acted upon by people for whom it is not intended (Williams, 1964). This emphasises again the need to integrate informal with formal warning systems, at the planning and operational stages, to help ensure the two systems re-enforce rather than compete with each other.

A useful way of integrating official and unofficial flood warning systems is through the use of local flood wardens. Flood wardens are unpaid community volunteers who agree to cascade flood warning messages to neighbourhood members. Where they exist, they have been shown to improve flood warning performance by linking official systems, with their technological strengths in flood detection, to personal and community networks with their strengths in local knowledge and information dissemination (Tunstall et al, 1991; Parker and Handmer, 1997).

Flood warden systems have been in operation for many years in the Severn and Trent catchments, particularly in rural communities that experience frequent flooding. In some areas it has been recorded that people are so used to the "annual" floods that they see no benefit in receiving an official warning as they feel they can cope better by acting on their own observations, but this is not typical however (Brown, 1995). In areas where wardens have been in operation for some time there is an increased level of community involvement in disseminating warnings. In some instances people have taken it upon themselves to warn and assist others in times of need even if their neighbours had formally declined to participate in the official warning scheme. In other areas the official and unofficial systems re-enforce each other through the exchange of river level information via a "River Watch System" established between the flood wardens and the Environment Agency. This enables the flood forecasters to receive valuable data from areas not covered by the Agency's river flow and level monitoring stations, thereby enhancing the quality of the official warning system.

Despite these positive integrative attributes, the Midland Region of the Environment Agency has recently decided not only to stop recruiting flood wardens but also to stop supporting existing warden schemes. Flood Defence managers have concluded that the AVM system is a more reliable mechanism for delivering flood warning messages to the public and that it is easier to control than the more "esoteric" community-based methods. This philosophy is also being followed in the Environment Agency Wales. In the Thames Region however, the opposite is true with greater emphasis being placed on community involvement in warning dissemination and integration with informal systems where they exist.

Table 7.9 shows the steady increase in warden recruitment across the Thames Region in the last 10 years, with some of these schemes having their origins in informal schemes that have been in operation for some time previously. In the Loddon catchment in Wargrave, Berkshire, for example, the chairman of the local residents association maintains a keen interest in the river and has kept records of gauge board readings for many years. He alerts local residents of high levels and flooding and with his agreement the Agency was able to add value to this local initiative by integrating the informal and official warning systems together in 1998.

Table 7.9: Number of flood wardens in the Thames Region in 1989 and 2000

River Catchment	Flood wardens	
	1989	2000
South London Rivers	14	14
North London Rivers	6	7
Lee	1	7
Roding	-	7
Colne	45	58
Mole	-	1
Wey/Bournes	-	4
Loddon	-	1
Thame/Wye	-	2
Cherwell/Ray (Oxon)	-	33
Kennet/Ock/Pang	12	14
Cotswolds Rivers	-	-
Fluvial Thames and minor tributaries	29	30
Total	107	178

Within organisations informal arrangements exist along side the official warning systems. In the Environment Agency for instance, although the main data gathering systems involve the use of telemetry gauges and computers, it is quite common for manual gauge reading or "flood runs" to continue in parallel. This involves river gangs routinely visiting sites upstream of flood risk areas to "check levels for themselves". Through discussions with certain local authorities, police forces and the British Waterways Board it is understood that this practice is duplicated in certain areas by their staff. The Royal Borough of Windsor and Maidenhead routinely patrol the River Thames in times of high flow for instance gathering river level data. It is also common for news crews from radio and television stations to drive around areas subject to flooding gathering information from residents at risk and from their own observations that can sometimes lead to exaggerated reporting. As with flood wardens it is important that information for whatever source is freely exchanged and for unnecessary duplication to be avoided although having back-up arrangements can be valuable.

The reaction to and management of informal systems by warning agencies therefore, can have an impact on integration. It is clear from the analysis presented above that particular attention should be paid to the following factors:

- It is important that the official agencies recognise the existence of informal arrangements and develop a positive attitude towards them. Some officials still view such schemes sceptically, preferring to replace them with their own arrangements. There is often a lack of trust in local people being able to manage their own affairs and this lack of confidence can often be then reciprocated. Agencies appear to have little confidence in "non-technical" solutions and prefer to rely on techniques over which they have complete control. Examples are documented of where agencies have become involved in community-based schemes only to withdraw when procedures have not functioned as they would like.

- There is some evidence emerging that where official systems are established unilaterally this can lead to the demise of informal arrangements, resulting on the public becoming over-dependent on the former system. The danger here is that if the official system fails for any reason there will no longer be any redundancy in local warning arrangements that the informal system could provide. To avoid this, warning agencies should actively seek out informal systems before introducing official warning arrangements. Where they exist it is important to share information, obtain advice and local knowledge from the people who operate them.

- Official schemes should not compete with informal warning systems, and effort should be directed towards integrating the two with the aim of enhancing overall warning system performance from the perspective of those at risk. Such a policy will help establish a sense of ownership amongst the local populace and improve the credibility of the official warning system. Informal arrangements operating within organisations should also be integrated to avoid fragmentation of response. These arrangements can often support the official system and provide on-the-ground confirmation.

- Flood warden schemes are seen as a good vehicle for integrating informal and official warning mechanisms. It is vital for such schemes to be well maintained and supported by official sources to minimise the possibility of failure. In the Thames Region four full-time flood warning dissemination officers have been recruited to improve the functioning of existing warden schemes and establish new ones in high-risk areas. One of their key objectives is to seek out informal warning systems and use them as the foundation of any official arrangements that may be introduced (see Chapter 8).

7.3.7 Feedback and confirmation

Most research on the effectiveness of flood warning systems stresses the importance of feedback within the system and the need for confirmation by those delivering the warnings and those receiving them (Foster, 1980; Williams 1964). In an integrated system feedback is desirable at each stage of the warning process and it is important that information should flow in both directions between the warner and the warned. Seeking confirmation is another important and integrative process; whether it is the forecaster being presented with information of an impending severe storm, or the recipient of a warning living in a risk area. Appropriate response may be delayed until confirmation is received that the information supplied is perceived as valid. It is clear that when people get confirmation the perception of the threat is higher than with those who do not (Drabek, 1986). People usually obtain information in two ways; it is sent to them or they seek it out (Burkart, 1991). An environment in which people can easily confirm an initial warning through alternative sources is one that fosters the development of warning belief and is well integrated.

In the detection and forecasting phases of the warning process, flood forecasters often seek feedback and confirmation especially when they are presented with information indicating extreme rainfall or river flows. In such cases, alternative data sources can be used to check the validity of information or advice can be sought from another party to confirm that a measurement is probable. A gauge indicating a rapidly rising river level, for example, might signify a malfunctioning instrument or a very localised flash flood, the forecaster would seek confirmation before accepting the validity of the information presented and responding. Knowledge of the prevailing weather conditions would help formulate a response: if forecasters know that high pressure is dominating weather patterns, for instance, they are more likely to conclude that the river gauge in question is malfunctioning in some way. On-site reports can also provide valuable feedback to the forecaster, both on the impact of flooding and on the accuracy of predictions. Such reports may come from a member of the emergency work force, local authority or emergency services staff, flood wardens or the general public. There is a danger here however, that reports of flooding received from the public may be exaggerated; people have been known to pressure a response agency into offering them assistance by indicating that flooding is worse than it actually is. But in general to develop an integrated system communication channels should be kept open to give and receive feedback from all parties involved in the flood warning process.

Feedback is increasingly being used in automated flood forecasting systems to improve the accuracy of predictions. Observed river flow information gathered via telemetry can be used to adjust the modelled flows so that the accuracy of future forecasts can be improved, this can be achieved in two ways; through correction of model states or prediction of model errors (Moore, 1993). In the former, techniques are used to correct the states or variables of the model in real-time to achieve concordance between observed and model predicted flow. Moore sees state correction as essentially a form of negative feedback and shows that it can be a very effective procedure. In the latter, rather than adopting empirical adjustment procedures to correct modelled flows, the structure of the errors is analysed, and based on this analysis, future errors are predicted which can be used to obtain improved flow forecasts. Care should be taken when adopting either technique however, as in some circumstances erroneous adjustments may be made especially where there are timing errors in the model forecast. It should be also noted that in instances where the forecaster has low confidence in modelled flows and is unable to confirm the prediction because the river may not yet have risen, it is likely that a warning will be delayed until confirmation is forthcoming, say from rising upstream levels. Bye and Horner (1998) make the specific point that flood forecasting procedures should ensure that, in addition to using model predictions, close attention is paid to monitoring flood levels. The recommendation that forecasters should not rely solely on model output but should also consider flood level information both measured and from on-site observations is an important integration point.

Confirmation and feedback are equally important in the dissemination and response phases of the warning process, acting as integrating mechanisms. Those initiating and delivering a warning need to confirm that the message has been disseminated to the target audiences by the appropriate means and that effective response ensues. This can be achieved after a flood event through liaison with the media and by carrying out post-event public surveys, or during the event to give those issuing warnings an immediate indication of whether there has been an appropriate level of recipient response. The use of feedback information to modify warning messages is particularly valuable, with the potential of integrating the dissemination and response phases of a warning system more effectively. To facilitate this, special communication channels should be established to ensure that user response to warnings can be closely and rapidly monitored. It is recognised however, that in practice little or no attempt is made by the warning officials to seek feedback and issue new information. In many instances the need for feedback is not even considered and where it does occur it is largely unplanned. It should also be acknowledged that in certain circumstances the nature of the hazard prevents feedback; very rapid flash flooding would be such an example.

Another group of people for which confirmation and feedback is important is the recipients of warning messages. It is recognised in the literature that warning messages will be accepted at face value only by a minority of the recipients and that most people will attempt to engage in some form of confirmation before taking any protective action (Mileti, 1975; Burkart, 1991). It is also recognised that the more warning messages that are received by an individual from different sources, the fewer the attempts at warning confirmation and that there are strong links between the seeking of confirmation, the belief in the warning message and the content of the warning message. In practice however, these processes operate sub-optimally and most people seek out additional information by calling friends and relatives to get their interpretations of the event and to determine what action they are taking (Drabek 1986). Most people contact their personal networks of friends, neighbours and family to confirm warnings or do so by direct observation, such as going to the river. The media is a popular confirmation source and can play an important role in getting basic information into social networks. This can become a valuable tool for emergency managers in the response phase of an incident and a useful integration mechanism. Burkart (1991) notes that in general people *switch* channels to confirm warnings and that this switching is done in regular patterns – from official to social, from media to social, from social to official, etc. This has implications for integration because without an integrated approach to warning message dissemination these different sources may well give the recipient a contradictory picture causing confusion and delayed response.

Confirmation behaviour is dependent on warning lead-time. When a warning is urgent and lead time short there is often less effort to confirm and more of a tendency to accept the warning at face value. In slow onset floods however, people are more likely to engage in confirmation behaviour, using their social network and the media as primary sources of information, but it can take time for these sources to start to function effectively. Burkart (1991) suggests that such behaviour can slow down eventual response to a warning and recommends that emergency managers should try to cut confirmation behaviour time to a minimum. It is important therefore, that confirmation should be facilitated, as people often delay appropriate response until they have satisfied themselves that the message is real and applies to them, and delay can be a precursor to failure. In Australia this has been addressed by establishing flood information centres during flood events for those seeking warning confirmation and other flood-related information (Emergency Management Australia, 1999). By providing a confirmation service, the chance of rumours is reduced, a greater credibility is conveyed because the source of further information can be specified in the broadcast warning message, and integration is facilitated.

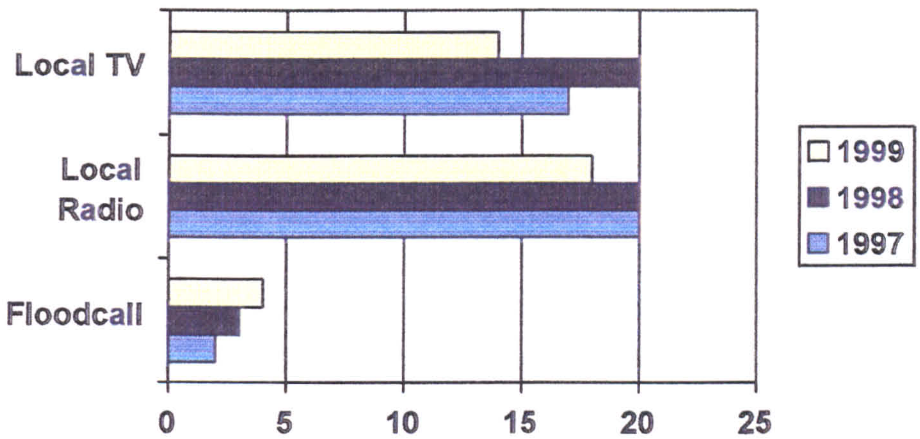
With the transfer of flood warning dissemination responsibilities in England and Wales in 1996, the Environment Agency recognised the need for feedback and confirmation, facilities for which had previously been rarely provided. It addressed the issue on two main fronts:

- By providing a dial and listen telephone service, FLOODCALL, that is designed to offer information and advice to people living in flood prone areas during flood events, and through the dissemination of flood warning messages via various media outlets (in addition to direct warning methods).
- By commissioning surveys in at-risk areas to determine the level of awareness of the Agency and its functions, awareness and understanding of flood warning methods, and the extent to which recipients of warnings are aware of the actions they should take in a flood event.

The Agency introduced FLOODCALL to allow the public to confirm flood warning messages, obtain up-to-date information for their local area, and to reduce the number of telephone calls made to Agency offices. The system has been well publicised both during flood events, where it is referenced on media broadcasts and warnings issued directly (such as via the AVM system), and at other times in newspaper adverts and public awareness material (including leaflets and merchandise such as fridge magnets, pencils, key-rings, etc). Quickdial codes allow the public to rapidly locate local information on the national system.

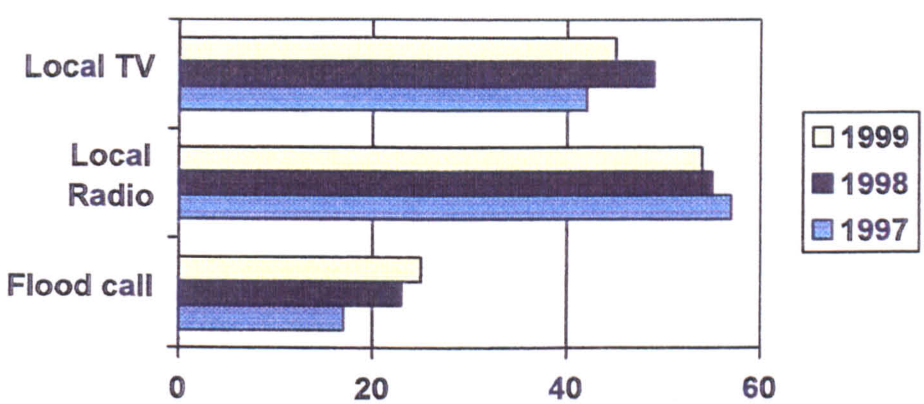
Public surveys conducted annually since 1997 indicate that the proportion of those interviewed who have found FLOODCALL to be either quite helpful or very helpful has steadily increased from 66% in 1997 to 78% in 1999, marginally higher than local radio (80% to 72%) (see Figure 7.2). Figure 7.3 indicates however, that the spontaneous awareness of the FLOODCALL system is very low, between 2 and 4 % of those interviewed, compared to around 20% for local radio. This percentage rose to between 17 and 25% when interviewees

Figure 7.3: Spontaneous awareness of flood information methods: 1997, 1998 and 1999 (after BMRB, 1999)



	Floodcall	Local Radio	Local TV
1999	4	18	14
1998	3	20	20
1997	2	20	17

Figure 7.4: Prompted awareness of flood information methods: 1997, 1998 and 1999 (after BMRB, 1999)



	Flood call	Local Radio	Local TV
1999	25	54	45
1998	23	55	49
1997	17	57	42

were prompted with a list of warning methods that might be available in their area, this compares to an average of 55% for local radio (see Figure 7.4).

Although the FLOODCALL service is a useful initiative it does have a number of drawbacks in relation to providing feedback and confirmation and these need to be addressed:

- Whilst such recorded information services are regarded as a vital checking facility for the public, they are inherently weak in providing specific feedback information to those at risk and equally to those issuing forecasts and warnings. The Agency's objective has been to reduce the amount of direct contact with the public for very valid reasons such as the fear of overloading switchboards and the limited number of duty staff who need to focus on forecasting and dissemination activities. But by seeking to curtail the amount direct public contact the scope for feedback is reduced.

- As discussed in Chapter 5 some members of society have difficulty relating to new technology, including automated information systems. The FLOODCALL system was fully tested during the Easter Floods in 1998 with mixed success and Bye and Horner (1998) made the following comment in relation to the service:

  > "For people who are unfamiliar with modern telephone based information systems, FLOODCALL is confusing and this inhibits its effectiveness as a warning mechanism. In one region, under 50% of calls made by the public connected to the message box and the majority of callers did not, therefore, obtain any information."

To meet integration criteria therefore, the Agency needs to focus on providing locally specific information, to update that information regularly during times of flood, to be aware that sections of the community have difficulty using technology-based systems, and introduce feed-back mechanisms during flood events.

To meet some of these requirements, the Agency is trialing a new service from October 1999 for a 12-month period called FLOODLINE. This service subsumes the FLOODCALL system but also gives the caller the option of speaking to a trained operator in an external call-centre to obtain basic advice. The caller can request to be transferred to an Agency Area office to either report a flooding incident or obtain more expert advice. The success of this service will be assessed during the trial period before longer-term commitments are made.

The need for slow feedback mechanisms or hindsight reviews is also being addressed by the Environment Agency on a national scale across England and Wales. In order to evaluate the effectiveness of the flood warning service over a period of years, a market research firm was commissioned in 1996 to conduct public surveys to establish baseline information on the current performance of the service. The intention is to compare future surveys against these benchmarks in order to assess whether the service is improving and that the needs of the customer are being met. Three benchmark surveys of public opinion were commissioned in 1997:

- **National Awareness Survey** - a survey of the general adult population in England and Wales to determine the awareness of the Agency's responsibility for flood warnings and of the existence of the flood warning service among the population at large.

- **"At Risk" Survey** - a nation-wide survey conducted amongst people who live in areas at risk of flooding to assess the awareness and understanding of the flood warning system operating in their area.

- **Post-event Surveys** - these surveys will be conducted on an *ad hoc* basis as and when a flood event occurs. The objective of these surveys is to provide an assessment of the efficiency of the flood warning service for people who are actually flooded.

The first national awareness survey was completed in January 1997 (BMRB, 1997). It showed that awareness of the Agency's responsibilities was low and only 8 per cent of respondents were aware that it is the lead organisation for issuing flood warnings. The more "common sense" methods of warning dissemination, such as television and radio, achieved the highest awareness, and awareness of such methods as AVM and FLOODCALL was low. The surveys were repeated in 1998 and 1999 (BMRB, 1998, 1999) and the number of interviewees that spontaneously named the Agency as being the lead organisation for issuing flood warnings has gradually increased (15% in 1998 and 24% in 1999). Awareness of the AVM and FLOODCALL systems has increased by 7% and 2% respectively over the 2-year period. The Environment Agency therefore, still has a big task in raising public awareness not only of itself, but also the ways in which it disseminates flood warning information to the public.

Feedback and confirmation therefore, are important processes in an integrated system and the following points are of particular relevance:

- The desire for feedback and confirmation can be identified at each stage of the flood warning process and in an integrated system this desire needs to be satisfied. This can only be done if flood warning systems are designed to facilitate a two-way flow of information and knowledge.

- Forecasters, response agencies and warning recipients all seek confirmation and feedback especially when they are presented with information indicating an extreme condition or where information is uncertain or conflicting. If this is not forthcoming, the appropriate response to that condition may be significantly delayed, and delay can be a precursor to failure.

- The need for confirmation and feedback is related to the level of the individual's knowledge and the number of channels via which information is received. It follows therefore, that an individual who is knowledgeable of a given situation and receives consistent information about that situation from a number of different channels, is less likely to seek out confirmation and require feedback, and is more likely to respond effectively and in a timely manner.

- Integrated flood warning systems should have in-built feedback loops to improve overall performance. This can be in the short-term, where information is used to improve the quality of forecasts or warning messages during an event, or in the longer term, which may result in changes to the way in which the warning system is designed or operates.

- Special communication channels should be established at various stages in the warning process to facilitate feedback and confirmation during flood events. In the Thames Region for instance, a special telephone line has been installed in the Regional Flood Warning Centre for flood wardens to relay information on local flooding incidents, blocked rivers etc., directly to the flood forecasters. For the longer term, post-event surveys are needed to review the operation of all parts of the process. This information should be fed back directly to the relevant managers for the necessary adjustments to be made to improve flood warning performance.

7.3.8 Flood experience and public information programmes

Most researchers recognise that the effectiveness of the entire warning system depends upon the awareness of the recipients of warning information of the flood risk, and their awareness of the appropriate actions to take when they receive that information. Knowledge and experience then are important elements of an integrated warning system, for in a flooding situation there is no substitute for knowledge, or as Williams (1964) puts it "experience is the great teacher". There are two main ways of gaining knowledge about flood risk and flood warning response; either through experiencing the effects of flooding directly, or through a public information programme. There is evidence in the literature that actual flood experience raises flood awareness and increases the tendency to respond effectively to flood warnings, but there is much less conclusive evidence that disseminating knowledge through a public information campaign performs the same task (Drabek, 1986; Penning-Rowsell et al 1982). There is the added complication that flood plain occupants may become "the prisoners of experience" (Kates, 1962), meaning that they can only perceive and interpret risk in terms of what they have experienced: this may extend to only low levels of flooding.

In many instances, people lack knowledge of and underestimate the hazardous nature of the environment in which they live (Drabek, 1986). These under-estimates reflect busy people who are occupied with their own-life priorities and the day-to-day issues of living. Lay persons are typically over confident about their risk estimates and this over confidence leads people to believe that they are comparatively immune to common hazards. This may be due in part to a wider underlying issue of society (especially urban society) loosing touch with environmental reality, pointing to the need for more extensive environmental education programmes. The same perceptions are found amongst flood plain inhabitants who tend to underplay the extent of the damage that might result from a severe flood (Drabek, 1986). There is a need in an integrated system therefore, for targeted public education programmes that raise awareness of flood risk and address the tendency to underestimate that risk. Some of the techniques that can be adopted in this context are set out in Table 7.10 and the key factors that influence the successful implementation of such programmes are presented in Table 7.11.

The Environment Agency recognises the importance of raising and maintaining public awareness not only of the flood warning dissemination arrangements in England and Wales, but also of the public's responsibilities with regard to effective response. A number of strategies have been adopted since 1996, all of which have been co-ordinated on a national basis for reasons of consistency. In response to the recommendations of the Independent Review into the Easter 1998 Floods, the Agency has increased the priority given to public awareness and education campaigns and these were re-launched with greater vigour in 1999. The strategies adopted by the Agency since 1996 are set out in Table 7.12.

Prior to this work, the use of public information to raise awareness was limited in England and Wales, and in some areas this approach was actively discouraged (Penning Rowsell, et al 1982). An exception was in London between 1978 to 1981, prior to the building of the Thames Barrier, when campaigns were launched that included television adverts, posters in public places, newspaper articles and advisory leaflets. Although opinion surveys indicated that there was a high level of awareness of the tidal flood risk in London and that two thirds of those in risk areas retained this knowledge for at least three months after the period of major publicity, the detail of warning arrangements was not fully understood.

The Agency has commissioned annual public opinion surveys since 1997 to gauge the effectiveness of its campaigns. These surveys indicate that they have only been partially successful in meeting the Agency's principal objectives of raising public awareness of itself and its functions, of its flood warning methods, and of the actions that recipients should take before and during a flood event. Table 7.13 illustrates that public awareness of the Agency's role in flood warning is steadily increasing and it is now the most mentioned organisation. A third of respondents were unable to name any organisation responsible for flood warnings however, and 12% still mention the National Rivers Authority even though this organisation was disbanded in 1996. Awareness of the Agency's Floodcall information system is consistently very low (2-4%), it remains to be seen if the new Floodline service, that was given extensive publicity in the October 1999 campaign (post survey), has wider recognition. In stark contrast, almost four in five respondents (78%) said they were aware of special precautions that should be taken in the threat of a flood, but it should be noted that this percentage has not increased over the three-year period. However, the percentage of people who had made any specific preparations in case of a flood event remains consistently low at just 5%.

Table 7.10: Techniques for raising public awareness of flooding and flood warnings.

Mode	Technique
Media based	Articles and advertisements in local newspapers, especially at the start of a flood season where one exists or on the anniversary of significant flood events
	Radio and television broadcasts with "expert" personnel and/or local radio personalities, again at strategic times of the year
	Advertisements on local radio and in local newspapers to promote the understanding of flood risk, warning arrangements and appropriate response
	The provision of awareness "information packs" to the media
Telephone based	Telephone answering service that is actively publicised and enables callers to obtain relevant and updated advice for their local area
	Placing information and relevant telephone numbers in the Yellow Pages and local telephone directories.
Visually based	Use of water and/or council tax bills to carry reminder messages about flooding and flood warning. Targeting those leaflets that people tend to keep, such as those giving information on refuse collection after public holidays.
	Encourage insurance companies to include flood risk and preparedness information with their annual reminders and information on premiums and insurance cover
	Provision of flood information brochures and leaflets to at-risk properties, libraries, Citizen's Advice Bureaux, schools, local authority offices, doctor's surgeries and other public places.
	Placing posters with maps and information on flooding on public buildings and other prominent positions such as bill boards
	Flood markers on telephone poles or buildings to indicate the levels reached by historical floods
	Provision of educational materials on local flooding to local schools, colleges and libraries. Use material on local rivers that fits in with the curriculum and cartoons to convey information to children on flood warnings and what to do in hazard situations
	Professionally produced videos preferably of local flooding and warnings to be used at public meetings, by community groups, local business organisations, and in libraries, colleges and schools. Enlisting a local TV or radio personality to narrate the video might add to its interest and credibility with the public
	Encourage people in risk areas to develop family disaster plans that focus on how the family or household would respond effectively to a flood
	Putting general and possibly localised flood warning information on the internet for public access
Verbally based	Open days with demonstrations at flood warning centres for the public, community organisations, media and schools
	Visits and talks by professional staff to schools, community and youth groups
	Flood warning exercises that have public involvement

(After Tunstall and Parker, 1999: Emergency Management Australia, 1999: Haggett, 1997)

Table 7.11: Factors influencing public education programmes

	Key factors
1.	Public education programmes must be planned and conducted outside times of flooding and maintained for long periods, particularly if flooding is infrequent.
2.	Programmes need to draw on the "community memory" of flooding to help communicate the effects of flooding to those at risk.
3.	Those who operate warning systems should listen to those at risk as well as seeking to educate them.
4.	There is a need to consider the experiences of flood victims when re-appraising response procedures.
5.	Public education programmes should stress the need for self-reliance and for the individual to recognise and respond to threat cues, such as heavy rainfall or rising river levels.
6.	The differing needs of recipients groups should be considered and catered for. Groups can be differentiated in terms of experience, age, intelligence, health and ethnicity.
7.	The distribution of information should be accompanied by an ongoing assessment of its impact
8.	A mix of strategies should be employed (as defined in Table 7.10) and a focus for educational initiatives should be created when community receptiveness to flood-related information is likely to be high (e.g. beginning of a flood season or anniversary of a flood).
9.	Efforts should be made to involve as many appropriate agencies as possible in public education programmes, this will encourage the perception of an integrated organisational response
10	The co-operation and support of the local or regional media to generate public interest is vital. Newspapers could carry photographs of previous floods with stories of how people coped, whilst reminding those at risk that flooding is still possible.
11	Periodic public surveys should be undertaken to discover whether information is being understood and will lead to the desired response

(After: Foster, 1980: Keys, 1997, Bye and Horner, 1998; Drabek, 1986; Penning Rowsell et al 1982)

A number of key issues can be drawn from this section that are particularly relevant to integration:

- The effectiveness of the whole flood warning system depends on the ability of the public to respond effectively to flood warning information. To achieve this, the public must become knowledgeable about the flood risk and on how to respond effectively when they are warned. They can gain this knowledge either through direct experience of flooding or via public information and education programmes. There is some concern in the literature about the ability of public education programmes to raise and maintain awareness in the longer term and this concern is confirmed by the results of recent public opinion surveys presented here.

Table 7.12: Flood related public awareness and education campaigns launched and planned by the Environment Agency since 1996.

Year	Adopted/planned strategies
1996	The issue of public information leaflets directly to properties considered to be at high risk of flooding from rivers and the sea and to public places such as libraries, local authority offices, police stations and Citizens Advice Bureaux. Two leaflets were produced: a national leaflet, which contained general information about where people can obtain warning information, and a local insert, which provided specific, local information for the area in question.
	A publicity campaign in local newspapers and on local radio at the time of the launch of the new arrangements on 1 September 1996, and reminder campaigns were planned at the beginning of flood seasons.
	Launch of the Agency's dial and listen flood information service, Floodcall. A single national number and a quick-dial code enables callers to receive recorded information about flood warnings in force in their area.
	The production of flood warning merchandise, including key rings, refrigerator magnets, pencils, memo pads and plastic cards to publicise the Agency's Floodcall service.
	Local poster campaigns targeted at public places in risk areas.
	Public opinion research was commissioned to determine the success or otherwise of the awareness campaign – repeated annually.
1997	A national news release to publicise the 50th anniversary of the 1947 floods that affected a large part of England and Wales and caused half a billion pounds worth of damage (at today's prices).
1999	Re-launch of a 3- year programme to raise awareness of floods and flood warning in response to the Independent Review of the 1998 floods.
	The first national "Flood Awareness Week" was launched in October 1999, focusing on the level of flood risk, the need for self-help and for people to relate to flooding on a personal level, and the role of the Agency and other response organisations.
	Greater emphasis placed on encouraging active citizenship with a shift away from talking about the Agency as the "protector".
	Launch of the sub-brand "Floodline" which is designed to work as an icon, a marker and a telephone information line. The aim is to provide a stronger link between floods and the Environment Agency.
	Floodline telephone service incorporates Floodcall but enables callers to speak to an operator to get advice and/or transfer to an Agency area office for local enquiries
	Radio and poster advertising tailored to each Agency region.
	Direct mail to properties at highest risk including revised local leaflets, fact sheets giving practical advice, stickers, flood kit and key ring.
2000	A pubic awareness launch in September 2000 that will centre on the introduction of new flood warning stages that will replace the existing colour coded warnings.
2100	The campaign will focus on the need to raise the percentage of flood warning recipients that take effective action to reduce flood losses.

Table 7.13: Spontaneous public awareness of the Environment Agency's principal education campaign objectives (after BMRB, 1999).

	1997	1998	1999 (May)
Spontaneous awareness of the Agency's flood warning role	8%	15%	24%
Spontaneous awareness of the Agency's Floodcall service	2%	3%	4%
Spontaneous awareness of precautions to be taken in the Event of flooding	83%	79%	78%
Special preparations made in case of a flood event	7%	5%	5%

- In an integrated system a range of strategies and techniques should be used to raise and maintain public awareness, and the key ones are presented in this section. This should be a two-way process drawing on the "community memory" of flooding and relying to a certain extent on community self-help and active citizenship. Strategies should acknowledge that communities are made up of different groups, some of which have special needs. Where practicable, campaigns should be targeted at these different groups, as broad-based and non-focused strategies have been shown to be the least effective.

- The effectiveness of awareness campaigns should be periodically reviewed through public surveys to discover whether information is understood and is being acted upon. The holding of exercises should be considered with public involvement. Organisations should be aware of how knowledgeable their target audience is regarding the hazard in question.

- Public information programmes can be costly to sustain and pressures on budgets can result in their curtailment. Signs of this had already begun to appear within the Environment Agency prior to the Easter 1998 Floods. There was a real danger that the extensive campaigns that were conducted in 1996/7 were about to be scaled down in subsequent years in some parts of England and Wales. The Easter 1998 Floods gave added impetus to this work, but this could be a temporary reprise especially if a period of drought follows and priorities are re-assessed. In an integrated system it is important to maintain long term awareness through repeated public information programmes. This is particularly relevant in urban areas such as London where population turnover is high.

- There is evidence to indicate that low public knowledge of the flood hazard is part of a wider issue relating to the loss of environmental awareness in general terms and a lack of appreciation of the potential hazards that can impact on peoples' lives. There is a tendency for people to believe that they are immune to common hazards, especially in low risk areas. To counter this perception there is a need for organisations such as the Environment Agency to focus more on promoting environmental education campaigns and raising awareness of the hazardous nature of the environment in which people live.

7.4 Summary and conclusions

In this chapter the importance of information and knowledge to the process of integration in flood warning systems has been critically analysed. This has been approached by following the flow path through an idealised total warning system as described in the literature. Key stages in this process have been identified, often at points where information and knowledge flow from one system component to another, and it is suggested that the degree of integration can be influenced by optimising the actions taken at these stages. For each key stage therefore, a series of recommendations have been made which, if implemented, can directly impact on the level of integration that is attainable. By analysing the recommendations further, a number of cross-cutting themes emerge: these apply to a number of stages in the process and are therefore likely to be the most important issues with respect to integration in this context. These themes can be summarised as follows:

1. **Time.** The speed of onset of a flood event significantly effects the type and amount of information required by all parties involved in the flood warning process. The detection, forecasting, dissemination and response elements need to receive information that is tailored to this variable for the overall system to operate in an integrated way. This will facilitate the issue of timely and accurate flood warnings and effective response.

2. **Uncertainty.** When the quality of information is uncertain it can act as a blocking mechanism and has the effect of preventing actions and limiting response. In an integrated system it is important that mechanisms are introduced that will allow uncertain information to be communicated and understood by the recipients of that information. It is

important that the holders of uncertain information are given the confidence and the means to communicate it to others.

3. **The knowledge of the individual.** The knowledge held by key individuals at various stages in the warning system is an important resource and should be nurtured and sustained in an integrated system. The assimilation, interpretation and decision-making processes that are undertaken by different individuals at different stages have an important influence on the cohesiveness of the total warning system. Experience and knowledge can also help overcome uncertainty.

4. **Confirmation and feedback.** The need for confirmation and feedback can be identified at each stage of the flood warning process especially when individuals are presented with information that is unusual and may indicate an extreme condition. It has been shown that this need is directly related to the knowledge of the individual and the number of sources from which information is received. It is important in an integrated system that the need for confirmation and feedback is recognised and planned for. This is closely linked to (1) above in that confirmation and feedback take operational time to achieve that may or may not be available.

5. **Adding value to information.** There are opportunities at various stages in the process for additional information to be added to the official information stream. This has the effect of adding value to and improving the quality of the original information. In an integrated system such information should be actively incorporated into official procedures and mechanisms should be put in place for this to be achieved. Such information may originate from staff within the forecasting agency or response agencies, from informal flood warning schemes, from key individuals such as flood wardens, or from members of the general public who live in risk areas.

6. **Understanding the information.** If information is clearly understood then it is more likely that it will be responded to in an appropriate way. This holds true for flood forecasters and local authority/emergency service officials as well as for the at-risk public. Information that is inconsistent, vague and unclear, at any stage in the warning process, results in confusion and misunderstanding and may block action and response. In an integrated system, information should be presented in a consistent and specific way, and should be targeted to the needs of the end-user. It should be borne in mind that some people are better equipped to process and respond to information because of their

knowledge, education, status, the resources at their disposal and the lack of physiological constraints. People with special needs may need help in understanding and responding to warning information.

7. **Believing the information.** Information should not only be understood by those who receive it, but it must also be believed. Again, this maxim applies throughout the warning process and recipients will not act or respond effectively if they consider the information that is presented to be false or not applicable to them. To ensure that information is believed in an integrated system, it should emanate from an authoritative and credible source, be delivered through more than one channel of communication, and be convincing and reasonable. As mentioned above, confirmation underlies the entire warning process and this also helps people believe the information they receive. Individuals, no matter what part they play in the warning system, are not easily convinced that the unthinkable (a flood) will happen. When they are presented with such information, they often will seek confirmation before they believe and act upon it, and this requirement needs to be designed into an integrated system.

Chapter 8

Case study

8.1 Introduction

This chapter presents the results of an in-depth case study undertaken in the Mimmshall Brook catchment in Hertfordshire to determine whether a policy of integration would be beneficial to flood warning procedures. Prior to this study only rudimentary official flood warning arrangements existed in this catchment and an assessment is made as to whether any of the integration factors identified in this study were present in these arrangements. An attempt is made to introduce improved and integrated procedures into the catchment using all relevant factors identified in this research and following the conceptual model described in Chapter 3. Special attention is given to the feasibility of integrating the improved official flood warning procedures with unofficial community-based arrangements that have been operating in the local community for sometime.

8.2 Background

The Mimmshall Brook is a gravel bedded stream located north of London in southern Hertfordshire (see Figure 1.2). The catchment is $53km^2$ in area, of which about 17% is under urban land use. Geologically, the catchment lies on the boundary between the chalk of Hertfordshire and the London Clay and Reading Beds of the London Basin. As a result of the relatively impervious nature of the valley slopes the catchment has a relatively rapid runoff response. The main tributaries of the Mimmshall Brook are the Potterells Stream, Potters Bar Brook, Catherine Bourne, Clare Hall Stream and Brookmans Park Stream. The most significant of these is the Potters Bar Brook that contributes approximately 35% of the flow.

Urban development commenced in the early 1950's. Urbanisation, road construction, land drainage and agriculture have all altered water and sediment discharges within the catchment. Development has increased flood flows in the Mimmshall Brook and reduced the time taken for runoff to enter the watercourses. The M25 and A1(M) motorways cross the catchment and although their combined area is only 1.4% of the total catchment area, it is estimated that they contribute 6% to flood flows (NRA, 1993a). The most significant increase in urban development has taken place in the Potters Bar Brook catchment. Catchment response, as measured at the river level station at Warrengate Road, can vary between 4 and 5 hours on average depending on the wetness of the catchment (see Table 8. 1).

The area at most risk of flooding is located in the lower reaches of the Mimmshall Brook, downstream of the Potters Bar Brook confluence, in the vicinity of Warrengate Road and Water End. The Thames Water Authority carried out a flood alleviation scheme in this area in the autumn of 1980, after the flooding of 1979. This involved channel regrading and resectioning, maintenance clearing and construction of a small flood embankment. Since these local improvement works, the NRA undertook frequent gravel and trash clearance work to help alleviate the flood risk. In the early 1990's the NRA attempted to introduce a flood storage scheme to offer protection to a 1 in 50 year standard in the lower reaches. The proposed works had an estimated cost of £2,266,000, but a benefit/cost ratio of only 0.37 has prevented the scheme from progressing despite persistent public and political pressure.

Prior to this study, flood warning arrangements in the Mimmshall Brook were no more than rudimentary. The Environment Agency's predecessors would issue flood warnings for the Colne catchment, which included the Mimmshall Brook, on the basis of general weather predictions, data from a sparse telemetry network and the experience of duty staff.

Table 8.1: Details of hydrological events in the Mimmshall Brook since gauge installation.

Date	Peak Level (m) at Warrengate Road	Rainfall total (mm)	Lag time (hrs)
8 December 1994	1.369	24.6	4.00
29 January 1995	1.238	12.0	4.25
1 February 1995	1.274	13.2	5.00
7 March 1995	1.325	10.6	4.75
1 November 1995	1.279	23.8	8.75
2 November 1995	1.318	16.8	4.25
9 January 1996	1.311	23.2	5.50
9 April 1998	1.085	19.0	6.25
15 April 1998	1.181	12.2	5.00
31 October 1998	1.279	26.0	9.50
2 November 1998	1.318	19.8	4.50
12 January 1999	1.058	12.4	5.00
24 December 1999	1.129	17.8	5.00
15 April 2000	1.045	14.2	5.00

As these warnings were poorly targeted, the police had difficulty in identifying the properties at risk and where to direct resources for public warning purposes (when they had this responsibility prior to 1996). In short, the general flood warnings that were issued by the forecasting agency never got translated into specific public warnings in the Mimmshall Brook catchment.

8.3 Flooding history

The Mimmshall Brook has a recorded history of flooding extending back to 1928. Table 8.2 gives details of the sixteen flood events that have affected the catchment from that time.

It can be seen that the types of storm that give rise to flooding include both frontal and convective. The former causing overtopping in the winter months when the catchment is saturated, the latter predominantly between the months of May and October. The most severe flood on record occurred on 22-23 September 1992. The nearest recording raingauge at that time at Radlett, recorded 53.4mm of rainfall over a 19-hour period from 13.00 hrs on 22 September to 07.00 hrs on 23 September, 80.2mm was recorded at Harrow Weald 5km to the south of the catchment during the same period. Analysis of this data (NRA, 1993b) suggests that the overall amount of rainfall has an estimated return period of approximately 1 in 20 years. The daily raingauge at the Warrengate Road Pumping Station recorded 68mm and this has a storm return period of over 1 in 50 years for the 24 hour period. The peak flow in the Mimmshall Brook at Warrengate Road has been estimated to be 26 m^3/sec which has a flow return period of 1 in 25 years. Table 8.3 shows the number of properties at risk of flooding for flow return periods from 1 in 2 years to 1 in 100 years. It can be seen that the properties that flooded during this event (24 properties) would rise to 55 for a 100-year event.

A telemetered river level gauge was installed at Warrengate Road on 7 July 1994 and since this date fourteen high-flow events have been recorded (see Table 8.1). All fourteen events produced peak levels below the bankfull level of 1.410m at the gauge, however useful hydrological information was obtained concerning the response time of the catchment.

The catchment is estimated to be 17% urbanised and there is every indication that this percentage will increase in the future as towns like Potters Bar expand. This will result in flows of a given magnitude occurring more frequently than previously. For example, Table

8.4 shows that the flow at which flooding to properties in Warrengate Road begins (17 m^3/sec) decreases from a 1 in 30 year event with 0% urbanisation, to a less than 1 in 5 year event with 50% urbanisation. The effect of urbanisation on flows is likely to be greatest in the summer months when most of the runoff will then be generated from the paved areas.

Table 8.2: Flooding history Mimmshall Brook at Warrengate Road (after NRA, 1993b)

Date	Storm Type	Comments
January 1928	Frontal	Serious flooding - no details
21 June 1936	Convective	Serious flooding – thunderstorm centred on St Albans, extending to Barnet and Harpenden. 100mm recorded to the north of St. Albans.
March 1947	Frontal	15 properties flooded. Widespread flooding in Thames catchment due to rapid snowmelt.
July 1958	Convective	Road flooding only
1955		Road flooding only
1960		Road flooding only
December 1965	Frontal	Road flooding only
1975		Road flooding only
February 1977	Frontal	Road flooding only
January 1978	Frontal	Road flooding only
December 1979	Frontal	11 properties flooded, depth of 450mm
21 October 1987	Frontal/ Convective	Flooding up to door of properties, road flooded 450mm
29 January 1988	Frontal	Road flooded to 450mm
3 February 1990	Frontal	Road flooded to 375mm
23 September 1992	Frontal/ embedded convection	21 residential properties and 3 commercial properties flooded to depth of 500mm
October 1993	Frontal	Road flooded to between 500 and 700mm. Garages and gardens flooded.

Table 8.3: Number of properties at risk of flooding against return period - Mimmshall Brook (after NRA, 1993b).

Return Period (years)	Flow (m^3/sec)	Residential	Commercial	Total
2	10.8	0	0	0
5	17.3	4	2	6
10	21.1	13	3	16
20	25.0	20	3	23
25	26.0	21	3	24
30	27.1	23	3	26
50	30.6	33	6	39
100	35.0	45	10	55

Table 8.4: The effects of urbanisation: flows (in m^3/sec) for Mimmshall Brook at Warrengate Road (after NRA, 1993b).

	Return Period (years)						
	5	10	20	25	30	50	100
0% urbanisation	11.0	13.4	15.8	16.4	17.1	19.2	22.0
10% urbanisation	13.0	15.9	18.7	19.5	20.3	22.8	26.1
17% urbanisation (present day)	14.4	17.8	20.9	21.8	22.7	25.5	29.2
20% urbanisation	15.0	18.5	21.8	22.7	23.6	26.6	30.4
30% urbanisation	15.8	18.7	22.6	23.8	24.8	27.7	32.9
40% urbanisation	19.1	22.7	27.1	28.6	29.8	33.4	39.7
50% urbanisation	21.7	25.9	30.8	32.4	33.8	37.9	45.0

8.4 Social characteristics

An assessment has been undertaken to ascertain the social characteristics of residents at risk of flooding in the Mimmshall Brook catchment. As part of a feasibility study and benefit assessment undertaken by the NRA, the properties at risk of flooding in the 1 in 100 year flood risk area were identified along with the social characteristics of the householders (NRA, 1993b). The details are presented in Table 8.5.

The properties at risk from flooding are a mixture of 1920/30's detached and semi-detached bungalows and turn-of-the-century semi-detached and terraced houses. They are located mainly in the lower reaches of the Mimmshall Brook in the Warrengate Road and Water End areas of North Mimms.

The community is relatively stable and is made up mainly of professional and skilled homeowners (see Table 8.5), many of who are elderly and retired. The frequency of flooding (13 events in the last 40 years) means that the residents are acutely aware of the flood risk and have been agitating for action to reduce the risk since 1955. Residents in Warrengate Road/Lane, who are the most susceptible to flooding, have formed themselves into a residents association that acts as an effective pressure group. The association's chairman is in regular correspondence with the Environment Agency, the district council, government departments and politicians concerning flood alleviation for the area. Regular newsletters are produced which keep the community up-to-date with matters concerning the river generally.

The severe flooding in September 1992, when 24 properties were flooded to depths of over 1 metre, resulted in extensive damage to property. It also severely traumatised those residents affected, some of whom were unable to return to their properties for several weeks after the event. Some of the residents have contracted longer-term stress-related illnesses and have a constant fear of a repetition of the incident. The fact that many of the properties at risk of flooding are bungalows means that residents are concerned about the possible loss of life in an extreme event due to the sudden onset of flooding and possible high flood depths.

Table 8.5: Social characteristics of residents in the lower Mimmshall Brook catchment.

Property Details	Social Band	Property Details	Social Band
Rockwood, Swanland Road	AB	24, Warrengate Road	C1
The Haven, Swanland Road	C1	Abdale Cott., Warrengate Road	AB
1, Warrengate Road	E	30, Warrengate Road	AB
5, Warrengate Road	C2	Abdale House, Warrengate Road	C1
7, Warrengate Road	C2	73, Warrengate Road	C1
9, Warrengate Road	C1	71, Warrengate Road	C1
11, Warrengate Road	E	60, Warrengate Road	AB
13, Warrengate Road	C2	62, Warrengate Road	AB
15, Warrengate Road	C1	64, Warrengate Road	AB
17, Warrengate Road	C2	66, Warrengate Road	AB
25, Warrengate Road	C2	68, Warrengate Road	AB
27, Warrengate Road	E	70, Warrengate Road	AB
29, Warrengate Road	C1	72, Warrengate Road	AB
31, Warrengate Road	C2	74, Warrengate Road	AB
33, Warrengate Road	E	76, Warrengate Road	AB
35, Warrengate Road	C1	78, Warrengate Road	AB
37, Warrengate Road	C2	80, Warrengate Road	AB
39, Warrengate Road	E	82, Warrengate Road	AB
Colne Cott., Warrengate Road	C1	84, Warrengate Road	AB
Maryland, Warrengate Road	AB	4, Mimmshall Brook Cotts,, Warrengate Road	C1
63, Warrengate Road	C1	3, Mimmshall Brook Cotts. Warrengate Road	C1
65, Warrengate Road	AB	2, Mimmshall Brook Cotts., Warrengate Road	C1
67, Warrengate Road	AB	1, Mimmshall Brook Cotts. Warrengate Road	C1
22, Warrengate Road	AB	Flint Cottage, Warrengate Road	C1

Key: AB professional, C1 skilled, C2 semi-skilled, E unskilled.

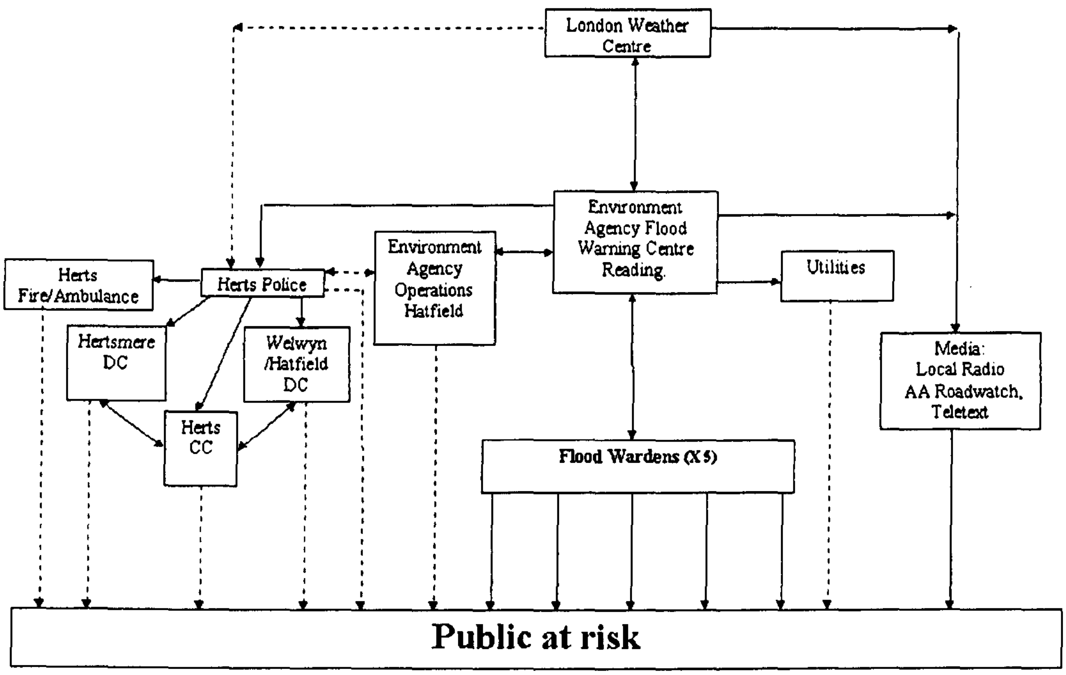
8.5 The impact of institutional and legal arrangements in the study catchment.

A number of organisations influence the management of flood defence in the Mimmshall Brook catchment and the way in which these bodies interact can have an important influence on the level of service that the at-risk public receive. The roles of some of these organisations are briefly described below.

Hertfordshire Police has issued flood warnings in the past, co-ordinate the evacuation of residents in extreme events and takes the lead role in emergency management. Hertfordshire County Council oversees emergency planning, including the development of emergency plans, and becomes involved in the rehabilitation process following flooding. Two district councils cover the catchment, Welwyn-Hatfield and Hertsmere, both of which have drainage responsibilities including sewerage and ordinary watercourses and a duty of care over local residents. The Environment Agency has overall responsibility for flood defence, including the issue of flood warnings for and maintenance of main river, and MAFF approve and grant-aid flood alleviation and flood warning schemes. The Met Office (London Weather Centre) issue local weather forecasts via the media, including the Agency's flood warning notices. The Highways Agency is responsible for drainage matters for major roads including the M25 and A1(M) in the Mimmshall Brook catchment. The difficulty for local residents, therefore, is to gain a clear appreciation of the roles and responsibilities of all these organisations and an understanding of how they relate to one another to meet their needs. Figure 8.1 attempts to illustrate the organisational arrangements in the Mimmshall Brook for flood warning dissemination and response. It is clear that the arrangements are both complex and, for the layman, potentially difficult to comprehend.

Through the activities of the chairman of the Mimmshall Brook Residents Association, the residents have been pressing a number of organisations for action to lessen the flood risk in the catchment for many years and this intensified following the severe floods in September 1992. The NRA carried out a detailed feasibility study following this event to lessen the risk of flooding and recommended a flood storage scheme that would offer protection to a 1 in 50-year standard in the lower reaches of the Mimmshall Brook. This scheme had the full support of the local community but despite persistent public pressure, the NRA and now the Environment Agency have been unable to proceed with its construction. This is

Figure 8.1: Organisational diagram for the Mimmshall Brook catchment



due to the fact that it cannot be demonstrated that the economic benefits that the scheme will bring to the community will exceed the cost of construction. The Ministry of Agriculture, Fisheries and Food has refused to grant-aid this or any other scheme that are not, by their definition, cost effective. The local residents continue to apply pressure for the alleviation scheme to be implemented through regular correspondence with key players in various organisations, including the distribution of a monthly newsletter. These include the local MP, Secretary of State at MAFF, the Chief Secretary to the Treasury and their parliamentary private secretaries, the Chairman of the Environment Agency and other staff, the parish council and district councils. The desire for action has driven the local community to build up a very detailed knowledge of the workings of the appropriate government departments, agencies and local authorities and where to apply the most effective pressure. Nevertheless, the fragmented nature of organisational arrangements in terms of roles of responsibilities and geographical coverage places huge demands on a local community as it tries to secure the necessary improvements. These demands would be less and the public would be better served if a more integrated institutional system was in place.

The local community is not only pressing for the implementation of a flood alleviation scheme, it is also trying to ensure that the existing flooding problem is not exacerbated further by the actions of the above organisations. Pressure has been placed on the Highways Agency for instance, not to increase the runoff to the Mimmshall Brook through the widening of the motorways that cross the catchment. The point has also been made that through their very existence, the motorways have increased direct runoff in the catchment and consequently the responsible agency should make a financial contribution towards any alleviation scheme. The Highways Agency has responded by stating that any further runoff would be stored in balancing ponds with a controlled discharge into the river, and that existing runoff is calculated to be small (3.7%) thereby not warranting a financial contribution to any river improvement scheme. A similar position has arisen with one of the district councils in the catchment. Hertsmere District Council had drainage problems in Potters Bar due to inadequate surface water sewers. By simply enlarging the sewers the flooding problem would be passed downstream to the Potters Bar Brook and the Mimmshall Brook. The activities of the Council in tackling this problem have been monitored closely by the local community. But interestingly the action the Council took was greeted both with suspicion ("the NRA have been asked to watch very closely the activities of Hertsmere Council and monitor any outflow of water to the Mimmshall Brook") and admiration ("Hertsmere Council are to be congratulated on their caring for Potters Bar residents who suffer from flooding"). The Council has overcome the problem by constructing enlarged sewers and tanks to store floodwater, releasing it into the river when levels are low. The local community understands the importance of close inter-agency liaison in matters such as these to ensure that any works one authority carries out does not exacerbate the problems of another. A knowledgeable public can effectively influence organisations to modify their policies resulting in more locally sustainable solutions. Organisations should take note of this expertise and develop integrated partnerships with local community institutions.

Organisational liaison in providing a flood warning service is also worth examination. Prior to 1994 the NRA only issued general and poorly targeted flood warning notices to the police for the River Colne and its tributaries, of which the Mimmshall Brook is one. The police had little information regarding properties at risk of flooding and for this reason was unable to notify residents in this area of any received warnings. Liaison between organisations on flood warning matters was generally poor, limited to an annual seminar covering the NRA's north-east operating area and ad hoc discussions at Hertfordshire emergency planning meetings.

The NRA had attempted to set out the respective roles and responsibilities of organisations in a written procedure, but this was not recognised as being a legitimate document by the local authorities and the police. Close working relationships between staff in relevant agencies had not been established and inter-agency exercises were not held. In summary, flood warning arrangements in the Mimmshall Brook catchment were poorly integrated with few of the integrative factors identified in Chapter 2 being met.

As part of this project, three important improvements were made in 1994. Details of property flooding in the catchment since 1965 were compiled and supplied to Hertfordshire Police and the local authorities. Flood detection gauges were installed and the local community was approached to discuss the setting up of a direct warning scheme.

In February 1995 these new arrangements were activated for the first time when the NRA issued a flood warning for the catchment. The local community received notification however, from the police (acting on the detailed property information) and the NRA directly. This gave rise to confusion as the local residents were not expecting (and had no previous experience of) any police involvement. In hindsight, improved institutional liaison would have resulted in the delivery of a more co-ordinated public warning service.

In 1996 when the Environment Agency took over primary responsibility for the dissemination of flood warnings, two main changes were introduced. In accordance with the Ministerial Direction a Local Flood Warning Plan was drafted for Hertfordshire that set out the arrangements for warning persons or bodies and the means by which this is to be achieved. In addition, a Flood Warning Planning Group was established for the County to facilitate improved consultation between the key organisations including the Agency, local authorities, the emergency services and utilities. Table 8.6 sets out the details of organisations in receipt of flood warning notices covering the Mimmshall Brook catchment as set out in the Local Flood Warning Plan (Environment Agency, 1996b). Even for a small river catchment such as this, a total of 18 different bodies have a role to play either in the dissemination of warnings or in the response to flooding. This makes the integration of organisational arrangements less easy to achieve.

Table 8.6: Organisations in receipt of flood warning notices covering the Mimmshall Brook catchment.

Organisation	Warned by Environment Agency			Warned by police		
	Fax	Phone	Telex	Fax	phone	Pager
Hertfordshire Police			X			
Hertfordshire County Council				X		X
Hertsmere District				X		X
Welwyn-Hatfield District				X		X
Hertfordshire Fire and Rescue					X	
Bedfordshire and Hertfordshire Ambulance Service					X	
Railtrack	X					
Thames Water Utilities	X					
MAFF	X					
British Telecom	X					
British Gas	X					
Eastern Electricity	X					
Meteorological Office	X					
BBC Three Counties Radio	X					
Greater London Radio	X					
97.3 FM Radio	X					
AA Roadwatch	X					
Teletext	X					

8.6 The application of technology to improve the flood warning service in the study catchment.

Following discussions with the residents in the flood risk area at the start of this research project in 1994, it was apparent that the only flood warnings that have been received by the community were those generated from their own observations. For example, trigger levels had been established by local people at river crossing points such as road bridges and on a river level gauge board in Warrengate Road. These are monitored manually, a process that is straight forward during the day if people have the time to devote to the activity, but becomes more problematic at night. The severe flooding that occurred in September 1992 reached its peak in the early hours of the morning, no warnings were issued to the community, either from official or informal sources, and householders in 24 properties awoke to find up to a metre of flood water in their homes. There is a clear need to improve warning arrangements therefore, but to integrate any improvements with the best features of what is existing.

The use of technology featured highly in the plans to improve the flood warning service in the catchment. But rather than imposing solutions, the author attempted to ensure that any enhancements were made in consultation with the community for which the service was aimed and in accordance with the integration factors developed in this study.

At meetings held with key individuals in the community, such as the chairman of the residents association, the options available to detect and forecast flooding and disseminate flood warnings were discussed in some detail. Residents could relate in particular to the importance of installing river gauges capable of issuing alert messages when pre-determined levels were reached i.e. automating their monitoring activities and trigger levels. The significance of rainfall measurement was also appreciated, especially the need to relate rainfall intensity and accumulation to river flow. Two types of storm were recognised by local people as causing flooding problems; short duration summer thunderstorms and more persistent winter rain falling over a longer period on a saturated catchment. One resident actually measured rainfall in a can in her garden and had established a relationship between the amount of rain collected and when flooding was likely. Automating this embryonic integrated process was seen as a logical progression. The forecasting of rainfall and river flow, although considered to be important, was not a subject that the residents felt qualified to influence and preferred to leave the issue in the hands of the "experts". Flood warning dissemination on the other hand was high on their agenda for improvement and a subject that they had strong views on.

A number of possible technological options for disseminating flood warning messages was put before the local community and discussed at length. These included the use of a siren linked to river gauges, faxed or paged alerts, the use of automatic voice messages and vehicle mounted loudhailer. But by far and above the most popular warning method was a direct telephone call from the Environment Agency's Flood Warning Centre to nominated flood wardens who would cascade the warning to others by telephone or a personal visit.

Following these discussions the following actions were taken with specific relation to the implementation of technology:

a) a telemetered river level gauge was installed on the Mimmshall Brook at Warrengate Road and linked by telephone line to the Environment Agency's CASCADE computer system (see Figure 1.2). The system has the ability of polling the outstation at frequent intervals (every minute if required) capturing and storing river level data at 15-minute intervals, archiving the information and displaying it in hydrograph form (see Figure 8.2). The telemetered gauge was located in close proximity to the river gauge board that had been installed for many years and formed a key element of the residents' informal detection arrangements.

b) alarm trigger levels were established at the outstation to alert flood duty officers of rising river levels. Four alarm levels were set based on data from past events, flood modelling information and importantly, advice from residents. The first alarm (standby) for instance, was set at 75m AOD to correspond with the trigger level for monitoring that the residents established through their own observations (see Figure 8.2).

c) two telemetered raingauges were installed in the catchment; one in the lower reaches at North Mimms, the second in the upper reaches at Borehamwood (see Figure 1.2). Both sites were equipped with intelligent outstations and linked to the CASCADE system as described in (a) above (see Figure 1.2). 15-minute rainfall totals are captured, displayed, archived and made available to forecasting systems. The outstations generate alarms when one of two rainfall intensities is recorded: 10mm in 1 hour (for convective storms) and 20mm in 8 hours (for frontal storms).

d) a 2km weather radar display was constructed for the Mimmshall Brook following the digitisation of the catchment boundary, rivers, roads etc. The display was incorporated into the CASCADE system and is used operationally to detect intense rainfall over the catchment. The raingauge adjustment procedure was amended to include the data from the two new raingauges, thereby increasing the accuracy of the radar data in this area (see Figure 8.3). These data are also made available to forecasting systems.

e) the Nimrod and Hyrad rainfall forecasting procedures were modified to allow the selection and display of forecast data covering the Mimmshall Brook catchment (see Figure 8.4). These systems give instantaneous forecast images and 15-minute forecast accumulations for 6 and 2-hours ahead respectively. Accumulation data are made available to flow forecasting models.

f) the operational rainfall/runoff model running on CASCADE (the Isolated Event Model) was calibrated for the Mimmshall Brook at Warrengate Road using data from a number of flow events of varying magnitude which were recorded in 1995. The model calibration was tested on other events and a rainfall/runoff relationship was established. The model was incorporated into operational procedures thereafter giving river flow forecasts up to 12 hours ahead (see Figures 8.5 and 8.6). Rainfall data can be derived from radar, raingauges or the rainfall forecasting systems outlined in (e) above.

g) a telephone warning system was instigated which included alerting 5 flood wardens or their deputies from either the Flood Warning Centre or duty officers' homes. A flood warden "help-line" was established giving a mechanism for feeding-back information directly to duty staff if the need arises.

In 1996, in addition to these specific applications of technology, the Agency introduced the FLOODCALL (later renamed Floodline) dial-and-listen telephone service that included an information box for rivers in Hertfordshire, and the Automated Voice Messaging (AVM) system that allows pre-recorded messages to be telephoned through to residents. These systems were discussed with the warning recipients and although a high percentage of people are able to access information using this technology (see Table 8.8), the systems were viewed as being too impersonal, providing information that is not specific enough for their purposes.

The new warning system was activated on the 29 January 1995, 1 February 1995 and 7 March 1995 when heavy rainfall caused river levels to rise and exceed alarm levels. The systems worked well and enabled the duty officer to alert the flood wardens and the police of high river flows and possible flooding. For the March event for instance, the duty officer predicted that river levels would rise to just below bankfull and that no property was in danger of flooding. The flood wardens were notified of this prediction at 14.30hrs. The river peaked at around 17.00hrs, just 85mm below the bankfull level some 2.5 hours after a warning was issued. This precision could not be achieved without the introduction of the appropriate technology.

On 31 October 1998 river levels rose to 0.292m below the bankfull trigger level. The wardens were contacted to reassure them that levels were unlikely to rise further and that flooding was not forecast. The wardens were able to advise the duty officer that the

Figure 8.2: Hyetograph-hydrograph for Mimmshall Brook at Warrengate Road, January 1995.

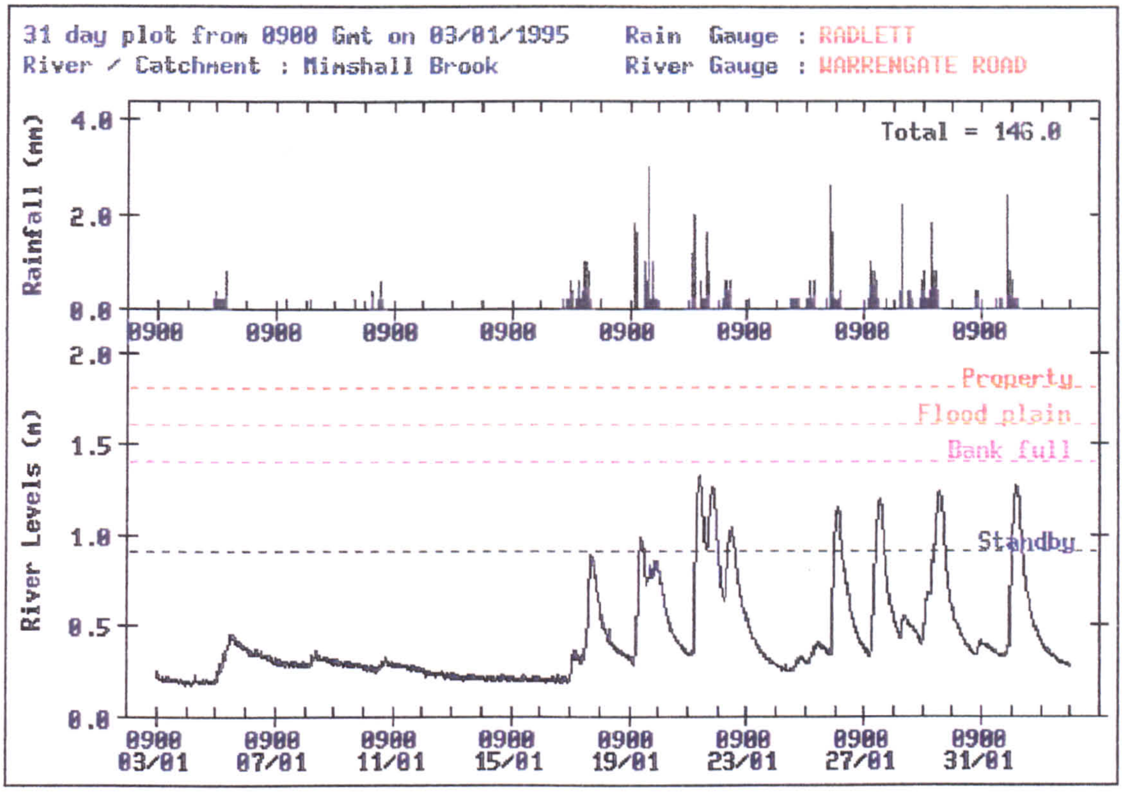


Figure 8.3: 2km weather radar display for the Mimmshall Brook catchment

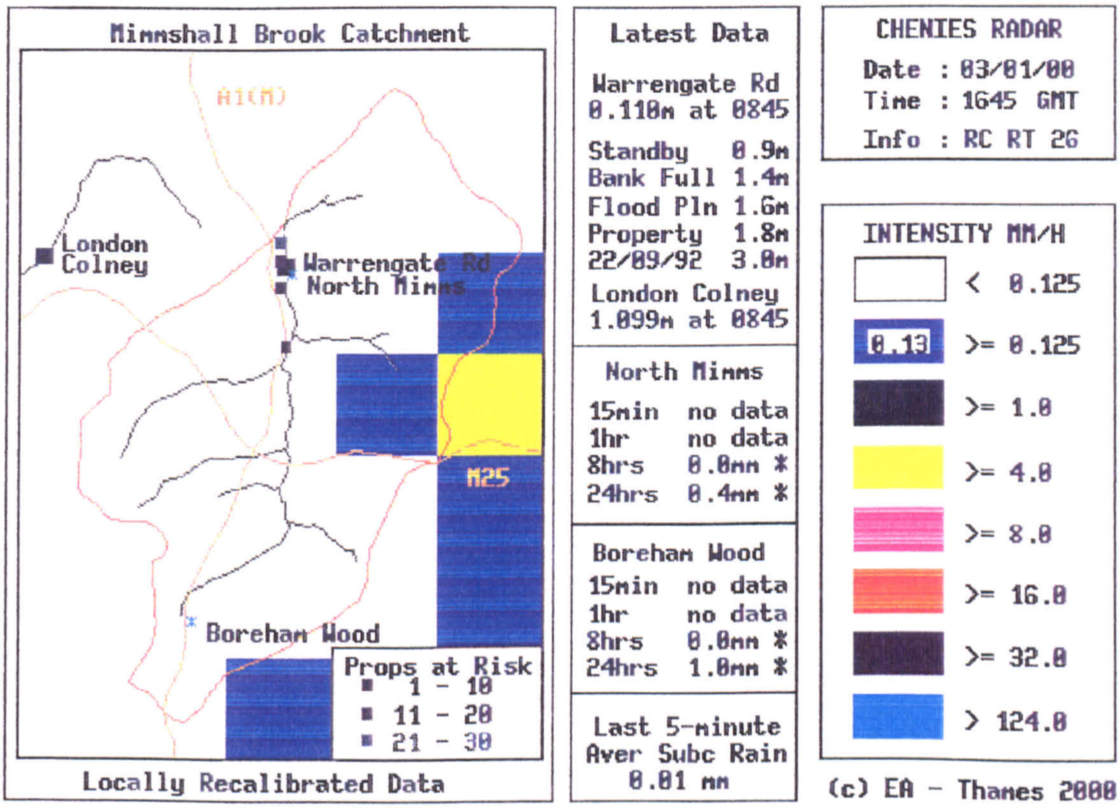


Figure 8.4: Nimrod rainfall forecast accumulations for the Colne catchment.

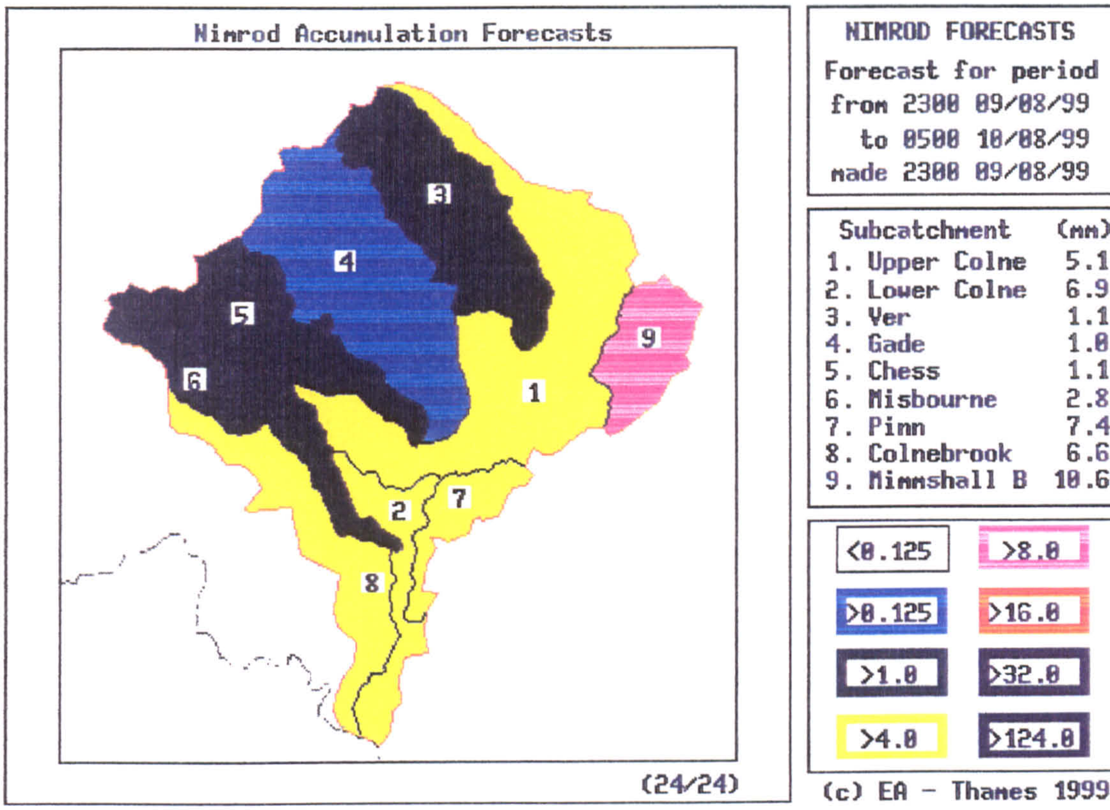


Figure 8.5: Isolated event model output for the Mimmshall Brook at Warrengate Road, 5-11 December 1994.

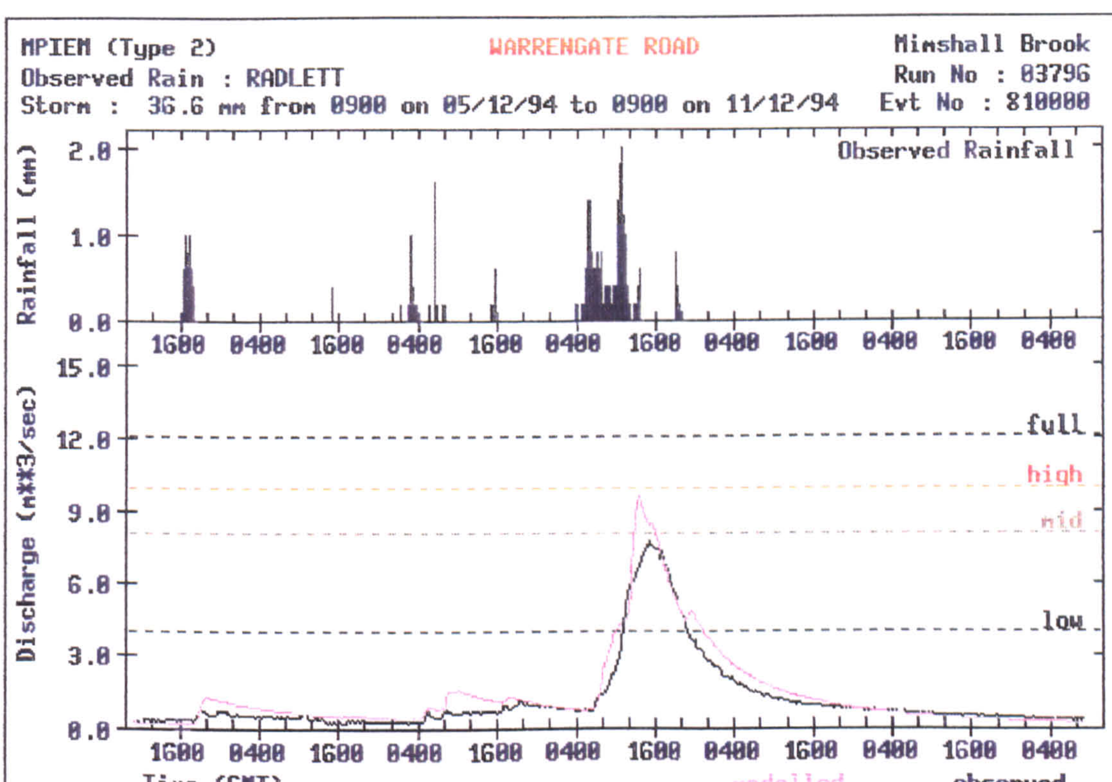
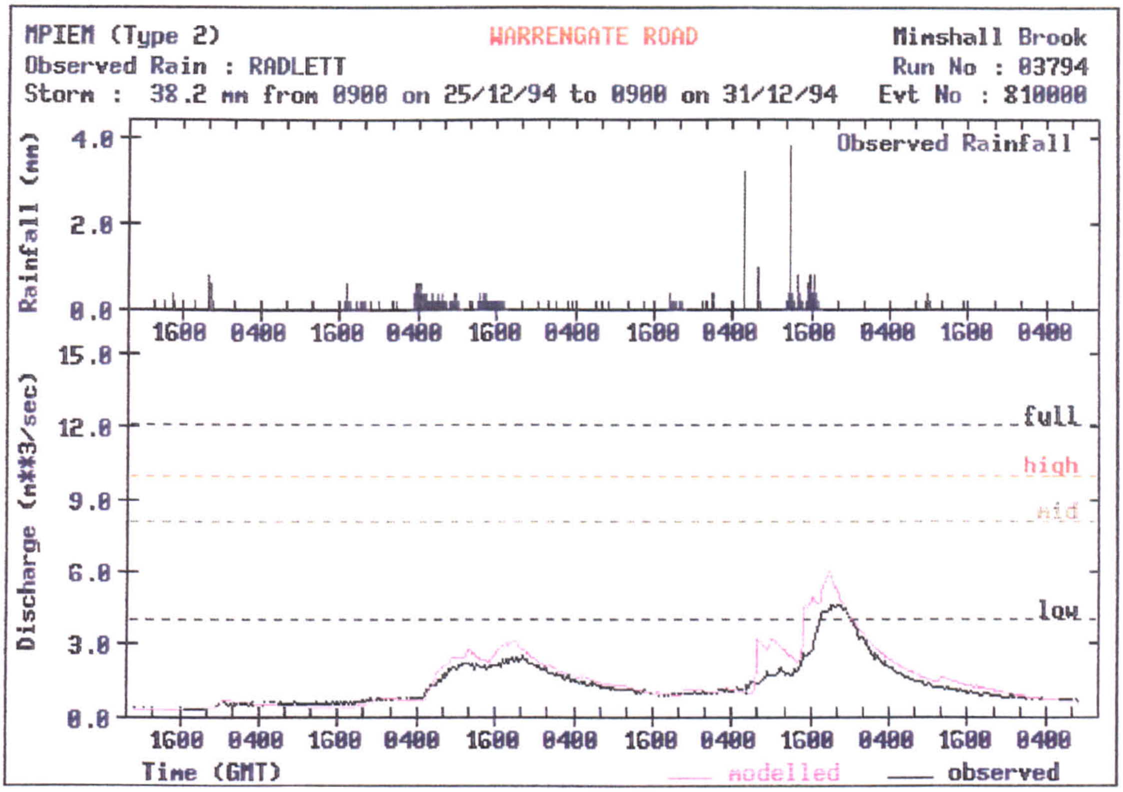


Figure 8.6 Isolated event model output for the Mimmshall Brook at Warrengate Road, 25-31 December 1994.



to investigate the matter further and for adjustments to be made to the trigger levels. This illustrates the importance of two-way communication and the value of feed-back from residents in the flood plain, a facility that would not be available if one-way AVM technology was relied upon.

8.7 Human interaction, expertise and training.

As has been discussed, people residing in the flood plain of the Mimmshall Brook are very knowledgeable of the risk facing them. The area has been subjected to significant flooding on average once every 4 to 5 years in the last 70 years, and the last major flood that occurred in 1992 severely traumatised those affected. Prior to this study, the absence of a credible official warning service resulted in the community establishing informal arrangements and these have a number of positive integrative elements.

Table 8.7: Introduction of technology in the study catchment.

Activity	Prior to 1994	1994 to 1999	Future Plans
Telemetered rivergauges	None	1	2
Telemetered raingauges	None (gauge in adjacent catchment used)	2	2
Weather radar displays	General 5km and 2km displays only	2km display developed for catchment – adjusted by local raingauge information	Use of Met Office quality controlled 2km data
Rainfall forecasting	General regional forecasts	Nimrod and Hyrad forecast displays developed for catchment	GANDOLF thunderstorm warning system extended to the catchment
Flow forecasting	Intuition only	IEM calibrated for Warrengate Road	Catchment incorporated into automated Regional Flow Forecasting System
Warning dissemination to organisations	Telex to police, then telephone messages to other emergency services, local authorities and utilities	Telex to police, use of integrated fax/pager system to local authorities, telephone to other emergency services, fax to utilities/media	None planned at this stage
Warning dissemination to local community	Ad hoc arrangements only	Broadcast via media, telephone to Wardens, telephone/door knocking to other recipients. All recipients backed – up on AVM system.	Extend the number of radio stations broadcasting flood warning information

Table 8.8: Type of telephone in use by flood warning recipients in the study catchment

Pulse	% of those responding	Tone	% of those responding	No response
1	13% (22 %)	7	87% (78%)	5

( ) – figures for Thames Region

The informal detection and forecasting process is based around local observations of rainfall and river levels (see Table 8.9). As has been discussed in Section 8.6, there is a good understanding of the types of storm that can give rise to flooding and residents provided details without prompting by the author. It has been mentioned that the local community has established trigger levels in the Brook and these activate a process of routine monitoring during hours of daylight when the level at the gauge board in Warrengate Road reaches the "red 75 danger marker". This involves a volunteer visiting the gauge board at regular intervals and noting the rate of rise (this duty is "combined with walking the dog"). Residents also become concerned when the river reaches the soffit of the bridge and backing-up occurs. Forecasting is attempted by some through a combination of measurement and observation and drawing upon past experience. Based on the amount of rainfall recorded in one person's garden for example, she "knows when to expect problems". Discussions with residents also revealed a good perception of lead-time and catchment response, with a rule of thumb of 2 hours being quoted for the river to peak at Warrengate Road following heavy rainfall in the catchment. In September 1992 however the floods occurred at night and the informal warning system was not activated, the residents awoke to find floodwater in their properties and were totally unprepared for the scale of the inundation.

Prior to this study the informal dissemination arrangements were organised on an ad hoc basis, with whoever had agreed to monitor the river levels undertaking to warn others either by personal visits or telephone calls (see Table 8.9). The local community has established an active residents association and it is this social network of friends and neighbours that is activated when the risk of flooding is thought likely. A regular warden scheme was not in place at this time and individuals did not have specific roles and responsibilities. The rather spontaneous procedures are prone to failure unless close liaison between local people is maintained. It was in this that area that the need for improvement was identified and where an official warning scheme could add value and enhance integration.

The response to flooding is also well developed in the community and even though many of the properties in the risk area are bungalows, some elaborate coping strategies have been put in place, learning from past experiences (see Table 8.9). Some of the residents have fitted loft ladders for instance, as the more elderly members of the community are in fear of their lives during flooding and find comfort in having an escape route. Other action that is taken includes moving cars (it can take 20 minutes to relocate a car out of the flood risk area), moving belongings above the anticipated flood level (especially clothes and valuables), using sandbags to block air bricks and door ways. One resident thought that the placing of sandbags could be a less efficient response than placing belongings above the flood water. It can take 20 to 30 minutes to put sandbags in place and this time can be better put to saving valuables. It is felt that sandbags can only slow the ingress of water into property and not prevent its entry. In bungalows there is a limit to what can be placed in the loft and stacking valuables on chairs and tables on the ground floor is often the most effective action. Some residents have developed a personal response plan to ensure that the most important matters are attended to first. There is concern about the well being of pets, with one family losing two dogs and goldfish from the garden pond. The dogs' health deteriorated markedly after they drank the floodwater and they died shortly afterwards – the family still misses the pets seven years after the event.

Drabek (1986) states that people have a tendency to believe that history will repeat itself and it is often difficult to persuade them that a new disaster will be different from an earlier one. This phenomenon was encountered in the Mimmshall Brook catchment. One family for instance, was flooded in 1979 and floodwaters were about four inches deep within their property. When they were flooded in 1992 they assumed that the depth of flooding would be the same and they proceeded to raise their goods just above this level. They placed many valuables in the bath for instance, only to find flood depths reaching 20 inches causing the bath to be filled with water and their goods ruined. The magnitude of the 1992 event was totally unexpected by the local community.

Nevertheless, there are examples of where individuals have gone to some lengths to minimise the effects of flooding to themselves and their property. One resident for example, has rewired his house to ensure that all electrical sockets are at least 12 inches above floor level and that there is no under-floor cabling. Some sockets have been placed higher than this and a separate circuit supplies the loft space where the family can retreat to if flood levels are excessive. The central heating boiler has also been raised so that the family can keep warm. Another family has replaced all their divan beds with metal bedsteads to reduce flood damage. Yet another has installed suspended floors in all ground floor rooms allowing them to lift the floorboards and install industrial dryers to dry the infrastructure quickly. They found that solid floors tended to absorb water and that it took some time to dry them out fully.

In Chapter 6 there is discussion about the enthusiasm of individuals in taking a lead role in local communities and in organising flood warning arrangements. Such individuals can often provide an integrating link between official and unofficial systems and should be encouraged and supported. This has certainly been found to be the case in the Mimmshall Brook catchment with one individual in particular taking on this role. The individual in question is chairman of the local residents association and has been leading the fight for a flood alleviation scheme for the Brook for many years. He first became interested in attempts to improve the official flood warning scheme when he observed the installation of a river-level telemetry device in 1994. He contacted the NRA and asked why this was being installed and whether it could be used to improve warning arrangements – pre-empting the author's intended consultation with the community. The author held an initial meeting with him to discuss possible options and the decision to establish a warden scheme was his, which he subsequently volunteered to organise and maintain. Assistance was also given with the establishment of trigger levels at gauging stations and in the mode of operation of the system. He has continued to carry out this role during the period of this research project despite his age (he is in his 80's) and ill health. In discussions with other wardens the author expressed concern about his frailty and suggested whether this role should be taken over by someone younger. There was a general reluctance to consider this and a desire to support his wish to continue to co-ordinate matters.

The new warning scheme was activated in January 1995 and a number of interesting perceptions by both "senders" and "receivers" have been recorded during the five years of operation.

- The warning colour codes are thought to be confusing by recipients and to be too general. There is a preference for more personalised warnings with locally relevant information. One resident stated that if his property is considered to be one of the "isolated properties" in the AMBER definition his perception is that the warning indicates a less serious situation, but if his property flooded it is a RED situation for him.

- Media warnings and FLOODCALL are also thought to be too general. One resident commented on flood warning information placed on Teletext - she found it to be of little use and it made her worry rather than reassuring her. Such outlets give too little information and this appears not to satisfy the requirements of local people.

- There is a perception that a flood warning service is only an interim solution and that a flood alleviation scheme (if one is ever constructed) will provide the "final solution" at which point the warning scheme will be redundant. There appears to be less concern about extreme events that may exceed the design capacity of any structural scheme.

- On a number of occasions when warnings were issued the wardens indicated that they had made their own predictions but were glad of the information. This indicates that the informal warning system is still functioning along side the official scheme – an important development for integration.

- Residents indicated that the knowledge that someone else (i.e. Environment Agency staff) is watching the river as well as them is comforting and reassuring.

- On one occasion public warnings were issued via the wardens and via the police. The NRA also sent staff to reassure residents personally. This was considered to be a positive response by the senders of the warnings but was viewed as being confusing by the recipients. The residents felt "over warned".

Although the new warning arrangements have been greeted favourably by most of the local community they did not adequately reassure one elderly couple who lived in Warrengate Road. In 1995 following the first heavy rain of the autumn that caused the levels in the Brook to rise, it is alleged that the strain of living with the flood hazard for another winter proved too much for this couple and they tragically committed suicide. They had experienced the effects of serious flooding on two separate occasions. The importance of the providers warning systems paying greater attention to the perceptions of people who live in risk areas is made even more poignant by this misfortune.

Table 8.9: Informal arrangements in operation in the study catchment

Detection	Forecasting	Dissemination	Response
• gauge board readings • trigger levels at bridge crossings • monitoring low points in river bank • awareness of storm types • measurement of rainfall • monitoring weather forecasts	• awareness of rainfall/runoff relationship • awareness of catchment response time • using a combination of measurement, observation and past experience	• alerting neighbours by telephone or door knocking • activation of social networks • attending to people with special needs	• flood proofing measures (sandbagging) • moving valuables to higher levels • moving cars • providing escape routes • rewiring house • raising boilers • relaying flooring

8.8 The flow of information and knowledge in the study catchment

As discussed, the initial environmental information that must be collected, collated and analysed prior to the issue of any flood warning was almost entirely lacking in the Mimmshall Brook catchment. This resulted in only a general official flood warning service being available for the wider River Colne catchment. The combination of poor information and a general lack of knowledge of the flood extents and properties at risk prevented the flood forecasters from issuing targeted warning messages and guiding the police in respect of where to go and who to warn. (In fact, detailed property information had been collated by new works engineers in the NRA as part of a feasibility study, but this had not been made available to flood warning staff – an example of poor internal integration). As reported in Section 8.6, the quality of environmental information accessible to the Environment Agency for this catchment has now been significantly improved. This, along with access to collated information on at-risk properties in the flood plain, has enabled a far more targeted and integrated flood warning service to be offered to the local community.

Prior to 1995, it is not surprising that local people had developed informal arrangements to detect and forecast flooding and alert each other when river levels became threatening. During discussions it became clear that key individuals in the community had developed a good knowledge base of the hydrological and meteorological conditions that give rise to flooding and the behaviour of the Brook in times of flood. One resident, for instance, recognised that slow moving thunderstorms posed the greatest threat; he had acquired the knowledge that storms depositing over 50mm of rain would give rise to floods, while accumulations below this figure were less likely to cause problems. Another resident pointed out that persistent winter rain falling on a saturated catchment could also give rise to flooding. Many residents had a good understanding of where the river was most likely to burst its banks and cause flooding. It is generally understood that the low point is upstream of the properties at most risk and that flood water is likely to flow down Swanland Road and enter the properties from the rear. Residents are also aware of the effects of additional runoff from motorways and new developments in the catchment. By introducing a flood warden scheme as part of the enhanced official flood warning service, the knowledge and information residing in the local community is not lost to the system and the total scheme becomes better integrated as a result. A conscious decision was taken to alert the wardens directly by telephone and not via the AVM system as is the normal practice in other regions of the Agency. This allows information to be exchanged between forecasters and wardens during flood events and for each to benefit from the others knowledge and expertise.

One useful mechanism for disseminating information and knowledge around the local community is via a monthly newsletter. The chairman of the residents association produces such a publication entitled "Prevention of flooding from the Mimmshall Brook" and this is circulated to the residents of Warrengate Road and Lane. The newsletter is also used to feed back information and concerns to the relevant external organisations and individuals, such as the Environment Agency and local authorities, local MPs and counsellors, and even government ministers. This newsletter was the vehicle for seeking volunteers for the flood warden scheme, publicising their contact details when they were recruited and details of who they are responsible for alerting. The newsletter also gives information on the progress of the campaign for a flood alleviation scheme and any operational issues arising for the activation of the flood warning system. Other issues that are covered include those relating to insurance and health, for example:

> "one resident is suffering from heart palpitations, shingles, migraine and has frequently to go to the toilet when it rains. Another has eczema and stomach pains. According to doctors these complaints are stress related."

> "our insurance companies have heavily increased our insurance premiums or excess amounts and we are terrified that if we are flooded again we won't be able to get insurance for our homes and contents."

Through first hand experience and the dissemination of flood hazard information and knowledge as detailed above, residents in the risk area have become well aware of the action that they should take to protect themselves and their families, and minimise losses to their property. In September 1996 when the Environment Agency embarked on its national public awareness campaign, flood warning information leaflets were distributed to all properties located in high-risk areas including those in the Mimmshall Brook catchment. A consistent approach was followed by the Agency making no allowance for variations in the experience and knowledge of local communities across the country. The information supplied to residents in the Mimmshall Brook catchment was not well received and was considered to be "a very insensitive communication". Residents felt that the information and advice contained in the Agency's leaflets was too basic and rather patronising. One response to the Agency was "of course we know there is a risk of flooding. It happened to us in 1979 and 1992 and what have you done to prevent us being flooded again as promised?" By distributing general leaflets of this type, the Agency actually offended the local community and their awareness campaign was counter-productive. A more sensitive approach was followed in the 1998 campaign. This illustrates the fact that different communities have different levels of awareness and knowledge, and as a consequence they have different needs. In an integrated system these differences need to be understood and built into any awareness campaign.

8.9 Operational experiences

One of the aims of this research project is to introduce an improved "official" warning service for the local community in the Mimmshall Brook catchment and to attempt to build on rather than replace or compete with the existing informal arrangements. Only through operational experience will it be determined whether both systems are functioning well together in an integrated way. Since 1994, the flood wardens have been contacted on a number of occasions, in some cases to issue formal flood warnings and in others to offer reassurance that flooding will not occur even though river levels were high. Some of the cases are documented in this section with an indication of how information disseminated by the Environment Agency was received and acted upon by the local community.

29 January 1995

The system was first activated on Sunday 29 January 1995 at 23.30 hours when the Brook rose to a peak of 1.238m, some 0.172m below the bankfull level. The duty officer decided to advise the wardens that the river levels were high but were unlikely to rise any further and that flooding was not forecast to occur. Technically this was not a flood warning, rather an information passing exercise to allay fears. The duty officer spent about 15 minutes talking on the telephone to the first warden on the list and indicated that he would notify the other 4 wardens in a similar way. By the time he was in a position to do this, the heavy rain had subsided and the level of the river had started to drop significantly. A decision was taken not to disturb the other wardens as the hour was late. The first warden however, took it upon himself to contact the others to make sure they had got the message, they hadn't so he relayed the information and in turn all wardens alerted their contacts. Most of the residents indicated that they stayed awake into the early hours of the next day and monitored the levels in the river "just in case". The original "official" forecast was in fact correct and the Brook remained within in its banks and no flooding took place.

One resident who received a message from a warden complained the next day, stating that he believed the "warning" to be unnecessary and requested that the warden should be more precise about the probability of flooding in future. In general however, the feedback from the community was positive, people were glad of the information but many had predicted the outcome for themselves, but conceded that their predictions might have been wrong. One warden questioned the need for a warning if the duty officer was confident that the river was going to remain in banks. On balance, local residents indicated that they would rather receive information in such circumstances than not.

The community newsletter reported the incident in the following way:

> "On Sunday 29nd Jan. we had our first official flood warning from the NRA, Flood Control Centre at Waltham Cross. It didn't quite work out as planned. The four other flood wardens had not been phoned by the NRA although my caller said he would. I phoned everyone and they alerted their contacts. Fortunately the Brook was contained but most of us stayed up until the early hours just in case!!
>
> One resident complained to me that it was an unnecessary warning and in future would I be more precise about the probability of flooding!! I referred him to my note 7 in the December 1994 Newsletter (The NRA has pointed out that there may be an occasion when they get their forecast wrong. I think better than no warnings)."

1 February 1995

On 1 February 1995 heavy rainfall and rising river levels prompted the issue of the first formal flood warning. At 09.45hrs an AMBER warning was issued to the Hertfordshire Police and this was the first time such a targeted warning had been issued to the police for the Mimmshall Brook. The police were initially confused by the warning message and sought confirmation from the Flood Warning Centre and requested further information. The rainfall and river levels were monitored closely over the following few hours and as there was a degree of uncertainty in the forecasts the duty officer delayed contacting the flood wardens. This was heavily influenced by the feedback received following the previous event and the duty officer did not want to alert the wardens unnecessarily. At 12.18hrs the decision was taken to notify the wardens and 3 out of the 5 were contactable. The back-up arrangement was activated to ensure that all recipients received the message - this involved advising the 3 wardens who were available to alert those residents who were normally contacted by the wardens who were not available. The river reached a peak level of 1.274m at 13.00hrs, some 0.136m below the bankfull level, and no flooding occurred.

On receipt of the AMBER flood warning the police toured the risk area and broadcast a warning message over their vehicle address system. This confused the local residents on two counts - (1) they were unclear as to why the NRA **and** the police were issuing separate flood warning messages and what the relationship was between the two systems, and (2) they did not understand what an AMBER flood warning meant. A letter was sent to the chairman of the residents association that addressed these issues and this was circulated to all residents with the monthly newsletter. The newsletter reported the incident in the following way:

> "On Wednesday, 1st Feb. the Brook was at its highest this year, fortunately during the daytime so we were at our best to cope with any flooding. We very much appreciated the visit to this area by the NRA executives to see for themselves the likelihood of flooding and to supervise the distribution of additional sandbags. Two constables also came during the morning as Hatfield Police had received a flood warning from the NRA. Fortunately about 1500 hours the rain abated and the water level in the Brook went down. We anxiously watched the TV weather reports that day and night and were horrified at what the people in the North of England, Holland and France were suffering. What has gone wrong with our global weather? Attached is an article from the Daily Mail which may provide an answer."

"At 22.00 hours on 1st Feb. I had a telephone call from Hatfield Police – "we have had a fax to say there is flooding in Swanland Road, did you know?" No! So Jo and I get out the car and traverse to Swanland Road but are unable to find any sign of flooding. Came to the conclusion that the policeman who rang confused the morning fax as a 10am fax and got the wires crossed. I've had a word with Waltham Cross Flood Control Centre and I attach a copy of an explanatory letter from them for information of residents. BUT, whatever warning we receive each resident must make their own mind as to action to be taken within their home."

7 March 1995

Heavy rain accompanied by melting snow caused river levels to rise in the Mimmshall Brook during the period 4 March to 7 March 1995. The first (standby) alarm was exceeded at 14.15hrs on 7 March and the duty officer predicted that levels would reach bankfull but were unlikely to exceed this level and no formal flood warnings were issued. All flood wardens were given this advice between 14.15 and 14.28hrs. The river peaked at 17.00hrs at a level of 1.325m, just 85mm below bankfull and no flooding occurred.

Feedback received after the event indicated that the residents were pleased to receive the information. One warden indicated that from his own observations and experience, the river would take a "couple of hours" to reach its maximum level from the time of receipt of the warning - the river did indeed peak some 2.5hrs after the notification was issued. Another warden passed information back to the Flood Warning Centre during the event indicating that there was a build up of silt in the river that needed to be cleared - this was relayed to operations staff.

12 January 1999

During the period between March 1995 and June 1999 no flood events were recorded and no flood warnings were necessary. On 12 January 1999 however, during a period of moderate rainfall the author contacted all 5 flood wardens to test the dissemination system. All wardens responded and were reassured to hear that the levels of the Brook were being monitored. The river level rose to just 1.058m and no further action was necessary. It is prudent to check dissemination arrangements periodically especially after a period of little flooding activity to ensure that those involved in the process have not become complacent.

15 April 2000

Persistent rainfall over the Mimmshall Brook catchment and rising river levels prompted a telephone call to all flood wardens on 15 April 2000 to notify them that the situation was being monitored but that flooding was not anticipated. It was apparent that the informal warning system had been activated and two of the wardens were monitoring river levels at strategic locations. One warden confirmed that the gauge board at Warrengate Road Pumping Station has exceeded the 75m "danger level" and that they were keeping a close eye on the river. The wardens were in agreement with the "official" assessment of the hydrological situation – that flooding from the Brook was unlikely.

8.10 Summary and conclusions.

The Mimmshall Brook drains a small catchment area in Hertfordshire, responds rapidly to rainfall and floods on a frequent basis. The population at risk is made up of a high proportion of professional people (42% in the AB social band) many of whom are elderly living in single storey bungalows. The catchment is by no means typical of those in the Thames basin, nevertheless from the analysis presented above, a number of relevant issues emerge with respect to integration and the development of total warning systems.

Critical assessment of institutional arrangements in the study catchment

Prior to the start of this project the official flood warning service was failing to reach the local community in the Mimmshall Brook catchment. This was partly due to an inadequate flood detection and forecasting system and to a lack of detailed information of the areas and properties at risk of flooding. It was also due to poor institutional liaison arrangements between the large number of organisations covering the catchment (flood warnings are issued to 18 different organisations), resulting in a lack of clarity of respective roles and responsibilities. By itself, the number of organisations involved is detrimental to an integrated approach, but this coupled with insufficient liaison and planning only compounds the problem, ultimately leading to fragmentation and not integration.

To influence the outcome of policy decisions in this function area the local community needs to establish a detailed knowledge of the roles and responsibilities of each of the organisations involved and ascertain which has the power to bring about change. This requires considerable determination and energy to master the intricacies of a complex organisational structure. The Mimmshall Brook flood alleviation scheme is a case in point.

It is interesting to note however, that in the case of the drainage issue in Potters Bar it was a local community institution (the Mimmshall Brook Residents Association) that policed the action of the official organisations to ensure that its best interests were being met. The OECD (1989) suggest that pressure from well informed and knowledgeable interest groups can sometimes push agencies and government towards more sensitive policy co-ordination over a particular emerging problem. This has been illustrated in this case study and points to the need for organisations to work in partnership with local community groups to arrive at the most appropriate solutions for a local situation.

The new procedures introduced in 1996 for flood warning dissemination have improved matters in relation to integration, but do they go far enough? The establishment of a Local Flood Warning Plan and Flood Warning Planning Group for Hertfordshire are steps in the right direction but they are not sufficiently focused at the local level to be of great benefit to the community in the Mimmshall Brook. The Local Plan for instance, only has 7 lines of text that specifically refers to this catchment (Environment Agency, 1996b). As flood warning is essentially a local service there is a need to establish local plans and local liaison meetings involving key local players to bring fully integrated organisational arrangements to this area.

Critical assessment of the use of technology in the study catchment

Technology has played an important role in delivering an improved flood warning service to the community in the Mimmshall Brook catchment. Indeed, without the use of remote sensing equipment (gauge telemetry and weather radar), computer and communication systems, the provision of timely, accurate and reliable flood warnings would not be possible. But as this study has illustrated, it is the way in which technology is applied that most influences the success of integration and ultimately the effectiveness of the total warning system. To achieve this aim a number of important principles were followed:

- technological solutions were not imposed on the community and enhancements were made in consultation with them. Local people wanted to influence those aspects to which they could relate, such as gauge installation. They were less concerned with other elements that were considered to be beyond their level of expertise - such as rainfall and flow forecasting. They were happy to leave forecasting to the "experts".
- technological solutions incorporated informal arrangements that were in existence and did

not attempt to replace them, e.g. use of trigger levels and local warning networks.

- the appropriate technology was introduced to suit the local circumstances and needs of the community rather than introducing the best systems available. The community requested a flood warden scheme with personal telephone communication with the Flood Warning Centre providing specific and locally relevant information. Some of the latest technological systems used for dissemination flood warning information, such as the AVM and FLOODCALL, were rejected as being too impersonal and providing information that was considered to be "too general".

The impact of human interaction and expertise, information and knowledge

The availability of quality environmental information has a crucial influence on the operation of the entire flood warning system. Poor initial information results in general, non-specific flood warning messages that frequently fail to reach their intended target. This was confirmed in this case study, with the Environment Agency and its predecessors issuing general flood warning messages for the River Colne and its tributaries based on inadequate information for many years. These general warnings had never been translated into a public warning for the Mimmshall Brook catchment.

This case study has shown that where the official warning mechanisms are failing and the frequency of flooding is relatively high, the local community seeks to "fill the gap" by developing their own informal detection, forecasting and warning arrangements. Key individuals develop a detailed knowledge of their river and how it responds to rainfall to cause flooding, and they are often the prime movers in organising the informal systems and passing information to others. The systems that are introduced are invariably "low-tech" solutions and require a sizeable community resource to operate and unless they are well organised they, like any arrangement, are prone to failure. This was dramatically illustrated in September 1992 when both the official and informal flood warning arrangements failed to alert the local community.

Even though informal arrangements may be in place, this does not diminish the desire for an official warning system. This was clearly demonstrated when the telemetry device was installed, local residents reacted almost immediately to try and secure the "maximum benefit from the new system". The individuals mentioned above can often become an integrating link between official and unofficial systems and should be encouraged and supported. They often display a strong desire to help make the official system work by influencing the parts of the system to which they can relate. This includes setting up trigger levels, organising wardens and determining the format of warning messages. In return they demand clear, consistent, locally relevant information and a recognition that they are knowledgeable about the flooding hazard in their locality and how to respond to it. There is not an expectation of perfection in relation to official system's ability to forecast flooding, nor a desire to stop being responsible for taking action themselves to prevent loss.

A clear indication was given that the community intended to continue to operate the informal systems in parallel "just in case" - this may diminish if confidence builds in the official system, but evidence is presented that the informal system is still active 5 years after the official system was enhanced. There is also evidence that both systems are operating successfully in parallel, one supporting the other.

Irrespective of the source, the public wants warning systems to be simple and straightforward. When warnings were issued for the Mimmshall Brook from two sources (NRA and police) for instance, local people found this to be both confusing and unnecessary. The advantages of redundancy in warning arrangements appear not to be fully appreciated by the community in their desire for simplicity.

A number of people in the flood plain have developed good coping strategies in the event of flooding. There have been instances however, where these strategies have been based only on past experiences and larger floods have rendered their strategies ineffectual. This is where official sources can improve peoples' knowledge by offering education on the potential impact of extreme events. This needs to be managed carefully however, to avoid patronising the public as happened when the Environment Agency circulated flood warning information in 1996.

The flow of information within the community is well developed and by means of a monthly newsletter focusing on flooding matters, local people are kept up-to-date with relevant issues. This is dependent however, on the drive of one elderly individual and it remains to be seen if his work would be continued by others if he ceased to be active. The Agency may wish to consider backing-up and supporting such initiatives and use community newsletters to publicise flood awareness information. The other main mechanism for disseminating information both during flood events and other times is via social networks. Such a network was already well established, as part of the informal warning arrangement and the warden scheme was able to integrate directly with this process. Little attention has been given to the use and cultivation of social networks in the dissemination of flood warnings by the Agency. The feedback mechanisms built into the system as part of this project between the community and the Agency appear to work well and add value. The two-way flow of information during flood events is seen by both parties as being particularly valuable, this would not be achievable if one-way AVM technology was adopted as is the case in other Agency regions. There is an issue surrounding the communication of uncertain information however, and in such situations duty officers tend to delay action. The feedback from the community is that in general they would rather receive uncertain information than not. One individual did criticise one of the wardens when he relayed such information stating that he "should be more precise about the probability of flooding in future" but this was not a universal view. Another issue is the need for clarity in warning information. Officials should not assume that the public automatically understands the meaning of flood warning terms such as "AMBER warning". The clear message from this study is that local people want to receive warning information in plain English.

Finally, there needs to be greater understanding by both parties of their respective perceptions of the flood hazard and their ability to respond to it. The community needs to be aware of the limitations of providing a flood forecasting and warning dissemination service, and the Agency needs to understand the impact floods have on the local population and their particular needs. The tragic suicide of an elderly couple in 1995 highlights the need for further work to appreciate the stresses of living with the flood risk.

In conclusion, therefore, the main issues and arguments raised in each chapter of this thesis have been tested and strengthened by reference to the case study material from the Mimmshall Brook. The author set about applying an integrated approach to flood warning arrangements in this catchment by satisfying as many of the integrative factors identified in this research as possible. This has been shown to be both feasible and practicable and hence has contributed in a substantive way to meeting the objectives of this project. In short, this case study has been a useful test of the theoretical propositions set out in this thesis and forms a useful basis to determine the feasibility of introducing such techniques on a more universal basis.

Chapter 9

Summary and Conclusions

9.1 Introduction

The main finding of this research project is that an integrated approach to flood warning can be highly beneficial in improving effectiveness. This chapter summarises this and other findings and examines to what extent the objectives of the research project have been achieved. The limitations of the work are discussed with an indication of what could have been attained with the benefit of more resources. The key findings of the research project are then presented under the substantive chapter headings, with an indication of lessons learnt and areas requiring further work. The implications of the research project are discussed in terms of policy and operational practice within the Environment Agency, and in the wider context of sustainable flood hazard management.

9.2 The purpose of the work revisited

The aims and objectives of this study as defined in Chapter 1 are re-visited in this section along with a brief assessment of the extent to which they have been addressed and achieved:

To determine whether or not a policy of integration would be beneficial to flood warning programmes

From the evidence presented in this thesis and elsewhere in the literature, it can be concluded that in general a policy of integration can be beneficial to flood warning systems. The consensus reached by many researchers (Mileti 1994, Leik et al 1981, Keys 1997, Handmer 1997, Penning-Rowsell 1986) that the most effective structure for flood warning is that of an integrated system is borne out by this study. Such an approach has shown to result in enhanced interaction and co-ordination that in turn can lead to overall improved effectiveness, but this needs to take place simultaneously along several paths for the strategy to be successful. There are instances however, when integration can lead to inefficiencies but this can often be traced to poor, often singular and narrow, implementation caused by a lack of attention to the criteria needed to facilitate this process.

To identify relevant integration factors that may be of significance and to present these in a conceptual model

The implementation of an integration policy has been recorded in a number of fields with varying degrees of success. Following a detailed review of the literature and the analysis presented here, it has been possible to identify a series of factors that are considered to be of universal relevance to the successful implementation of a policy of integration. As can be seen from Table 9.1, these have been compiled under four main headings that have in turn been used to structure the substantive chapters of this thesis.

- Institutional and legal arrangements
- Technology
- Human resources, expertise and training
- Information and knowledge

The limited number of models that attempt to conceptualise flood warning systems in an integrated way have been summarised and critically examined. Although these models offer a useful framework in which to contemplate such systems, a number of fundamental flaws in their approach have been identified. These include a tendency to oversimplify what is a complex process and an inclination to focus too narrowly on a limited (but nevertheless important) number of integrative factors. It is concluded that there is a need for a wider and multi-dimensional perspective.

This research project has attempted to rectify this perceived deficiency by presenting a conceptual model that is derived from a more comprehensive assessment of "integrative devices" that are considered to be most relevant in the flood warning context. The approach adopted a two-staged process with an initial identification of a wide range of issues and variables, leading to a more focused set of factors presented under the four headings listed above. These integrative factors have been conceptualised as crosscutting strands running through the main components of a flood warning system: detection, forecasting, dissemination and response. The model is presented in Chapter 3 of this thesis and its main elements are detailed in Chapters 4 to 7.

Table 9.1 Integrative factors

Institutional Arrangements	1.	Secure political commitment, establish clear objectives, and define roles and responsibilities, preferably in a written plan. Agree rules for conflict resolution.
	2.	Establish functions and structures to foster integration, consider the designation of a lead agency.
	3.	Establish a forum for negotiating between all relevant organisations.
	4.	Instil a positive organisational climate and culture for a policy of integration.
	5.	Inter-agency exercises should be held at regular intervals followed by comprehensive debriefing sessions.
	6.	Close working relationships should be cultivated between staff in relevant agencies at a local level.
Legal Arrangements	7.	Revisit and update legislation with a view to making laws compatible and not contradictory.
	8.	Legislation should clearly define roles and responsibilities of all relevant authorities and the mechanisms for resolving conflict.
	9.	Periodically review legislation and seek continued political support to underpin the principles of integration.
	10.	Reliance on non-statutory, co-operative agreements between organisations is not conducive to integration in the long term.
Technology	11.	Technological integration can lead to organisational change and structures should be flexible enough to cope with this.
	12.	Technological advances should be applied to all functions rather than focusing on one function in isolation.
	13.	The application of technology should not be an end in itself. Low-technology solutions may be more effective with respect to integration. Applications should be need driven.
	14.	The social access to technology can be variable and certain social groups can become excluded from the benefits it brings, causing fragmentation. Steps should be taken to cater for these groups when designing communication strategies.
Human resources, Expertise & Training	15.	Formal human resource management strategies should be adopted, such as multi-disciplinary team working practices.
	16.	The use and cultivation of informal contacts and personal networks should be encouraged both in organisations and communities.
	17.	Staff development programmes and recruitment of staff from a wide base of expertise will ensure an organisation has the necessary skills.
Information and Knowledge	18.	There should be free flow of, and ready access to information within and between organisations and communities.
	19.	The use of expert and decision support systems should be explored to merge machine and human knowledge.
	20.	Steps should be taken to ensure that the recipients of information understand and believe it, and are able to confirm its accuracy.
	21.	The incorporation of information and knowledge from unofficial sources should be encouraged.

To assess whether these factors are present in existing operational flood warning arrangements in England and Wales

As a general statement it would be true to say that prior to 1996 few of the integrative factors reproduced in Table 9.1 could be identified in operational practices in England and Wales. Following the establishment of the Environment Agency as the lead authority in both flood forecasting and flood warning dissemination, a number of improvements were made in the following areas:

- Greater political commitment and legitimisation was secured for flood warning, it is now the Government's top priority for flood defence.
- Attempts have been made to clarify the roles and responsibilities of relevant institutions through the development of local flood warning plans.
- Inter-organisational forums have been established for discussing flood warning matters on a county/metropolitan area basis.
- A Ministerial Direction was given to the NRA/Environment Agency in relation to its flood warning duties that went part way to clarify roles and responsibilities.
- Technology has been applied more evenly to all elements of the warning process, including flood warning dissemination.
- Multi-disciplinary team working has begun to feature more in the implementation of the new flood warning dissemination arrangements.
- More emphasis has been placed on the need for good-quality, locally specific information both during flood events and at other times, and on the necessity for public education and awareness programmes to improve response.

Despite these improvements, a number of weaknesses have been identified in the post-1996 arrangements that impede the establishment of fully integrated flood warning procedures in England and Wales. These can be summarised as follows:

- A failure to secure legislative change to clearly define roles and responsibilities of relevant authorities and the mechanisms for resolving conflict.
- A failure to achieve universal commitment and a positive climate in all relevant organisations involved in flood response.
- The frequent lack of close working relationships between staff in partner organisations at a local level.
- The tendency to apply technological solutions without fully considering the needs and abilities of the customer.
- A need to widen further the expertise base in organisations and to fully implement multi-disciplinary team working practices.
- A failure to understand the value of informal contacts and personal networks both in organisations and communities.
- The lack of appreciation of the value of a free flow of information and feedback between organisations and communities.
- The need to give greater attention to the human and social aspects of warning message construction and dissemination to encourage effective responses.
- The need to ensure that information is understood and believed and that recipients are able to confirm its accuracy.
- A failure to make provision for information and knowledge from unofficial sources in official warning systems and a tendency to ignore and deride this resource.

This research demonstrates therefore, that while a number of positive improvements have been made to integrate flood warning systems, the systems in England and Wales still suffer from a variety of highly significant integration problems that threaten to undermine the effectiveness of the entire system. Solving these problems is critically important if the at-risk public is to have confidence in their flood defence agency's ability to provide the levels of safety and security demanded by them. These problems have been diagnosed for several years and many stem from the difficulty that technical and engineering organisations such as the Environment Agency have in recognising and addressing the social and behavioural aspects of risk communication and warning recipient response.

Through the use of case studies, determine the plausibility of introducing a fully integrated approach to future programmes

Throughout this research project the main issues and arguments raised in each chapter have been tested and strengthened by reference to case study material taken from the Thames catchment. The Mimmshall Brook in Hertfordshire was chosen as the principal case study area where, prior to this research, only rudimentary official flood warning arrangements were in place. The author set about introducing more comprehensive warning procedures using a more integrated approach by satisfying as many of the integrative factors identified in Table 9.1 as possible. The feasibility and practicability of following such an approach was recorded and analysed, and used to determine the feasibility of introducing such techniques on a more universal basis.

9.3 Limitations of this study

As discussed in Chapter 3, the methods adopted in this study, the status of the researcher, and the sources and extent of information and data used, all impose limitations to the study and this needs to be recognised.

Due to resource constraints, the research focused around a limited number of case study areas in the Thames basin, the principal one being the Mimmshall Brook in Hertfordshire. With additional time it would have been desirable to extend the number of in-depth case studies to allow an analysis of communities with differing social attributes, differing levels of experience of flooding and flood warning systems, and river catchments with differing hydrological responses and land-use.

Conducting a research study as an "insider" offers a number of distinct advantages over a conventional research student. These include unlimited access to data and information, professional staff and recipients of flood warning information, to name but a few. Such a position does bring with it however, a number of disadvantages and limitations. The insider may be too close to the subject area and could be less objective than an outsider, and the ability to be constructively critical may be impaired. In addition, the researcher may have become conditioned into a certain way of thinking and may have biased or prejudiced views, influenced by the very organisation he or she is attempting to study. A number of strategies have been adopted by the author to counter these disadvantages including the development of a critical approach to his work and that of his employer, the Environment Agency. These are fully set out in Chapter 3 of this thesis.

The third area of limitation was the information and data on which the study is based. Although it is comprehensive and extensive in many areas, it can be restricted in others. Much of the information held by the Environment Agency for example, has been collected by engineers and hydrologists and tends to be selective and biased towards the flood detection and forecasting elements of flood warning systems. There are large gaps in the data relating to the dissemination and response elements and details covering behavioural aspects are sparse prior to 1990. Post 1990, the main source of this kind of information in the Thames Region is from commissioned research by the Environment Agency and its predecessors.

Despite these limitations, the author believes that the results of this research project are both sound and credible and significantly improve the understanding and knowledge of integrated flood warning systems.

9.4 Key findings

9.4.1 Institutional and legal arrangements

It can be concluded that the legislative and organisational framework covering flood warning and response in England and Wales presents a number of severe problems in relation to integration. Typically, precise roles and responsibilities of the key institutions have not been adequately defined, inter-organisational co-ordination and liaison have often been poor, and the fostering of close working relationships has been largely ad-hoc[1]. This has been compounded by non-coincident organisational boundaries and poor translation of national

[1] See Integration Factors 1, 3, 5 and 6 in Figure 9.1.

strategic priorities into positive action on the ground.

No organisation has an unambiguous statutory duty to prepare for, issue warnings for and respond to peacetime emergencies such as floods. The Environment Agency has permissive powers to establish and operate flood warning systems, but the legislation focuses on the provision of equipment and the Agency's general supervisory role over matters relating to flood defence. There is no reference to the social and behavioural aspects of risk communication, the need for effective warning recipient response and the raising of public awareness. This is reflected in the Government's procedure for grant-aiding new capital equipment that fails to integrate the technical with the social and behavioural aspects of flood warning[2].

Evidence is presented of the gradual breakdown of the voluntary agreements between organisations that underpin flood warning arrangements, precipitated by tightening resource constraints, the fear of legal liability and low political commitment. It is concluded that reliance on non-statutory, co-operative agreements between organisations is not conducive to integration in the long term[3]. This is compounded by the distinction in the legislation between "main" and "ordinary" watercourses and the resultant fragmentation of flood defence responsibilities.

The Ministerial Direction issued to the Environment Agency in 1996 established the Agency as lead authority for flood warning and was designed to clarify matters. Indeed, many of the changes introduced by the Agency since this time have had a positive impact on integration. The production of Local Flood Warning Plans and the establishment of Flood Warning Planning Groups are obvious examples. However, as confirmed by the Independent Review of the Easter 1998 Floods, a number of serious shortcomings are still prevalent. For example, the Direction fails to address the specific question of roles and responsibilities and this is left for the Agency to tackle through discussion with other organisations but without the power of direction. There is a failure to include other relevant organisations that have important roles in flood warning and management, such as the Met Office, the media, utility companies and research bodies. The media for example are not obliged to broadcast warning notices and the

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[2] See Integration Factors 7, 8 and 9 in Figure 9.1.

[3] See Integration Factor 10 in Figure 9.1.

procedure is dependent on voluntary agreements with individual radio and television stations. The need for rules for conflict resolution between organisations is not addressed, nor is the need for inter-agency exercises, both of which are important criteria for integration. In short, although the Direction may have had a positive influence on integration, it has been issued within the context of a set of institutional arrangements that have led to fragmented responsibilities. It could be argued therefore, that any positive influence that any Ministerial Direction might have had on integration is likely to have been badly degraded by these contextual problems[4].

The present Government has indicated its desire for "an integrated and seamless service for flood forecasting, warning and response" but to achieve this many more of the integration factors set out in Table 9.1 need to be addressed. For instance, this concept has yet to be reflected in the legislation, the relevant sections of which were originally drafted in the 1970's when legislators had little notion of the "total warning system". Another example is the need for a positive organisational climate and culture for a policy of integrated flood warning to be instilled in all relevant agencies[5]. Even though much has been achieved in the Environment Agency in this regard, this is not matched in other organisations where fluvial flooding in particular is often not seen as a particular priority.

9.4.2 Technology

Technology has had a major impact on flood warning systems over the last thirty years. The influence of technology on integration has been variable however, at times positive, at others more negative.

Since the 1970s, technology has been progressively applied to integrate the technical aspects of detection and forecasting systems, in particular in the collection, processing and presentation of environmental data from various sources to enable the monitoring of current and prediction of future conditions. Technology has not been applied uniformly however, and as demonstrated in the Easter 1998 Floods, there has been a tendency to focus investment in areas at high risk of flooding at the expense of lower-risk or defended areas. This fragmented

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[4] See Integration Factors 1, 2, 3 and 5 in Figure 9.1.

[5] See Integration Factor 4 in Figure 9.1.

policy can have devastating consequences during extreme events when flood defences may be overtopped without adequate warning, as in Northampton in 1998[6].

Ever since technology was first adopted in flood warning systems there has been concern about its reliability and fallibility especially in times of emergency. Due to shrinking staff resources however, it has been increasingly necessary to place greater reliance on technological methods. Nevertheless, there is still a perceived need to provide visual confirmation, especially in extreme conditions, when measurements and forecasts tend to be trusted less, no matter how sophisticated the technology. A lack of confidence can act as a blocking mechanism for action resulting in delayed response. It is an important integration point therefore, to build into any operational detection and forecasting system the means to obtain confirmation from alternative sources to minimise periods of uncertainty.

The use of technology in the dissemination and response phases has been far more limited and a number of reasons can be given for this situation:

- The tendency for legislation and government support to focus on technical solutions in the detection and forecasting areas.
- The differing perceptions of organisations involved in flood warning dissemination and response leading to variations in investment policy.
- The lack of a co-ordinating organisation to oversee the total warning process prior to 1996.
- The tendency of some professionals to develop the science of flood forecasting in its own right using the best available technology[7].

Since 1996, technology has been embraced far more readily to disseminated flood warning information but it can be argued that this has resulted in a more impersonal public service giving rise to integration problems at the customer interface. There is evidence to indicate that the public still prefer a personal approach, with certain social groups being unfamiliar with

[6] See Integration Factor 12 in Figure 9.1.

[7] See Integration Factors 11 and 13 in Figure 9.1.

and confused by modern telephone-based information systems (Bye and Horner, 1998). Public access to and understanding of technology is not universal resulting in a sizeable section of society becoming excluded from technology-based systems. As pressure increases on organisations such as the Environment Agency to deliver information to an increasing number of people, the temptation to use impersonal technological solutions is likely to increase. This could well lead to a fragmented flood warning service with the prospect of societal inequalities widening further as the pace of technological change accelerates. To counter this, it is important that the technological methods that are adopted are appropriate for the local circumstances and satisfy the needs of the warning recipient[8].

9.4.3 Human interaction, expertise and training

Flood warning is essentially a social process involving a wide range of players with varying levels of knowledge and expertise, all with different perceptions and modes of interaction. For an integrated system to evolve the key players need to communicate effectively, to minimise their differences in beliefs, attitudes and language, and be open to the acquisition of new skills. A number of key issues have been identified in this study that can facilitate the development of an integrated approach in the area of human interaction, expertise and training.

For many years flood warning has been dominated by a small number of professions and it can be argued that as a result there has been a preoccupation with a narrow range of issues principally within flood detection and forecasting. The social and behavioural science of risk communication and warning recipient response, for instance, has received comparatively little attention historically. Within organisations, the establishment of multidisciplinary teams is an essential development if the necessary range of professionals are to work together to deliver an effective and integrated service[9].

Variation in risk perception exists amongst all players involved in flood warning and flood response. This can not only exist between the experts and the public, but also within these

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[8] See Integration Factor 14 in Figure 9.1.

[9] See Integration Factor 15 in Figure 9.1.

groups as well. In an integrated system a greater account should be taken of the variation in public response caused by differing background experiences and situations. Perceptional variations amongst the experts also need to be addressed to avoid possible inconsistencies in service levels that could ultimately have a detrimental impact on system integration. The effects of this can be minimised through better training including the holding of regular multi-agency exercises involving the public.

Personal networks have been shown to be central to the functioning of warning systems, facilitating effective response. When people become separated from their networks, whether in communities or organisations, delay and inaction can result. As demonstrated in the Mimmshall Brook catchment, personal networks are an important community mechanism for disseminating unofficial flood warnings and for an integrated system to flourish it is important that official and unofficial schemes coexist and reinforce each other. This can be achieved through the use of flood wardens and where the flood warning agency and a local community have entered into such a partnership, local flood warning arrangements are demonstrably more robust and effective[10].

Individuals can play important integrative roles at all stages in the flood warning process. For instance, the enthusiasm of key staff members can determine how effectively an organisation responds in an emergency and it is important that they are empowered to actively support a strategy of integration. There are individuals within communities who are more capable of detecting and interpreting signs of danger and are often prepared to play a leading role in disseminating information to their neighbours and friends. In an integrated system these "local experts" would be brought into the warning process (say as flood wardens) and supported to ensure their long-term involvement[10].

Learning and training strategies for individuals in both organisations and communities and for organisations themselves have an important role in an integrated system. Within organisations, individuals should receive regular training in all elements of the flood warning service including the social and behavioural aspects of risk communication. In communities, well-targeted and focused education campaigns offer a mechanism for

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[10] See Integration Factor 16 in Figure 9.1.

raising awareness of flooding and effective response. Like individuals, organisations also need to learn from experience and have the flexibility to modify their structures and decision-making procedures if appropriate. The commissioning and response to the Independent Review of the Easter 1998 Floods by the Environment Agency is a good example of an organisation initiating and implementing a learning strategy[11].

9.4.4 Information and knowledge

Flood warning is all about obtaining information about a flood hazard and communicating that information to those who need it in sufficient time for them to take mitigating action. In many operational flood warning systems information and knowledge flow mainly in one direction from the warner to the warned in a linear communication chain. This study has shown that for an integrated system to function effectively, it is important to establish a circular communication process around which information and knowledge flow and to allow feedback from responses at various stages. There should be free flow of, and ready access to, information within and between organisations and communities for instance[12].

The time of onset of a flood event will govern the type and amount of information that is available, can be assimilated and acted upon, and the total flood warning system needs to be integrated around this variable. There is no point in developing a sophisticated flood forecasting system that can deliver very detailed information for instance, if a river catchment responds faster than the information is made available to the decision-maker, be it the forecaster or the individual about to be flooded. In rapidly responding catchments there is likely to be greater uncertainty over the quality of the information available and this can act as a blocking mechanism preventing action. It is important therefore, that the holders of uncertain information are given the confidence and the means to communicate it to others, and that the recipients of that information understand the context in which it is issued and know how to respond appropriately.

Another important integration point, which can be identified at each stage of the flood warning process, is the need for confirmation and feedback. Individuals, whether they be

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[11] See Integration Factor 17 in Figure 9.1.

[12] See Integration Factors 18 and 19 in Figure 9.1.

flood forecasters or flood plain dwellers, will seek confirmation before acting especially when the information they are presented with is unusual and may indicate an extreme condition. The level of confirmation needed is directly related to the knowledge and experience of the individual concerned and the number of sources from which information is received. In an integrated system the need for confirmation and feedback needs to be recognised and planned for[13].

There are opportunities at various stages for additional information to be added to the official information stream, thereby adding value and quality to the original data. It is vital to have the ability to integrate such information into official procedures as this can significantly improve the cohesiveness of the total warning system and can help overcome uncertainty. As has been shown in the Mimmshall Brook case study, the information and knowledge residing in the local community is an important resource and should be nurtured and sustained. Within organisations however, there is a danger that information and knowledge can be lost, especially during times of re-organisation and structural change. There is a need to limit the impact of such losses through the careful documentation of flood information and the development of expert and decision support systems[14].

This and other research has shown that information is more likely to be responded to in an appropriate way if it is clearly understood and believed by those who receive it. This holds true for flood forecasters, local authority/emergency services personnel as well as the at-risk public. Information that is inconsistent, unclear or thought not to be applicable will result in confusion and misunderstanding and may block action and response. In developing an integrated system the following factors need to be addressed:

- information should be presented in a consistent and specific way, it should be convincing and reasonable, and emanate from an authoritative and credible source

- information should be targeted to the needs of the end-user, people with special needs, for example, may need help in understanding warning information

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[13] See Integration Factor 20 in Figure 9.1.

[14] See Integration Factor 21 in Figure 9.1.

- information should be delivered via more than one channel of communication, thereby allowing confirmation from an alternative source
- it should be recognised that the response to information will be made in different ways depending on the knowledge, education, status, gender, ethnic origin, etc. of the receivers of that information.

In conclusion, a range of factors has been identified in this section that attempt to distinguish an integrated system from a more fragmented approach that is more often than not the norm. These factors can be usefully summarised as a series of key words and phrases such as those presented in Table 9.2 below.

9.5 Implications of the study

The implications of this study can be summarised under two broad headings: those of direct relevance to flood warning agencies such as the Environment Agency in England and Wales, and those with wider relevance to flood hazard management in general.

9.5.1 Implications for the Environment Agency and other flood warning agencies

It is important for the success of an integrated flood warning system that sound relationships are developed and maintained between its constituent parts. This applies not only to the main elements of detection, forecasting, dissemination and response, but also to a range of other constituents such as organisations, human interaction and the application of technology. It is at the interfaces of these constituent parts where the greatest weaknesses lie and hence the greatest potential for failure. Perhaps the most significant interface that requires attention is between the experts and the public or the Environment Agency and its customers. It is suggested that matters will not improve in this crucial area unless there is a fundamental shift in organisational culture and perception within the Environment Agency. Some of the specific issues that need to be addressed are outlined in this section.

Table 9.2: Integrative and Non-Integrative Factors

INTEGRATIVE	NON-INTEGRATIVE
Proactive	Reactive
Multi-disciplinary	Single-discipline
Holistic	Selective/singular/narrow
Social and technical	Techno-fix
Inclusive	Exclusive
Political legitimisation	Ambiguous legitimisation
Free flow of information	Restricted access to information
Enshrined by statute	Voluntary agreements
Compatible laws	Contradictory laws
Confirmation	Uncertainty
Feedback	Uni-flow
Environmental awareness	Own-life priorities
Formal and informal	Formal only
Customer orientated	Systems orientated
Locally specific	Nationally consistent
Targeted approach	Blanketed approach
Varying messages	Standard messages
Flexible	Rigid
Multi-agency	Single agency
Written plans	Ad hoc procedures
Incorporated	Excluded
Liaison	Isolation
Open	Confidential
Public involvement	Public exclusion
Personalised	Impersonal
Simple	Complex
Learning and training	Custom and practice

As discussed by Bye and Horner (1998) the public often does not understand the organisational arrangements that cover flood warning and response in England and Wales. This is not surprising as the number of organisations is large (eighteen relevant authorities were identified in the Mimmshall Brook catchment alone), reorganisation is frequent (in London the flood warning agency has changed four times in the last fifteen years), and their respective roles and responsibilities are unclear and are not fully defined in the statute. The Environment Agency has been directed by government to clarify the situation by means of Local Flood Warning Plans, but although these are now in place they are not widely distributed and are not easily accessible by the public. In addition, flood warning arrangements are rarely exercised and when there are, public involvement is minimal. As lead organisation, the Agency needs to consider giving greater public access to its plans and procedures (say on the internet and in public libraries) and to holding regular exercises involving the at-risk public.

The Agency has moved towards introducing technological solutions more evenly across the flood warning process, focusing recently on using technological means to disseminate flood warning messages and information. Although this is a positive development for integration in one sense, it can have more negative implications in that a far more impersonal service could ensue in contrast to that previously provided by the police. As illustrated in the Mimmshall Brook catchment, the public prefers a personalised service and is often confused and unfamiliar with modern telephone-based information systems. It is often overlooked that technology is not universally accessible and that sections of society may be excluded from its use. Nevertheless, there are some within the Agency that see the use of technology as the great panacea as it gives direct control and is relatively easy to operate. The alternative community-based arrangements are generally considered to be prone to failure, difficult to control and time consuming to maintain. It is clear that technology has its place in public warning procedures but the Agency must put greater effort into developing more user-friendly techniques after assessing the specific needs of the target audience.

Flood warning is a social process but is sometimes viewed only in technical terms. For historical reasons the Agency and its predecessors have focused on the detection and forecasting elements and disseminating warnings to other organisations. As a consequence a few professional disciplines have become dominant within the Agency, namely science and engineering. The skills needed for dealing with social and behavioural issues are severely lacking and this requires staff development and training to rectify. It follows therefore, that there is limited appreciation within the Agency of the social processes that operate within at-risk communities and as a result problems arise at the public interface. An assumption is often made for example, that the community is a single mass of people that will react in a uniform way to standard warning messages. The Agency fails to fully recognise that communities are stratified in terms of degree and type of risk, past experience, language, gender, ethnic background and other differentiating characteristics. Community processes such as personal networks, local experts and informal warning mechanisms, that can be central to the successful functioning of flood warning systems, are often not perceived as being relevant and are generally not trusted. The role and value of public awareness programmes however, is gaining acceptance in the Agency and this is resulting in greater interaction with the public, which can only be beneficial if maintained in the long term.

The flow of information between the Agency and those at risk of flooding both during flood events and at other times needs closer examination. There is an increasing tendency to rely upon a small number of dissemination techniques over which the Agency has direct control and to make little or no provision for feedback and confirmation. This strategy is unlikely to meet public expectations and there is a need to incorporate a wider range of disseminating techniques. Greater engagement of the broadcast media could help satisfy the public need for confirmation, clarification and repetition of warning information. The Agency is actively taking steps to review and replace its colour-coded warning messages that are misunderstood by most people, but it needs to do more to open up communication channels with the heterogeneous at-risk communities. There should be greater realisation that the Agency is not the sole receptacle of knowledge and with it a greater readiness to trust and involve local people who are willing to participate in flood mitigation activities but over whom the Agency does not have direct control. Working in closer partnership with local communities will necessitate a major shift in culture within the organisation, but without this it is difficult to know how sustainable arrangements will evolve. The importance of sustainability in warning and hazard management will be explored more fully in next section.

9.5.2 Implications for flood hazard management

The Environment Agency's principal aim is to protect and enhance the environment in such a way as to contribute to sustainable development. In recent years this sustainability paradigm has been increasingly adopted by researchers and practitioners in environmental science to frame their work. More recently still, there has been a fundamental reassessment in the United States of how natural hazards should be managed and a desire to embrace the principles of sustainability within the context of hazard mitigation (Mileti, 1999). This section will briefly explore the key issues emerging from the reappraisal of natural hazard management and examine the synergies between these developments and the work presented in this thesis.

The current thinking surrounding natural hazard management involves the moving away from policies that focus on controlling floods to one of living more in harmony with them. This includes a shift from central government dominance to local level involvement, and the development of local commitment to flood management and renewed emphasis on self help (see Parker, 2000). The goal is to develop sustainable and resilient communities that are able to withstand natural hazard stresses and live in harmony with nature's varying cycles and processes. Sustainability in this context means that a community can tolerate and overcome damage, diminished productivity, and reduced quality of life from an extreme event without significant outside assistance (Mileti, 1999; Godschalk et al, 1999). To achieve this position, communities must become pro-active rather reactive, take responsibility for choosing where and how settlements are located and built through a planned process, and evaluate its environmental resources and hazards with the aim of reducing their vulnerability. A number of factors have been identified in the literature that will help achieve greater sustainability in the context of hazard mitigation, many of these have strong parallels with the conclusions reached in this study (see Table 9.3).

Effective warning systems are an important element of a sustainable hazard mitigation strategy. It is recognised that there is a need to make local warning systems more uniform, and to provide the at-risk public with better information and technical assistance. Technology is seen as an important tool that can support sustainable hazard mitigation and enhanced warning arrangements. GIS, remote sensing, decision support systems, risk analysis techniques and computer-based communication systems are some of the technologies that are considered to have great potential in this regard (see Mileti, 1999). All these findings echo the conclusions reached in this study.

In many respects the main findings of this study can be viewed as confirming several of the guiding principles of sustainable hazard mitigation. Both approaches require relevant organisations to work in a networked way, working as one to tackle common problems with the benefit of comprehensive planning and improved legislation. Communities are required to share responsibility for natural hazards and acquire a greater awareness of the risks they face. There is a need for better collation of risk information and knowledge and for this to be shared amongst all parties, and for new technology to be used in an appropriate and supportive way. Greater emphasis is placed on education and training that focuses on real-world problems. By providing an integrated and hence more effective flood warning service, people in risk areas will be supported in the management of their vulnerability to flooding resulting in the building of more resilient and safer communities. Conversely, a sustainable approach to flood mitigation can be viewed as an integrative process: the integration of flood management with environmental management and sustainable development, and the integration of local stakeholders into flood hazard management decision-making processes.

Table 9.3: Factors for a sustainable approach to hazard mitigation (after Mileti, 1999)

	Key objectives	Details
1	• Establish sustainable hazard mitigation networks • Develop integrated local plans • Identify and assess social capital • Secure stakeholder responsibility	The need to build local networks involving all relevant stakeholders. To produce comprehensive plans that identify hazards, potential losses and the locality's ability to recover from a hazard. Focus local stakeholders on taking responsibility for natural hazards.
2	• Establish holistic government framework • Develop integrated policies and programmes • Secure local and national government commitment	All policies related to hazards and sustainability should be integrated and consistent. Re-assessment of legislation to reflect principles of sustainable mitigation. Apply across all levels of government.
3	• Undertake nation-wide hazard and risk assessment • Construct national databases • Improve community-scale hazard information • Share information – locally nationally and internationally	Obtain better information and knowledge on risk, losses, and the social impact of hazards. Collate this information nation-wide but at the community-scale. Focus on interactions among the physical, social and constructed environments and on how they are reshaping the impact of natural hazards.
4	• Provide comprehensive education and training • Secure interdisciplinary education in hazard mitigation • Aim for holistic training that focuses on real-world problems	Focus better training and education on managers who have to tackle and understand the complex physical and social processes that are generated by hazards. Greater emphasis needs to be placed on interdisciplinary education and training programmes.

9.6 The problem of complacency

The successful operation of a flood warning system (and for that matter a policy of sustainable hazard mitigation) is heavily dependent upon the enthusiasm of the people that are involved in the process, be it influential individuals in organisations or the general public. Much that is written on flood warning systems in the literature assumes that those involved will react and respond in an optimal way if they are provided with the appropriate information and are made aware of the risk that faces them. Practical experience suggests however, that there are many instances when people will not respond effectively, irrespective of the amount of information and education provided to them. This can occur in organisations as well as in at-risk communities and is often associated with a lack of direct experience of the flood hazard. This is most acute in the large areas of the flood plain where flood risk is low and in areas that are "protected" by flood defences. In these localities flooding is infrequent and as Keys (1997) puts it "the community mind is not tuned" to receiving information about flood warnings. This is also true of organisations such as local authorities and the emergency services that operate in such areas. They may not have experienced flooding for many years and as a consequence may focus their resources on planning their response to other hazards that occur more frequently. If communities and organisations are not receptive to attempts to make them aware of the flood risk, then the Environment Agency will struggle to make flood warning systems operate effectively. It is perhaps only after a flood when those living and operating in low risk areas become receptive to attempts at education but such moments will only be few and brief. The scale of this problem can be illustrated in the Thames basin in that only around 15,000 properties can be classified as being at high risk of flooding from rivers, whereas over 400,000 are estimated to be at low risk, 250,000 of these are located behind the 1 in 1,000 year Thames tidal defences. It follows therefore, that the vast majority of people in the flood plain in the Thames Region are likely to be indifferent to the risk of flooding.

It can be argued that the failings of the flood warning systems during the Easter Floods of 1998 were partly due to complacency. Many of the 5,000 or so properties that were affected were in areas of low flood risk, such as Northampton and Kidlington, and many people thought that the flood would not affect them. Some of those who heard the flood warnings on local radio did not think they applied to them and took no action, they were surprised by and unprepared for the subsequent flooding. The same unpreparedness was evident in some of the local authorities and emergency services. In Northampton for instance, procedures had not been updated for many years and warnings were not passed to the correct authorities and important flood response actions were not carried out. Bye and Horner (1998) conclude that "effective interfacing between the Agency, the borough council and the emergency organisations was not achieved because all concerned were unprepared for an extreme event". The Environment Agency too was caught unawares by the severity of the event at both a local and a national level. Many of the Agency's senior managers were new to the organisation and had not experienced a flood of this magnitude. As a consequence, they did not fully appreciate the risks involved and the implications for the organisation especially in the context of its new responsibilities for flood warning dissemination. At the time, flood warning and flood defence were not high on the Agency's list of priorities with greater emphasis being placed on its other functions. This has changed since the flood but the Agency should ensure that a "boom-or-bust" approach to flood hazard mitigation is not perpetuated. This is usefully summarised by Godschalk et al (1999):

> "Past mitigation planning operated in a boom-or-bust setting. After a declared disaster, the boom is on. Money pours in, staff levels are built up, elected officials are very concerned, and a variety of agencies and organisations are eager to co-operate. However, not only do the compressed time-scales make it difficult to carry out effective mitigation, but once recovery is compete, the climate returns to bust. Budgets are cut, staff levels are reduced, decision-makers lose interest and other organisations return to normal business. This kind of crisis management is prone to mistakes and inefficiency."

A more sustainable approach would be to view hazard mitigation, including flood warning, as a valued and on-going activity. This requires stable budgets and dedicated staff complements and for all relevant organisations to maintain close working relationships in the long term, with the involvement of people in at-risk areas, to overcome complacency and develop sustainable and resilient communities.

9.7 Future research directions

It is doubtful whether any warning system justifying the title "total flood warning system" yet exists. This research project has attempted to address this issue by identifying what is needed to develop the constituent parts of the total system and integrate them into an effective whole. The conceptual model based on a set of integrative factors that is presented here focuses on experiences in the Thames Region using case study material from areas that are of high risk of flooding. Further research is required to ascertain the applicability of this approach to other regions in England and Wales and perhaps to areas of low flood risk where the introduction of an integrated approach to flood warning may be more difficult to achieve. Attempts have been made to implement such an approach in other developed countries (Emergency Management Australia, 1999) and in developing countries (Walsh, et al, 1997). It would be of both academic and applied interest therefore, to determine how the techniques presented here and developed there could be combined, adapted and applied on a more universal basis.

It is at the interfaces of the constituent parts of a flood warning system where the main weaknesses lie and where failure is most prone. This study has shown that the interfaces are large in number and extend beyond those traditionally thought to be most relevant. They can include the interfaces between organisations, between organisations and communities, between researchers and practitioners, between professional disciplines, between technology and the recipients of information, between those at high risk and those at low risk of flooding, and so on. Further research is needed therefore, to understand these interfaces more fully and to determine ways of optimising interactions where they occur.

This thesis focuses on the notion of integration and how this can be best applied to flood warning systems to improve performance. It has been demonstrated that the idea of integration and total flood warning system design is analogous in many ways to the concepts of total quality management and sustainable hazard mitigation. All three paradigms advocate a holistic approach to management, emphasising the need for continuous improvement through comprehensive planning and liaison, group problem solving and people involvement, good customer relations, better information, knowledge, education and training, interdisciplinary communication and the building of high-trust relationships. Research is needed to analyse these synergies in greater depth and to determine whether flood warning systems can benefit further from ideas and concepts developed in other fields of study.

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APPENDIX 1

Appendix 1: Flood Event Database

Date	Magnitude of storm	Magnitude of flow	Detection details	Extent of flooding	Areas affected	Organisations warned	Public warned	Public action
March 1947	Greatest widespread flood this Century (& 2nd only to 1894 on record). Snow melt	Max flow at Teddington of 710 cumecs (compared to average flood 260 cumecs)	No telemetry, lockkeepers records & news bulletins.	Catchment-wide	Most Thames catchment	No warnings issued. Army & Civil Defence utilised.	No	Mass evacuation.
September 1968	Around 150 mm's rainfall in 12 hours.	63.3 cumecs at Horley.	No Telemetry, internal reports & news	River Mole had most extensive flooding.	Esher to Molesey (this flood instigated the Mole alleviation scheme)	No warnings issued. (Flood warning system covered Thames only until this flood)	No	Not on record.
14 – 27 November 1974	100 + mm's in 9 days.	550 cumecs at Teddington.	Lock-keepers observations and Churchill gauges.	Catchment-wide	Mainly in S/East areas.	Police & local authorities with some local media cover.	No, but extensive phone liaison.	No, but extensive phone liaison.
16-17 May 1975	40mm in 24 hours 52.2mm in 48 hours	Not known	Telemetry network "40% complete"	Roads, Gardens, basements of a few properties	East and SE London	None - internal warnings only	No	Not known

Date	Magnitude of storm	Magnitude of flow	Detection details	Extent of flooding	Areas affected	Organisations warned	Public warned	Public action
14 August 1975	170.8mm in 2.5 hours. Point 1in20,000. In London 1in25. Damage estimated over £1M	1 in 50 years (approx.) Upper Brent	"40% complete". Raingauges at centre of storm were overwhelmed and failed	Extensive flooding of property (100's) - river and surface water.	Brent catchment and NW London. Centred on Hampstead	None	No	Not known
13-14 September 1975	77.3mm in 48 hours (Orpington) <1in20	No details	"Not fully operational"	Not known	South London	No details	No details	No details
25 September 1975	44.3mm Southwark Park	No details	Alarms from 3 raingauges and 3 river gauges	Local flooding in Hammersmith	Central London	Internal warnings only	No	No details
8 May 1975	43.8mm Brockwell Park	No details	Localised storm – alarms from one raingauge	Local flooding Deptford	Central and East London	Internal warnings only	No	No details
16 July 1976	45mm Keston	Approx. 1in2	Limited, lightening strikes reduced nos.	Localised river flooding Wandle and Ravensbourne. No property.	South London	Internal warnings only	No	No details
30 November 1976	29.6mm Mill Hill	No details	Alarms from 2 river gauges and 3 raingauges	Flooding of North Circular Road, and roads in Ealing. No property	NW London. Brent	Internal warnings only	No	No details

Date	Magnitude of storm	Magnitude of flow	Detection details	Extent of flooding	Areas affected	Organisations warned	Public warned	Public action
12-14 June 1977	12th 29.6mm Beddington, 1in5 14th Biggin Hill, 1in10	Flows 1in5+ but gauges in lower reaches	Alarms from 9 raingauges and 5 rivergauges. Lightening strikes reduced effectiveness.	Upper Wandle, up to 15 properties – 6" above floor level. Graveney – 42 properties. Ravensbourne – roads and gardens	South London Wandle and Ravens-Bourne	Internal warnings only. (Internal report addresses lack of resources to maintain telemetry and poor warning issues)	No	No details
16-17 August 1977	115mm Chalfornt St. Peter. Areal 1in100, Brent and Crane	Brent and Upper Crane 1in50	"Installation of telemetry gauges almost complete but the operational arrangements were untried and in the earliest state of organisation." 5 out of the 18 gauges malfunctioned	Brent and Crane – 1100 houses, 20 factories, 20 shops, several schools, churches, roads, rail/tube, 40,000 phone lines affected. Pinn – estd 300 houses and 50 shops flooded. Damage estd at over £1m. Culvert collapsed in Leighton Ave.	Centred on Brent, Crane and Pinn catchments in NW London	Internal warnings only. Warnings not passed to police or local authorities. Poor liaison between organisations. MAFF Inquiry into FW arrangements in NW London.	Police warned public using their own initiative. Door to door knocking. "Many people warned."	No details

Date	Magnitude of storm	Magnitude of flow	Detection details	Extent of flooding	Areas affected	Organisations warned	Public warned	Public action
27 August 1977	69.8mm Orpington, 63mm Sidcup	Half 30-year flow at Bromley Ravensbourne. Beddington 1in5 Wandle.	Poor coverage in upper Ravensbourne. Only 1 raingauge detected storm in this area.	Kyd Brook – 100 properties flooded – plus extensive surface water flooding	Upper Ravensbourne	Internal warnings only	No	No details
20-21 October 1977	20-30mm in 48 hours Brent.	No details	Adequate	North Circular Road Flooded	NW London	No details	No	No details
1 May 1978	35.5mm Keston, 32.0mm Beddington	Approx. 1in2	Poor coverage in upper reaches of Ravensbourne	Rivers at bankfull - no direct flooding reported	Upper Reaches of Wandle and Ravensbourne	London boroughs warned directly Bromley, Lewisham, Croydon, Merton and Greenwich	No	No details
5 May 1978	25-40mm North of Thames. 39.5mm Oakwood	Crane approx. 1in10 Brent approx. 1in5	Brent and Crane adequately covered	North Circular Road, Roads in Ealing/ Greenford. No properties flooded.	NW London	London Boroughs warned – Ealing, Hounslow, Richmond.	No	No details
31 July 1978	55mm Waddon. Point 1in 30. Areal 1in10	No details	Poor cover in upper reaches	Wandle and Ravensbourne – local overtopping – 3 properties flooded.	Wandle mid-reaches. Ravensbourne – upper and mid reaches.	All riparian London Boroughs expt. Greenwich, Lambeth, Croydon.	No	No details

Date	Magnitude of storm	Magnitude of flow	Detection details	Extent of flooding	Areas affected	Organisations warned	Public warned	Public action
10 December 1978	Ruislip 31.5mm Uxbridge 27.0mm	No details	Adequate	Crane – road flooding in Ruislip. Brent – mainly surface water flooding	NW London	LBs Brent, Barnet, Ealing, Harrow, Hillingdon, Hounslow, and Richmond. All South London Boroughs. "took ¾ hour to warn, response varied from prompt to failed"	No	No details
7-8 April 1979	30-40mm across London 20 hours duration	No details	No details	Local overtopping - rivers running generally at bankfull	NW London Brent and Crane catchments	Warnings issued to London boroughs north of the Thames	No	No details
30 May 1979	Thunderstorms north of Thames 30-40mm	Alarms from 2 raingauges	Lightening strikes reduced cover	Several houses and shops, parks, gardens and roads	Silk Stream Wealdstone Brook and lower Brent	Warnings issued to Boroughs north of the Thames and New Scotland Yard. Took 1 hour to make contact.	No	No details

Date	Magnitude of storm	Magnitude of flow	Detection details	Extent of flooding	Areas affected	Organisations warned	Public warned	Public action
9-10 October 1979	41mm Leyton 35.5mm Deptford	No details	No details	Garden flooding only	Graveney South London	Warnings issued to all London Boroughs and New Scotland Yard for advice.	No	No details
28 December 1979	59.6mm Keston 34.0mm Ruislip	"Most widespread floods for several years"	New alarm system installed on Pinn	1 property flooded from Pinn. Widespread flooding from Thames and tributaries. Severe flooding of 6 bungalows from Mimmshall Brook – residents evacuated.	Pinn, Mole, Wey, Thames, Mimmshall Brook	Amber and Red flood warnings issued by TWA	Yes. Local alarm system in Pinner alerted 10 wardens. Mimmshall Brook residents not warned – "they woke to find beds floating in 2ft of water"	River Pinn patrolled by wardens keeping continuous watch. Residents association passed warnings to "everyone living in the area"
26 July 1980	50mm over 2 days 52.1mm Green Lanes	No details	New "watchdog" system installed Yeading Brook.	Bankfull, but no reports of overtopping.	North London	No formal warnings issued.	Yes. Local "watchdog" device alerted wardens in Ruislip Gardens (upper Crane)	Wardens decided not to warn others. "simple obs. dictates what action to take on receipt of an alert"

Date	Magnitude of storm	Magnitude of flow	Detection details	Extent of flooding	Areas affected	Organisations warned	Public warned	Public action
15 October 1980	30-40mm across London. 48mm Holland Park, 40,5mm Beddington Park, 42.5mm Eltham.	No details	New "watchdog" alarms activated in London	Roads, parks and gardens. No properties flooded from rivers. North and South Circular Roads. Costons Lane – Brent overtopped banks	NW London severest.	All London Boroughs alerted.	Yes via "watchdog" alarms	Presumed yes following receipt of alarms. No details.
6 August 1981	Thunderstorms 70.7mm Hogsmill, 66.2mm Cheam, 65.3mm Worcester Park Point rainfall 1in 75 to 100 years	Flows in Beverley Brook, Wandle and Ravensbourne 1in10 years	23 local "watchdog" devices had been installed, 12 activated by high river levels	Beverely – 80 houses, 1 factory, 5 shops. Wandle – 23 houses, 2 factories. Ravensbourne – 1 house, garages and gardens. Brent – 11 houses Hogsmill – several houses flooded	North, SW and SE London	All 17 riparian London Boroughs warned. Radio pagers used to make contact failed due to BT maintenance. Warnings made by direct phone call.	Yes – via local "watchdog" devices. In Beddington, residents had requested their numbers be removed – so no warning given	Residents in Beddington protested about "totally inadequate warning system and failure to warn residents of immanent flooding"

Date	Magnitude of storm	Magnitude of flow	Detection details	Extent of flooding	Areas affected	Organisations warned	Public warned	Public action
25-26 June 1982	Thunderstorms in north London. 36mm Harrow 38mm Perry Oaks "gauges may have missed maximum rainfall"	In excess of 1in10 Colindeep Lane, Wembley and Yeading West.	Adequate cover	Silk Stream - three fatalities. Three boys washed away by flood wave.	North London	Warnings issued to Barnet, Brent, Richmond, Hillingdon, Ealing, Harrow and Hounslow	Assumed that wardens received watchdog alarms – but no record kept. Police warned some residents by loudhailer. Also via local radio.	No details
3 August 1982	Thunderstorms over north London. 26.0mm Brent Reservoir, 23.5mm Oakwood Park	Maximum flows in Silk Stream. 1in5 at Colindeep Lane.	Adequate cover	No details	Upper Brent received highest rainfall	London Boroughs north of Thames – Barnet, Brent, Richmond and Hillingdon all responded. Ealing, Harrow and BWB failed to respond.	No details	No details
3 May 1983	Thunderstorms across London. 36.2mm Sutton, 39.0mm Cheam 32.1mm Mill Hill	1in5 flows – Upper Wandle, Upper Brent and Upper Crane catchments.	Watchdogs – good cover upper reaches but alarms do not reach forecasters – only wardens	No details	Across London	No details	No details	No details

Date	Magnitude of storm	Magnitude of flow	Detection details	Extent of flooding	Areas affected	Organisations warned	Public warned	Public action
6 July 1983	Thunderstorms across London – heaviest in south. 87.0mm Croydon, 68.4mm Putney Heath	Locally high flows in Graveney, historically high!	Storm centre between raingauges in south London. 2 gauges out of action.	Graveney at Kenlor Road Tooting, 70 properties flooded (54 AFL and 16 BFL). Norbury Brook, 39 properties flooded (18 AFL and 21 BFL)	Localised in south London	No warning from Met Office. Warnings issued to LB Wandsworth	Watchdog device in Longley Road alerted residents in Kenlor Road. "Warning issued in time for action to be taken to reduce damage to property"	Wardens alerted neighbours. Stored sleepers on adjacent railway line strewn across track by flood. A local resident warned British Rail of the danger.
17 June 1984	56.0mm Gt. Missenden P S	No details	No details	Severe flooding in Pinner	No details	No details	No details	No details
5 July 1985	East London 81.0mm Raphael Park 68.0mm Weald Bridge, Ongar	No details	No details	Gave rise to a number of properties being flooded to depths in excess of 1m. in several villages along the Cripsey Brook.	East London and Essex	No details	No details	No details

Date	Magnitude of storm	Magnitude of flow	Detection details	Extent of flooding	Areas affected	Organisations warned	Public warned	Public action
25 December 1985	Over 50mm of rain in South London. 51.0mm Gap Road, 46.2mm Worcester Park.	No details	No details	No details	South London Wandle and Beverely Brook	No details	No details	No details
29 July 1987	Isolated thunderstorms in Essex. 68.4mm in 1.25 hrs, Toot Hill, 63.0mm Thornwood Common. Point – 1in1000	Cobbins Brook – 35 cumecs. 1in125 Cripsey Brook – 34.7 cumecs 1in25 (estimated higher in upper reaches). Damage estimated £277K Waltham Abbey at£247K at Thornwood (under-estimated?).	Trigger levels not established at gauging stations. In both catchments gauges located d/s of risk areas – for water resources.	Cobbins Brook – 90 properties flooded to depths of 1.2m in Waltham Abbey. Cripsey Brook – 41 properties to depths of 0.6-1.2m. 73ha of farmland flooded, M11 closed and other A-roads.	West Essex – villages of Thorwood Common, Waltham Abbey worst affected.	RED warnings issued to Met and Essex police by telephone. Some liaison with local police and local authorities. Epping Forest DC, however, acted on their own initiative (reacting to reports of surface water flooding). Poor liaison with TWA, police failed to alert LA's, key depots flooded.	No. Flooding took residents by surprise. 92% of residents in Thornwood not at all satisfied with FW service. District council highlighted greater use of local radio to alert public	Little or no action possible due to flashy nature of the flooding and the lack of warning.

Date	Magnitude of storm	Magnitude of flow	Detection details	Extent of flooding	Areas affected	Organisations warned	Public warned	Public action
22 – 23 August 1987	87.4mm Theydon Bois, 77.2mm Chigwell	Beam/Rom 18.2 cumecs	Poor river level cover in upper reaches of Beam. Poor raingauge cover in these catchments.	200 properties in Romford flooded – evacuation by Essex police. All non-main river. Some flooding from Roding - roads and fields – between Ongar and Abridge.	West Essex Beam/Rom and Roding	AMBER for Beam and Roding. No warning service for Rom as it is non-main river – even though flooding widespread!	Police liaised with local borough and evacuated residents. Not clear what triggered this action.	No details
25 August 1987	28.2mm Thornwood 25.4mm Chipping	Clavering in banks at gauging station.	Poor raingauge coverage in Upper Lee	Stort – overtopping at Manuden car park and fields affected. Mayes Brook – gardens of 12 properties flooded.	East Herts and West Essex	AMBER Upper Stort and Ash.	Close liaison with police – police sensitive following Rom flood – preparing to evacuate Romford again.	No details
2 September 1987	60mm Royston 54.4mm East Hyde STW, 47.8mm Luton Airport	High flows Upper Ash – not gauged.	Poor rain and river gauge coverage in upper Ash. "Storm missed the telemetry gauges".	Upper Ash – 3 properties flooded from main river – many more from non-main river.	North Herts	AMBER Upper Ash – but issued late.	Police had insufficient time to act due to late warning – probably no public warning	No details

Date	Magnitude of storm	Magnitude of flow	Detection details	Extent of flooding	Areas affected	Organisations warned	Public warned	Public action
9 October 1987	76.4mm Takeley, 74.5mm Hatfield Heath 65.0mm Perry Oaks 1 in 10 storm	Cobbins Brook – 29.7 cumecs 1in 60 Brent 1in 20 Monks Park, Wandle 1in 30 Beddington Park, Stort 1in 30 Gypsy Lane, Ash 1in 35 Mardock	70 alarms received from telemetry gauges. No river level gauge Nazeing Brook, Upper Cobbins Brook, Upper Salmons Brook.	Nazeing Brook – 16 properties, Lee at Hatfield – 6 properties, Cobbins Brook – 4 properties flooded in Waltham Abbey, Salmons Brook – 2 properties, Stort at Bishops Stortford – 3 properties and caravans in Roydon. Overtopping in Brent, Crane and Wandle.	Across London, Herts and Essex	RED Nazeing Brook, AMBER Silk Stream, Wandle, Beverely, Crane, Cobbins Brook, Ash, Cripsey Brook. Police alerted and local councils notified.	Watchdog systems activated in London rivers	Assumed wardens alerted neighbours but not recorded.

Date	Magnitude of storm	Magnitude of flow	Detection details	Extent of flooding	Areas affected	Organisations warned	Public warned	Public action
21-22 October 1987	30-40mm across London. 45.5mm Beddington	Bankfull exceeded Wandle, Beverely, Crane, and Brent	Poor telemetry coverage in Luton, and Colne catchment generally.	Brent – 2 properties Silk Stream Crane – flood plain Beverely – local flooding Pyl/East Pyl Brooks. Lee – u/s Hertford – 1 property and football ground. Mimmshall Brook – road flooding 350mm Colne – small nos of properties. Salmons Brook - 6 properties	Across London and West Herts	RED Wandle/ Graveney, Silk Stream, Beverely, Lee at Luton, Brent and Crane AMBER issued for all main rivers in London, and Nazeing Brook. Warning levels in excess of flooding in many catchments. Police started warning for Tidal Thames – high level of confusion - warnings poorly targeted.	Watchdogs alerted residents - high level alerts issued.	Residents warned by police on Thames in error. No details of warnings elsewhere.

Date	Magnitude of storm	Magnitude of flow	Detection details	Extent of flooding	Areas affected	Organisations warned	Public warned	Public action
29 January 1988	Average of 25mm in 27 hours across London and Lee Valley.	Roding 1in50 Ash 1in45 Beane 1in25 Shows importance of antecedent conditions.	Poor coverage Nazeing Brook, and upper reaches of other small tributaries.	Roding widespread flooding, 1 property, roads and gardens, Nazeing Brook – gardens and roads only, Ash – roads and farm land, Mimmshall Brook – local roads Elsewhere local overtopping.	Across London and Lee Valley	RED Nazeing Brook, AMBER Upper Lee, Roding, Salmons Brook, Cobbins Brook, Crane.	Watchdogs triggered warnings but no record of which ones.	No details

Date	Magnitude of storm	Magnitude of flow	Detection details	Extent of flooding	Areas affected	Organisations warned	Public warned	Public action
7-8 May 1988	Two thunderstorms during same day in NW London. a. 63.5mm (in 2.5 hrs.) Hillingdon Court, 53.6mm Ruislip 1in100 b. 35.0mm (in 75mins) Ruislip 1in25	Brent at Monks Park 1in50, Yeading West 1in10, Wembley 1in25	Pinn – telemetry could be improved in upper and middle reaches – poor telemetered raingauge cover. Very poor coverage elsewhere on the Colne	Pinn – >200 properties flooded. At least 2000 telephone subscribers cut off for up to 3 weeks – main trunk cable had to be replaced. Old peoples home flooded (Milmans), TA helped evacuate. Much flooding from surface water plus Pinn. Crane - 5 properties, Silk Stream - 50 properties, Wealdstone Brook - 9 properties, Colnebrook – 100 properties. Railway bridge collapsed in Colne.	NW London – Colne, Crane and Brent catchments	RED Colnebrook, Frays, Pinn, Wealdstone Brook, Yeading Brooks, Silk Stream. AMBER Brent, Crane and Pymmes Brook.	Pinner residents alerted by TWA by telephone. Confusion on behalf of wardens as to the action they should take. Some assumed that all residents would be warned directly by TWA. Watchdogs alerted wardens in Brent and Crane catchments.	In Pinn catchment, wardens warn (amongst others) the Traders Assn. Who should warn other traders - this did not work well. Other residents were notified, however. Wardens produced flood report– Promoting self help. One resident called out TA to help evacuate OAP's. Many wardens used their own initiative to warn others.

Date	Magnitude of storm	Magnitude of flow	Detection details	Extent of flooding	Areas affected	Organisations warned	Public warned	Public action
31 August/ 1 September 1989	20-25mm on 31/8, then a further 15mm on 1/9 In NW London	No details	Coverage in Crane good.	Yeading Brook – bankfull with some overtopping.	Upper Crane catchment.	AMBER Yeading Brook	Watchdogs high level at Ruislip Gardens and Village Way	Presumed wardens acted on alerts - no details.
6 June 1989	24mm Keston (missed centre of storm)	Kyd Brook at bankfull	Good telemetry coverage in Kyd Brook - but levels not recorded.	Kyd Brook/ Quaggy – gardens, parks and roads – no properties.	SE London Kent	AMBER Kyd Brook, East Branch Ravensbourne. NSY warned who in turn alerted local police stations, who warned local boroughs.	Watchdogs – along Kyd Brook alerted wardens of high levels in river.	Presumed wardens acted on alerts – no records of this.
7-8 July 1989	64.5mm Braughing Friars, 53.5mm Nags Head Lane	High flows Silk Stream and Wealdstone Brook	Coverage adequate	Silk Stream running at bankfull – local overtopping into gardens and parks.	North London and Herts.	AMBER Silk Stream	Watchdogs alerted wardens Edgware Brook and Yeading Brooks.	Presumed action by wardens – not confirmed.

Date	Magnitude of storm	Magnitude of flow	Detection details	Extent of flooding	Areas affected	Organisations warned	Public warned	Public action
10 August 1989	15-35mm across London 34mm Ealing	Wandle 1in5. Brent, Crane 1in2	Coverage adequate in catchments affected.	Wandle – minor overtopping - no properties.	NW and South London.	AMBER – Upper Wandle to police. Telephone warning to Sutton Council. Rivers subdivided into FW Reaches - allow more targeted warnings to police.	Watchdogs functioned – no details	No details
14-18 December 1989	Long wet period. 97.4mm in 1 week at Hertford.	London rivers generally 1in 2 – higher in tidal Crane	20 low level alarms received	Crane – garden flooding on 16/12 – tidal reach.	Across catchment	YELLOW Lee catchment. Automated telexing facility introduced - speeded up warning issue to police.	Watchdog Tidal Crane – high level alerts. No wardens on system only LB Hounslow Richmond	No details
20 December 1989	Wet catchment 30-40mm across catchment 43.9mm Wey 39.4mm Colne 35.0mm Nags Head Lane	No details – widespread flooding across region.	Poor telemetry cover in west of region.	Widespread flood plain inundation in west of region. London – Upper Brent roads and gardens.	Across Region.	AMBER - Thame, Cherwell, Ray, Thames, Upper Brent, Wandle. Thames Valley police failed to pass on all warnings LA's	Pinn – wardens alerted	No details

Date	Magnitude of storm	Magnitude of flow	Detection details	Extent of flooding	Areas affected	Organisations warned	Public warned	Public action
February 1990	Very wet January, 18-31 rained every day. First 3 days of Feb. 50-60mm Upper mole, Wey and Kennet. Jan. 133% of average rainfall, Feb. 228% of average rainfall.	Flows 1in5 across catchment	Poor telemetry cover in upper reaches of western tributaries.	Thames – 100-200 properties affected by flooding. Tributaries – minor property flooding, flood plain inundation widespread.	Across Thames catchment.	RED Thames at Maidenhead, Thame, Chertsey bourne, Wey. AMBER Mole, Loddon, Thames, Colne, Brent, Wandle, Cobbins Brook, Roding.	Public warnings issued but poorly targeted and often after flooding occurred.	See Middx report
1 March 1990	Tidal	High fluvial in Crane plus spring tides up the Thames – but below Barrier closing criteria	Need to upgrade telemetry in Tidal Crane to monitor 15-minute levels.	Crane – gardens of 2 properties flooded.	Lower Crane Twickenham	AMBER Tidal Crane	Watchdog alerted LB Hounslow – no direct warnings to public	No details

Date	Magnitude of storm	Magnitude of flow	Detection details	Extent of flooding	Areas affected	Organisations warned	Public warned	Public action
30 July- 1 August 1991	31/7 25mm in 12 hours. 1/8 Thunderstorms 10mm in 30 mins.	South London 1in 2-4 years	Thunder-storms difficult to forecast improved forecasting highlighted.	Wandle – flooding of 30 properties in Beddington - due to works in river and blockage. Norbury Brook – gardens in Thornton Heath Beverely Brook – allotments flooded.	South and NW London mainly.	AMBER Silk Stream, Norbury Brook. Telephone warning to Sutton Council re Wandle flooding	No public warning - blockage, difficult to predict flooding	Public taken completely by surprise - no action possible.
7 August 1991	15mm Stevenage. Likely centre of storm missed	Very localised flooding - not gauged.	Poor telemetry cover in Stevenage. Stevenage council has gauges but they failed (non-main river in town)	Stevenage Brook – flooding of B197 – no properties at risk from main river. Widespread flooding from blocked non-main river.	Stevenage – local storm.	No warnings issued.	No warning issued	No details

Date	Magnitude of storm	Magnitude of flow	Detection details	Extent of flooding	Areas affected	Organisations warned	Public warned	Public action
18 November 1991	30mm across London 33.0mm Brent	No details	Luton poor coverage – missed flooding due to this. Ching Brook no telemetry.	Ching Brook – gardens, Upper Lee-roads and 1 shop flooded, Kyd Brook/Quaggy – minor flooding, Wandle – Goat Bridge failure of auto-weir caused local flooding.	Across London, Herts and Beds,	AMBER Ching Brook, Kyd Brook/Quaggy. No warning issued for Upper Lee at Luton.	Watchdogs alerted wardens in Kyd Brook	No details of action taken.

Date	Magnitude of storm	Magnitude of flow	Detection details	Extent of flooding	Areas affected	Organisations warned	Public warned	Public action
29-31 May 1992	Upper Lee 90.2mm in 28 hours Upper Crane 85.2mm (Northolt) in 25 hours. 1in100 year storm	Upper Lee at Luton Hoo 1in40 Brent at Monks Park 1in14. Elsewhere 1in2-4 years	Lack of telemetry in Colne, Pinn and in Luton restricted monitoring. Reliance on manual reading of gauge boards – "tied up valuable resources".	Upper Lee – Wheathampstead – mill, 6 shops, 2 industrial units. Mayes Brook – 3 properties including a church. Cherwell – several properties from Bloxham Brook. Colne – gardens from Pinn, Colne Brook. Thame – minor flooding in Aylesbury Minor flooding from Quaggy, Mimram, Stevengae Brook, Ching Brook, Pymmes Brook and Lower Lee.	Across north of Thames catchment - especially Upper Lee	RED (minor) Upper Lee – Luton to Hertford. AMBER Beane, Mimram, Ravensbourne, Crane, Brent, Colne, Thame, Cherwell. Herts police faxed property at risk details for areas issued with flood warnings (Upper Lee, Mimram and Stevenage Brook.) Local authorities alerted in London	Herts Police used details to issue warnings to those properties. Prior to this blanket warnings made targeting difficult. Warnings were issued using door to door knocking, distributing leaflets and loud-hailers on police vehicles.	Watchdog warnings received in London catchments - flood wardens alerted. Residents in Wheathampstead confirmed they had received a warning from police and that they were able to take effective action to reduce flood losses and "avert a far more serious situation".

Date	Magnitude of storm	Magnitude of flow	Detection details	Extent of flooding	Areas affected	Organisations warned	Public warned	Public action
9 June 1992	Ravensbourne 70.2mm Grove Park Point return 1in1000 Brent 29.0mm Brent Reservoir	Quaggy at Chinbrook Meadows >1in50, Main Branch at Catford Hill 1in 33, Silk Stream at Colindeep Lane 1in10	Telemetry cover good on Kyd Brook/ Quaggy. 2km weather radar displays invaluable for tracking thunderstorms – but hail caused radar to overestimate rainfall accumulations.	Quaggy – extensive property flooding – 123 properties flooded, commercial and residential. Ravensbourne - 8 properties Silk Stream/Wealdstone Brook – gardens and road flooding	South East London. Some rain in NW London	RED (minor) Quaggy AMBER Kyd Brook, Ravensbourne,, Pool, Chaffinch Brook, Silk Stream. Underestimated severity of flooding in Quaggy (major RED). Met Police and London Boroughs alerted. Confirmed that NSY passing all warnings to correct destination.	LB Lewisham informed that they had limited resources to respond – some of their depots hit by lightning. Traffic grid-locked in Lewisham/ Bromley area. In Grove Park handicapped children trapped on first floor	Majority of residents not warned by police or local authorities. Limited resources and inability to reach areas affected by car. In Grove Park residents used "toy" inflatable boat to evacuate handicapped children and pets
1 July 1992	Lee catchment 17.4mm in 45minutes at Hadley Road, 12.6mm in 1 hour at Rye Meads. 1in3 storm.	Salmons Brook 1in3, Pymmes Brook 1in2	Lack of river level gauges in upstream reaches of Salmons, Turkey and Pymmes Brooks.	Salmons Brook – 1 house and 3 maisonettes flooded from Hounsden Gutter. Gardens and sheds.	East London	No external warnings issued - "as heaviest rain was moving away when problems began to occur"	No warnings issued	No action possible

Date	Magnitude of storm	Magnitude of flow	Detection details	Extent of flooding	Areas affected	Organisations warned	Public warned	Public action
22-28 September 1992	North of Thames. Heaviest in Brent, 80.2mm Harrow Weald, 59.6mm Ealing, 58.2mm Mill Hill, Colne – 53.4mm Radlett, 55.6mm Markyate.	Silk Stream at Colindeep Lane >1in50 Brent at Brent Cross and Monks Park >1in50.	Poor telemetry cover in the west of the region – manual reading of gauge boards not possible. Poor cover in the Pinn catchment delayed warnings - complaints from residents. No warnings issued for Mimmshall Brook, Radlett Brook and Hartsbourne due to no telemetry cover.	Silk Stream – 102 properties flooded AFL. Edgware Hospital flooded to 0.5m, 60 beds affected, Cardiac Unit lost power. Edgware Brook - 61 properties, Radlett Brook – 50 properties car submerged, Mimmshall Brook – 16 properties, Hartsbourne - 25 properties, Pinn - 12 properties, Upper Lee - 5 shops, 5 industrial units. Lesser flooding in Cherwell in Banbury and Bloxham.	Brent, Lee and Colne catchments	RED – Silk Stream/Deans/ Edgware/Brook Upper Lee. AMBER Brent, Pymmes Brook, Stort, Pinn, Thame, Cherwell, Ock, YELLOW Roding, Lower Lee, and all catchments u/s of Teddington. NO WARNINGS for Mimmshall, Radlett Brooks, Hartsbourne. Generally good liaision with LA's and police. Requests that FW Reach System be extended to other catchments in west of region.	Wardens warned in Brent and Crane catchments. In worst affected areas no wardens established. Few residents warned in Silk Stream catchment. No warnings for Mimmshall/ Radlett Brooks and Hartsbourne. Numerous radio interviews given to pass warning information.	Little information on action taken. One warden in Edgware failed to act on warning (went back to sleep) and found property flooded in morning. Mimmshall Brook residents taken completely by surprise woke up to 1m flooding in bedrooms (bungalows)

Date	Magnitude of storm	Magnitude of flow	Detection details	Extent of flooding	Areas affected	Organisations warned	Public warned	Public action
19-21 October 1992	25-30mm across Thames catchment. 65.0mm Burstow – Mole, 52.0mm Stanford Rivers – Roding, 50.0mm Keston - Ravensbourne, 50.0mm Stansted – Stort.	Roding 1in30 Stort 1in12 Ingrebourne 1in29	Maintenance work on Upper Stort changed regime of river and affected trigger levels at telemetry stations. Flooding less than anticipated.	Strort – gardens of 5 properties at Clavering, 1 property flooded at Manuden - 6 gardens, 1 property at Sheering, 10 chalet properties in Roydon. Roding – depot flooded, gardens and roads. Ingrebourne – gardens of several properties. Mole – Agricultural land only.	West Essex and Surrey.	RED Upper Stort, Cripsey Brook. AMBER Ash, Roding, Ingrebourne, Mole. Good liaison with police and local authorities in Essex and on Mole. Councils providing sandbags in Essex.	Some indication that Essex police warned residents in Manuden/ Clavering area. NRA issued press release giving advice to public on action to take if they think their property is likely to flood.	Sandbags provided in Manuden and Clavering - no details of publics' response.

Date	Magnitude of storm	Magnitude of flow	Detection details	Extent of flooding	Areas affected	Organisations warned	Public warned	Public action
November-December 1992	Rainfall recorded on each day from 21/11 to 5/12 on a wet catchment. Average of over 100mm in this period.	Mole 1in5-10 Kennet at Marlborough 1in25-30. Elsewhere in western catchments 1in2-5. Roding 1in5-15.	Need to display all telemetered data on one computer system (5 different systems at present). No telemetry alarms for western rivers. 95% of outstations remained in service. Some warnings issued as a precaution due to poor detection capability.	Thames – 12 properties Wey/Mole – 5 properties Pang – 22 properties (7 main river) Cherwell - 3 properties Thame – 1 property Ock – 2 properties Kennet/ Lambourn - 11 properties Stort – 2 properties Roding - 1 property Ravensbourne – 3 properties	Across the Thames catchment	RED Mole, Thames, Loddon. AMBER All tributaries upstream of Teddington (excl. L Mole, Pinn and Frays.) and Roding. Good communication generally. "Use of follow-up phone calls clarified any misunderstandings." Good feedback during event – provision of information seen as essential. Proactive use of the media to pass warning information.	No details concerning public warnings	No details

Date	Magnitude of storm	Magnitude of flow	Detection details	Extent of flooding	Areas affected	Organisations warned	Public warned	Public action
8-16 January 1993	Rainfall on all days from 3-16 January. Average rainfall over this period – 68.3mm	Generally a 1in2-4 year flood. Between 1in 5-10 in Loddon.	Same comments made as previous event. Reliance on field observations to trigger warnings	Pang - 2 properties Kennet/ Lambourn – 2 properties.	Across western catchments	RED Loddon, Thame, Thames (Purley). AMBER Wey, Thames, Kennet, Pang, Cherwell, Windrush	No details	No details
1-5 April 1993	10 to 50mm in 12 hours 49.0mm Basingstoke 29.6mm Cheam 25.4mm Lilley Manor	Flow generally 1in 2-4	Poor coverage in some upper reaches of smaller tributaries	Lee – car parks Ching Brook – car park Pyl Brook – golf course	Upper Lee and small tributaries in London	AMBER Beverley Brook, Wandle (Graveney), Wye.	LB Lambeth initiated their Emergency Plan - they misunderstood the meaning of an AMBER warning!	Wardens notified by Watchdog devices in Beverley Brook.

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26 May 1993	Thunderstorms over west of Thames region. 128.7mm Uping Farm, Berks 73.6mm Maddle Farm, Kennet	High flows in Kennet and tribs., Ock and Pang.	Warnings issued too late due to lack of alarms on telemetry in western catchments, no access to radar at duty officers' homes, and lack of rainfall forecasting facilities. LWC under-forecast severity (10-15mm only).	Ock – 1 house, roads to 0.3m, farmland. Stutfield Brook – 2 properties. Kennet/Lambourn – several properties much surface water flooding.	Storms moving from south over western catchments	MINOR RED Kennet, Lambourn, Enbourn, Ock and Pang. AMBER Ray, Cole, Churn, Windrush, and Evenlode.	Warnings issued to police but after flooding occurred as "storms developed too quickly".	No details - no formal warnings issued in time.

Date	Magnitude of storm	Magnitude of flow	Detection details	Extent of flooding	Areas affected	Organisations warned	Public warned	Public action
2 June 1993	Variable rainfall totals due to thunderstorms. 41.0mm Brent Reservoir, 34.0mm New River Head 1in15 point.	Brent: Monks Park 1in12 Colindeep Lane 1in5	Used flow forecasting model to predict flow in upper Brent tribs. Trigger levels at Colindeep Lane indicated river above bankfull, but was well in banks. Cause for over-reaction? Tried to forecast conditions "rather than wait for confirmation that flooding has occurred."	Silk Stream - Edgware General Hospital boiler room, roads and gardens elsewhere. Wealdstone Brook - roads Lower Brent – flood plain and parkland.	Brent catchment in NW London	MINOR RED Brent tributaries. Police and local boroughs notified. Confusion between river flooding and surface water flooding – a number of properties flooded near to river but from SW - local authorities insisting that this is NRA's problem - roles and responsibilities issue.	Wardens notified in upper Brent catchment - Edgware General Hospital provided with direct warning.	Confusion on part of public regarding the organisations responsible for different types of flooding. No warnings issued for surface water flooding which was more severe than that from the river.

Date	Magnitude of storm	Magnitude of flow	Detection details	Extent of flooding	Areas affected	Organisations warned	Public warned	Public action
10-12 June 1993	Series of thunderstorms crossing Essex, E London, Herts and Beds. 124.6mm (in 3.25 hours) North Weald, 96.2mm Thornwood, 99.2mm Runley Wood (2 days), 78.0mm Markyate (2 days)	Cripsey Brook – 40 cumecs at Chipping Ongar 1in128 – estimated 1in150 in upper reaches (Thornwood) Canons Brook at Elizabeth Way 1in38	Warnings for Cripsey Brook issued on rainfall accumulation, no flow-gauge in upper reaches. Forecasting based on duty officer's experience on impact of rainfall. Warnings issued hours before levels at Chipping Ongar gauge started to rise. At Markyate no river gauge and raingauge failed so no warnings.	Cripsey Brook – 161 properties at North Weald (non-main), 25 Thornwood, 2 Morton, 5 Chipping Ongar. Roding – 12 Toot Hill (one partly demolished - children nearly washed away), 3 Shonks Brook. Ver – 22 Markyate (culvert blockage). Stort – 1 Harlow.	Thunderstorms over east of Thames region.	MAJOR RED Cripsey Brook, MINOR RED Ver, AMBER Colne, Canons Brook, Upper Lee, Salmons, Turkey and Pymmes Brook. Very good liaison with Essex Police and Epping Forest DC. Able to target warning effectively, knew that flood larger than 1987 – knew properties at risk, collated in FW Reach system.	Police able to warn public by door to door knocking and loud hailer, especially in lower reaches of Cripsey Brook. In Thornwood/ North Weald lead time too short for police to respond. No warnings in Markyate as rainfall and flooding not detected.	Public in Cripsey Brook acted on their own initiative - many experienced flooding in 1987 so were better prepared. Many said they saw and heard the heavy downpours and took precautions as flood water started to rise.

Date	Magnitude of storm	Magnitude of flow	Detection details	Extent of flooding	Areas affected	Organisations warned	Public warned	Public action
22 September 1993	Variable due to thunderstorms. 46mm Putney, 33mm Hounslow, 29mm Orpington	Highest flows Pyl Brook and Quaggy	Poor coverage in upper Beverely Brook – river level and raingauges.	Minor overtopping in Beverely Brook catchment. Widespread surface water flooding.	South London	AMBER for upper reaches of Beverely Brook. Met. Police and LB Merton warned.	Wardens in Beverely Brook alerted	No details of action taken by wardens.
29 September – 4 October 1993	4-day rainfall total up to 100mm in South and East London and Surrey. 102mm Burstow, 97.4mm Keston, 82.2mm Central Park.	Beam 1in 40 at Bretons Farm, Mole 1in25 at Kinnersley Manor, Ravensbourne 1in10 at Chinbrook Meadows and Bromley South	Satisfactory in NE Area. Data return from telemetry only 70% in SE and W areas – 95% expected. Unified display and alarm system lacking in west of region.	Ravensbourne – 15 properties estimated flooded across catchment, also many roads and gardens. Flood plain, roads and gardens flooded in Mole, Wey, Beam and Roding catchments.	South and East London and Surrey	RED warnings issued for Ravensbourne and Mole. AMBER warnings Wey, Brent and Beam. Warnings to police and local authorities. Good liaison between organisations	Warnings placed on BBC CEEFAX – flood warden schemes activated in Ravensbourne and Brent catchments.	Wardens alerted neighbours

Date	Magnitude of storm	Magnitude of flow	Detection details	Extent of flooding	Areas affected	Organisations Warned	Public warned	Public action
11-14 October 1993	3-day rainfall total over 70mm in Herts, Surrey and North London. 70.4mm Radlett, 71.2mm Bragbury Park, 71.6mm Farnham.	Mimram and Beane 1in200, Lee 1in80, Rib 1in35, Brent and Stort 1in10. Thames Barrier used to keep tide out of London and to let tributaries discharge into Thames.	As above. Met Office forecast a further 25mm of rain but this did not materialise. If it has a major flood would have occurred, especially in the Lee catchment ("a 1947 flood!")	The following nos. of properties flooded , Colne 38, Stort 27, Beane 6, Nazeing Brook 1, Salmons Brook 4, Crane 4, Blackwater 5-10. Also isolated properties in Brent, Lee and Pinn. Flood plain inundation in Mimram, Roding, and Ash.	Concentrated mainly in north and east of Thames catchment.	RED warnings for Colne, Mimshall Brook, Nazeing Brook, Roding, Stort, Pinn, Lee, Ash, Crane,Wey, Lambourn. AMBER warnings for Brent, Salmons Brook, Pymmes Brook, Mimram, Beane, Cobbins Brook, Rib, Wey. Good liaison with police and local authorities – warnings backed-up with telephone conversations. Proactive approach taken with media.	Warnings placed on BBC CEEFAX and warden schemes activated in Brent, Crane, Stort, Pinn. Essex police request that RED warnings be issued so that resources could be allocated to alerting residents and responding to flooding incident.	Wardens alerted neighbours

Date	Magnitude of storm	Magnitude of flow	Detection details	Extent of flooding	Areas affected	Organisations warned	Public warned	Public action
January 1994	December 1993 rainfall 110-180% of mean. In January rained every day until 19th – 132% of mean. Max. December total 210.6mm, January total 140.6mm.	1in40 Ampney Brook, 1in16 Colne, 1in2-4 in most other catchments.	Telemetry – lack of regional data acquisition system, but fast links into Reading Flood Room allowed better access to data. Forecasting – rainfall useful, but flow not developed.	West – all river full and overtopping into flood plain, flood defence schemes prevented flooding in Aylesbury and Somerford Keynes. SE – 4 properties from the Thames and flood plain. NE – Stort 2 properties, Colne 2 properties, sandbagging prevented more flooding.	Across whole of Thames basin.	RED (limited) Loddon, Chertsey Bourne, Addlestone Bourne, Thames at somerford Keynes. AMBER Mole, Wey, Thames, Kennet, Cherwell, Windrush, Colne, Crane and Roding. Warnings sent by unified faxing/telexing system in standard format from office or FDO's homes.	BBC CEEFAX – but public did not read warnings - calls received from defended lower Mole but no warnings issued here. Letter sent to residents in Maidenhead who flooded in 1990 – low tech and effective for long lead times. Much media interest – E. Standard stated falsely that Thames on RED.	Public education called for. Perception that public not responding well to flood warnings and do not know where to get official information on flooding etc.

Date	Magnitude of storm	Magnitude of flow	Detection details	Extent of flooding	Areas affected	Organisations warned	Public warned	Public action
10-11 August 1994	50mm in south and central London. 87.6mm Holland Park, 55.0 mm Deptford.	Highest flows Ravensbourne, Beverely Brook and Wandle. Also Pymmes Brook and Silk Stream.	Improved telemetry coverage in upper Lee - 2 new river level stations in Luton.	Most significant flooding from surface water. Tube network closed down (Central line) - affected shops' income in Oxford Street.	Central and south London.	AMBER Kyd Brook and Ravensbourne in LB Bromley. Police and local authorities alerted.	Wardens alerted in Ravensbourne Wandle and Beverely Brook.	No details
January/ February 1995	December 130% of average rainfall. January average of 127mm - 220% of mean.	Rainfall pattern resulted in a multi-peaked event in catchments across the Thames basin.	18 new river level sites installed in Colne catchment - resulted in more targeted warnings - event used to establish trigger levels. Need for additional 35 sites in western catchments highlighted.	SE – 2 properties and 6 industrial units from Thames, agricultural land and roads. West – some roads and agricultural land NE – 2 industrial units in Roding, elsewhere roads and farmland.	Across Thames Basin.	RED Thames and Roding. AMBER Mole, Loddon, Thame, Kennet, Colne, Stort and Roding. Mimmshall Brook, police able to target warnings using FW Reach System, able to alert residents in good time. Telemetry allowed more targeted warning.	Warnings issued via CEEFAX, letters issued to residents on Thames, and warnings issued to wardens. New warden scheme on Mimmshall Brook activated. 5 wardens notified.	Wardens alerted those at risk in Mimmshall Brook catchment.

Date	Magnitude of storm	Magnitude of flow	Detection details	Extent of flooding	Areas affected	Organisations warned	Public warned	Public action
26 July 1996	Thunderstorms across Region. Most active over Herts. 54.4mm Whitwell 51.0mm Bragbury Park	Mimram 1in200 at Panshanger	Trigger levels not well established. No history of flooding in Mimram catchment so FDO's taken by surprise – exacerbated by blockages.	Mimram - 5 properties, exacerbated by blockage at mill at Tewin. Up to 150mm in houses damage to carpets, furniture, food, etc.	North Herts – Mimram catchment	AMBER Mimram to police, AA Roadwatch (trial basis), media. Good liaison with police – Herts police alerted Agency of Mimram overtopping before warning issued.	No wardens in Mimram. First warnings directly to media but fast response precluded timely warnings on radio.	Residents not warned - complaints received. Unwilling to set up warden scheme however.
10-11 August 1996	Thunderstorms over Essex, Herts, and NW London. 35.0mm Epping 25.0mm across rest of affected area.	Silk Stream 1in2	Good gauge coverage in catchments affected.	Edgware Brook – gardens flooded	NW London and Herts	AMBER Silk Stream and Edgware Brook. YELLOW Pinn. Police, local authorities and utilities alerted.	Wardens notified and warnings issued via media (local radio and AA Roadwatch). Local radio responded 3 hours after warnings issued - lost effectiveness – problem with fast responding rivers.	Residents complained that they heard that warning had been issued after the event. Media warnings not geared for short lead time events.

Date	Magnitude of storm	Magnitude of flow	Detection details	Extent of flooding	Areas affected	Organisations warned	Public warned	Public action
26 June 1997	Thunderstorms across region. 44.8mm Lilley Manor 30-35mm Upper Lee, Colne and Brent.	Silk Stream 1in8	Radar performed well, improved calibration by Met Office. GANDOLF thunderstorm warning system performed well. Telemetry trigger levels accurate at Colindeep Lane.	Silk Stream – 20 gardens, roads, parkland (to 1m). Close to entering properties reaching air-brick level.	NW London, Beds and Herts.	RED Silk Stream, Deans, Edgware brooks. AMBER Dollis Brook, Wealdstone Brook, Upper Brent. New flood warning dissemination arrangements activated for first time. Large demand for media interviews - staff resourcing issue.	Wardens alerted. Dedicated phone line installed in flood rooms to facilitate 2-way exchange of information Floodcall system activated - 250 calls made by public to obtain information.	Flooding from main and non-main river. Those flooded from latter responded more effectively than those from former. Results of public education programme. They knew what to do and where to get information.
8 July 1997	Intense storms south London and Surrey. 51.8mm (49.8mm / 1 hour, 23.2mm / 5 mins) Leatherhead 48.2mm Selhurst Point 1in3000	Graveney 1in8 – flashy response (urban) cf. Mole responded little (more rural)	Poor telemetry cover in upper reaches of London tribs/ Mole. Radar performed better than gauges. Growing confidence in GANDOLF.	Wandle – 21 gardens in Norbury Brook, sewers/ gullies blocked held water back from rivers. Mole – surface water only – rivers hardly responded.	South London and East Surrey	AMBER Norbury Brook and Graveney. Police, local authorities and utility companies alerted.	Wardens alerted in Graveney. Rest warned via media – but again fast responding situation not dealt with well by media outlets.	Wardens advised to watch situation and alert neighbours if necessary.

Date	Magnitude of storm	Magnitude of flow	Detection details	Extent of flooding	Areas affected	Organisations warned	Public warned	Public action
6 August 1997	Thunderstorms over Surrey and south London. 70.2mm Burstow 59.8mm How Green	Only moderate response in Upper Mole. Hogsmill flows not recorded due to defective gauge.	Poor telemetry coverage in Upper Mole and Upper Hogsmill. Kingston gauge (lower reaches) in Hogsmill not functioning – so no telemetry in catchment.	Mole – no river flooding - surface water only. Hogsmill – some flooding of property but no details available.	Surrey and south London	YELLOW Upper Mole and tributaries. No warnings issued for Hogsmill – not detected. Yellow issued to police and local authorities - not media.	No warnings issued for Hogsmill.	No official warning issued.
9-11 April 1998	70mm in 15 hours at Byfield	In excess of 100 year flow in Cherwell	One raingauge flooded, river gauges failed to measure magnitude of the flood - failure of measuring equipment (beyond range) and telemetry. "None of the gauges was without problems".	Cherwell - 563 properties flooded in Banbury, Kidlington and villages in between. Many areas affected that were not flooded before (i.e. in 1947 flood). Agency and residents taken unawares.	Storm affected upper Cherwell - was not raining in Kidlington, this confused the public.	RED warning issued for Cherwell - 2 hours before flooding of first property in Banbury and 2.25 hours in Kidlington. Authorities, media, Met Office, utility companies, British Waterways.	No flood wardens in place. 9 high risk properties alerted directly by field staff. Leisure centre manager alerted - located on banks of river.	Most of the people who were flooded failed to receive a warning. Some heard the media warnings but thought that it did not apply to them. Flood awareness was low.

Date	Magnitude of storm	Magnitude of flow	Detection details	Extent of flooding	Areas affected	Organisations warned	Public warned	Public action
1 August 1998	Severe thunderstorms in South London. 67.8mm (54.0mm in 1 hour) Kelsey Park, Beckenham.	River level gauges in upper Wandle and Ravensbourne reached high level sensors	Poor coverage in upper reaches of some small rivers, especially in Lee catchment. (Pincey Brook, Roding and Stanstead Brook)	Wandle – gardens flooded from Norbury Brook Ravensbourne – gardens and a car park flooded from Chaffinch Brook. Extensive surface water flooding.	South London – but across London and Lee catchments.	AMBER Upper Wandle and Ravensbourne Police, LA's, utilities warned. Radio stations in London (3), AA Roadwatch, Teletext, Met Office also alerted directly.	All wardens in relevant reaches in Wandle and Ravensbourne alerted by telephone. Two-way communic-ation stressed as important.	Wardens advised to alert neighbours - many used their own judgement following receiving the warning. "I've been here 30 years so I know how this river responds"
27 September 1998	Slow moving front. 80.6mm Lilley Manor nr. Luton (15.8mm falling in 30 mins). 106mm at Aylesbury in Thame catchment (1 in 500years return period at that point).	Highest levels recorded in Upper Lee catchment in Beds and Herts (return period of approx. 25-30 years) – flood peak dissipated by the time it reached Waterhall u/s of Hertford. Rural Thame stayed in banks.	Radar under-estimating over Luton due to blockage in radar beam. New telemetry site in Luton worked well – need for an additional raingauge upstream of Luton. Some problems with warnings issued from Met Office.	14 industrial units flooded in Coldharbour Lane, Batford, Lower Luton road and Lee Valley Industrial Estate. 2 commercial properties in Wheat-hampstead.	Upper Lee between Luton and Wheathamp-stead	AMBER for reach 1 of Lee (Luton), READ for reach 2 (Harpenden to Hertford). YELLOW for the Thame. All relevant organisations notified by fax/phone but problems in cascading warnings to other organisations.	Wardens alerted in Luton/East Hyde - but industrial unit keyholders not on direct warning scheme – no warning received via police as set out in FW Dissemination Plan.	No action possible in Batford due to lack of direct warnings, considerable losses as a consequence (e.g. computers store on ground in factory). Some sandbagging by Agency of houses adjacent to industrial site.

Date	Magnitude of storm	Magnitude of flow	Detection details	Extent of flooding	Areas affected	Organisations warned	Public warned	Public action
24 December 1998 to 1 February 1999	January's rainfall total 150% above average – highest in West and SE of catchment. Persistent winter rainfall.	Highest levels and flows in Churn (10-15 years), Coln (15-25 years), Kennet (20-25 years), Windrush (15-20 years) and Loddon (5-10 years)	Radar reliable, problems with telemetry polling and alarm forwarding due to equipment failures. Computer system crashed due to data overloading. Problems with telemetry outstations and inaccurate setting of trigger levels at new sites	Relatively few properties flooded from main rivers in West and SE of Thames basin (estimated 6 plus caravan park). Extensive flooding of agricultural land. A number of properties flooded from Ordinary watercourses (estimated 20 in Cranleigh)	Most rivers in SE and West of Thames basin.	81 YELLOW and 18 AMBER warnings issued. Issuing warnings very time consuming and keeping recorded message system up-to-date. All relevant organisations notified but some problems with dissemination.	All direct warning recipients notified. Some confusion in SE Area due to residents expecting a warning but not receiving one – not part of Agency's procedures. Confusion about when to alert wardens in the Cherwell catchment - since resolved.	Many people telephoned the Floodcall service but were not satisfied with the service. Agency staff opened incident rooms to give personalised service and assisted public on the ground with pumping/ sandbagging. Many people still unclear on action to take.
2 June 1999	Thunderstoms NW London and Colne catchment. 44.8mm in Stevenage, 44.0mm at Wolverton Rd (Stanmore) (19.6mm in 15 minutes)	Highest flows in Pinn and Upper Brent catchments. Flood Plain alarm exceeded at Waxwell Lane – upper Pinn.	99 telemetered raingauges were operating at start of event, 12(12%) failed/ blocked. River gauges misreading. Radar under-estimating rainfall totals.	Most severe flooding from surface water especially in London area. Up to 7 properties reported flooded from Pinn. Upper Brent bankfull.	Mostly in NE part of Thames catchment - Cole and Brent catchments.	AMBER warnings issued for Pinn and Upper Brent. All warnings disseminated to relevant organisations correctly.	Pinner Flood Warden scheme activated. Some initial reluctance by co-ordinator – but then worked well.	Good liaison between wardens and Agency. Wardens patrolled risk areas, notified residents. Letter of commendation from Res Assn

APPENDIX 2

Appendix 2: Conceptual models of the warning process

Williams' Conceptual Model.

Williams (1964), studying warnings relating to natural disasters in the United States in the 1960's, attempted to conceptualise a warning as a system involving the origin, coding, and transmission of information about the existence of possible danger, together with responses to, and feedback from responses to this information. He contrasts this with looking at a warning as if it were only the issuance of a warning message, or the transmission of such a message, or the behaviour of the sender or receiver of such a message. He considers, therefore, a warning to be a process and not a discrete message or act.

As illustrated in Figure A2.1, Williams states that the warning process comprises of the following steps:

- detection and measurement or estimation of changes in the environment that could result in a danger of one sort or another.
- collation and evaluation of the incoming information about environmental changes.
- decisions on whom should be warned, about what danger, and in what way.
- transmission of a warning message, or messages, to those whom it has been decided to warn.
- interpretation of the warning message by the recipients and action by the recipients.
- feedback of information about the interpretation and actions of recipients to the issuers of warning messages.
- new warnings, if possible and desirable, corrected in terms of responses to the first warning messages.

In the first stage of the model Williams recognises that both official and unofficial sources may originate and transmit warning messages to the public. The unofficial sources may be individuals who have specialist knowledge and experience or are particularly sensitive to environmental changes. It is important to recognise that more than one source may be collecting and reporting warning data that can have its advantages but can also create opportunities for distortion, attenuation, contradiction and redundancy.

When information is received from whatever the source, these data have to be collated and evaluated. Evaluation involves such questions as:

- is the information reliable?
- if some or all of it is from unofficial sources, are these sources reliable?
- what do the data imply in terms of specific dangers to specific places at specific times?

The next step is the decision to warn and this involves such questions as:

- is the danger really going to materialise to a certain degree at a certain place?
- when will it strike and how much warning do people need to take protective action?
- what will be the consequences if an extreme event strikes and there is no warning?
- will it do any good to give a warning?
- is there time to take protective action?
- how will people behave if they are not warned?

Williams stresses that the decision to warn may also be influenced by anticipation of the behavioural consequences that may result from an incorrect warning. The decision-maker may be pressurised by the anticipation of blame if either a warning is issued and the danger does not materialise or if no warning is issued and the danger does materialise.

Once a decision has been made to issue a warning, it may be transmitted by a variety of means: television or radio, sirens or other signals, or police or other officials going from door to door or using loudspeakers. Williams considers that different channels of communication may have different degrees of credibility for the recipients. These differences may vary in relation to the culture and social structure of the population, so the use of multiple channels for transmitting warnings may increase the chances of reaching all the intended recipients. Williams goes on to discuss, however, the existence of sub-points through which warnings often pass. These sub-points can delay, distort, attenuate, contradict and even block a warning message. He stresses the importance of psychological variables involving human operators that exist at each sub-point. They often have difficulty operating automatically in a warning situation and may delay a warning message seeking confirmation or even block it all together by not believing its content.

Interpretation of the warning message is another important area. Williams points to the fact that different persons may react differently to the same warning message and that some of the reactions appear illogical. He goes on to suggest that this is a function of how the individual defines the danger situation. This definition includes the following factors:

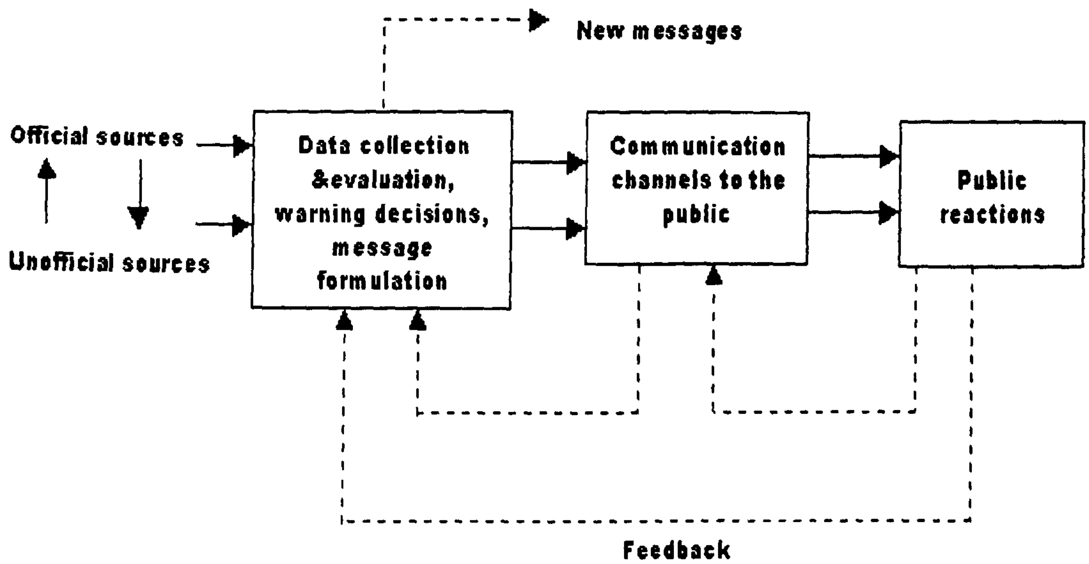
- the strength of the threat (how likely is the danger to materialise, and how serious will the loss be if it does?)
- the time element (how long will it be before one has to decide, and how long will it require to take protective action?
- the cost of taking protective actions (economic, psychological, social)
- the presumed effectiveness of available countermeasures (will they do any good against the threat?)

All these factors are interrelated. Thus the greater the strength of the threat the less weight is given by the warning recipient to the cost of taking protective actions.

Williams does not imply that response to warnings is a conscious, coldly calculating process. Unconscious and irrational factors, such as repressive denial and even perceptual distortion of incoming information, may occur. Informal social communication and personal observation are other important factors in the warning response process. People often try to confirm the hazard situation through discussions with others and are influenced by the actions of others. They also try to seek proof of the situation with their own eyes by looking at a river for example. In short, interpretation of and reaction to a warning is not a simple or automatic process, it is a complex and often highly social process.

Finally, Williams emphasises the need for feedback from the warned to the warner and concludes that it is valid and useful to regard warning as a circular communication process, rather than simply a linear process. This would involve fast feedback during the event itself that allows new information to be issued accordingly, and slow feedback that continues to occur after the incident is over which may give rise to system improvements over a period of time.

Figure A2.1: Model of warning-and–response system (after Williams, 1964)



Foster's Conceptual Model

Foster's model (1980) of integrated flood warning design usefully reveals the complexity of the process. It involves the interaction of physical, technological, and social systems, the operation of which must be carefully co-ordinated if the desired result, the avoidance of disaster or reduction of the scale of devastation, is to be achieved. He illustrates the complexity of total warning systems by suggesting that the successful design and operation of such systems involves sixteen basic steps (Figure A2.2) that he goes on to describe in detail.

1. The first stage of the model is the recognition by decision-makers that there is the possibility of danger from a particular source.

2. Danger recognition precedes the design of the warning system that involves evaluating the "disaster agent" and its characteristics that have implications for the warning process. Factors that must be considered when designing a system include: frequency, physical consequences, speed of onset, length of possible forewarning, duration, scope of impact, destructive potential, gross predictability and gross controllability.

3. The installation and operation of the system involves defining the type and distribution of sensors used to collect data. There is often a minimum number below which he system is incapable of fulfilling its obligations.

4. So that the warning recipients are familiar with the warning system and its meaning, education of the user groups is important. It is important to present the warning message at a level that can be readily understood by those members of the public at which it is aimed. This will facilitate effective response to a warning.

5. Testing the system to ensure that it is technically sound and that those involved in issuing and receiving its warnings act as required, is essential to provide scope for improving accuracy and effective dissemination.

6. Modifying the system if test results indicate that changes are necessary.

7. Detecting and measuring changes in the hazard that could result in increases in death, injury and/or property damage.

8. Collating and evaluating incoming information. This requires value judgements based on experience.

9. Deciding to warn. This carries with it a great deal of responsibility and represents a major threshold in the warning process.

10. Warning messages must be designed and transmitted with great care. Messages must include details of the time of impact, the specific area threatened and the likely consequences. A wide variety of channels and media should be used to distribute warning messages. Individuals are more likely to respond if they receive information from several sources.

11. Interpretation of warning messages and actions by recipients have a great influence on the effectiveness of warning systems. This element, however, is the most difficult to predict because it is conditioned by the beliefs, experiences, prejudices, education and perceptions of those at risk. Foster believes that response can be improved through education.

12. Information in a warning system should flow both ways, passing both to and from those threatened. Such feedback permits operators of the warning network to assess the impact of their messages and transmit modified messages designed to achieve their desired impact.

13. Warning messages should be repeated frequently and modified to relay changes in the nature of the threat.

14. Transmitting all-clear messages when danger has passed is important.

15. Foster believes that it is essential to record in detail the operation of the warning system. Such a hindsight review allows malfunctions to be identified, future operations to be improved and aids the training of new personnel.

16. Once a system has been enhanced through hindsight review it should be tested once more.

Mileti's Conceptual Model

Mileti (1994) states that the most effective structure of a warning system is that of an integrated system. Such a system has two qualities that make it unique:

1. To ensure preparedness, the warning system is composed of three relatively separate subsystems, the detection, management and response subsystems.
2. Integration requires that sound relationships among these subsystems be developed and maintained.

The Detection Subsystem

This focuses on the monitoring of the natural environment that could induce a flood emergency. It collects, collates, assesses and analyses information and when warranted, makes a prediction about the potential occurrence of a flood. The prediction is then communicated from the detection subsystem to the management subsystem.

The basic functions of the detection subsystem are to detect the presence of a potential emergency and then inform those who must manage the event. In an integrated warning system the detection subsystem has specific structural characteristics.

1. The environmental-detection linkage is clear and routine
2. The link between detection and the management subsystem is clear and familiar.

The Management Subsystem

This system focuses on integrating the risk information received from the detection system and warning the public when warranted. This subsystem is composed largely of local emergency management officials. After receiving information from the detection system, these managers must interpret that information in terms of potential losses and then decide if the risk warrants a public warning. In making such decisions manager's use specified or ad hoc criteria. Official public warnings are made following a positive decision. One part of this subsystem often overlooked is the monitoring of public response once warnings are issued so that subsequent warnings can be refined or changed if people are not responding in a way that would minimise their exposure to risk. This subsystem is typically the domain of local government.

The management subsystem has particular structural characteristics in an integrated system.

1. Linkage between detection and management systems is clear and familiar.
2. There is communication between personnel in each system to help with interpretation.
3. Links with the public through actual warnings and monitoring of response is comprehensive and informed, not ad hoc.
4. The ability of the environment to bypass the detection system and directly influence managers is recognised and incorporated into plans.

Response Subsystem

People respond to warnings received from the management subsystem on the basis of their own interpretations of those warnings, this can differ from the interpretation of detectors and managers. Moreover, the response system contains an additional warning element, in that people generate unofficial warnings for others. Unofficial warnings can come from a variety of sources and people can issue unofficial warnings according to their own perception of events and their own social realities.

The ideal response system has particular structural characteristics in an integrated warning system:

1. Comprehensive and multiple channels of communication to the public have been prepared

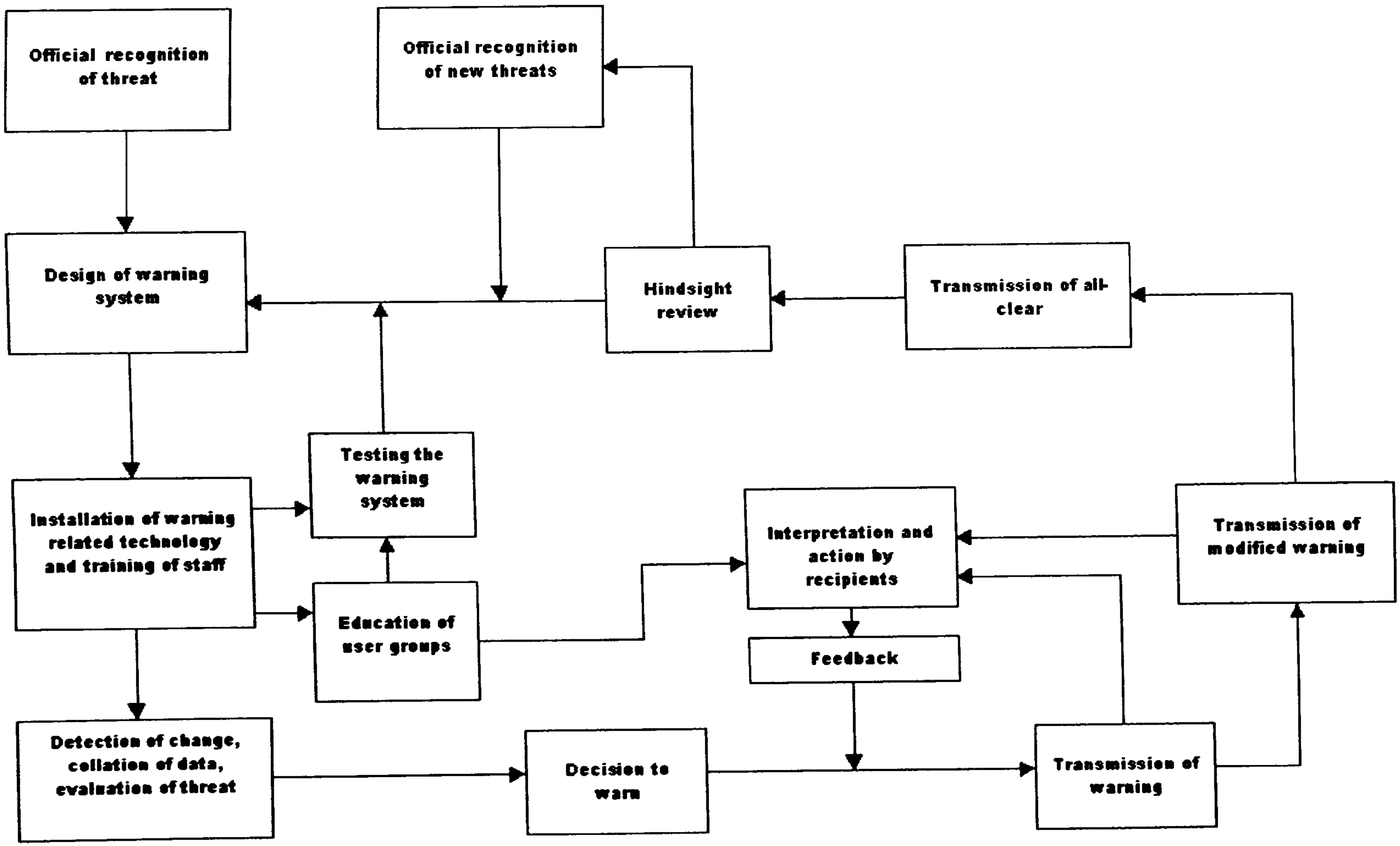
2. Warning messages are comprehensive and provide the public with all that it needs to know

3. Public response is monitored as it occurs and fed back into the management system so that adjustments in warnings can be made as needed

4. The ability of the environment to bypass the detection and management subsystems and directly influence public response is planned for

5. The possibility that detection-system personnel may informally give the public direct information, that supports or contradicts official warnings, is recognised and managed.

Figure A2.2: Idealised warning system (after Foster, 1980)



APPENDIX 3

Appendix 3: Institutional and legal background

The legal framework covering flood warning

The Environment Act 1995 (S.6 (4)) gives the Environment Agency a general supervisory duty relating to all flood defence related matters in England and Wales and this can be interpreted to include flood warning. The Water Resources Act 1991 (S.106) stipulates that most of the Agency's functions in relation to flood defence must be carried out through Regional Flood Defence Committees (RFDCs). The extent of the Agency's operational role however, greatly depends upon the designation of a watercourse with responsibility for Main River, sea and tidal defences resting primarily with the Agency via RFDCs and for other watercourses (defined as Ordinary Watercourses) with the appropriate local authority or internal drainage board. The Land Drainage Act 1991 gives local authorities and internal drainage boards the power to carry out works on ordinary watercourses (Ss. 11 & 14).

The Agency is empowered to provide and operate flood warning systems and to provide, install and maintain apparatus required for the purpose of such systems (Water Resources Act, 1991 S.166). A Flood Warning System is defined to mean:

> "any system whereby, for the purpose of providing warning of any danger of flooding, information with respect to:
>
> a) rainfall, as measured at a particular place within a particular period; or
> b) the level or flow of any inland water, or part of an inland water, at a particular time; or
> c) other matter appearing to be relevant for that purpose,
>
> is obtained and transmitted, whether automatically or otherwise, with or without provision for carrying out the calculations based on such information and for transmitting the results of such calculations" (S.148).

The legislation therefore, focuses very firmly on giving powers to install equipment to detect storms and floods. Critically for the development of an integrated approach, the issue of flood warning dissemination was not addressed at the time and prior to 1996 reliance was placed on voluntary agreements between the Environment Agency (and its predecessors), police and local authorities. A number of reasons can be put forward to explain why the legislators chose not to address the issue of warning dissemination:

- the tendency to concentrate on technical issues only;
- a narrow understanding of the total flood warning process or,
- the issue was just side-stepped

The establishment of these voluntary arrangements for the dissemination of flood warnings can be traced to procedures that were drawn up in the 1960s between the then River Boards, local authorities and the police. In 1968 the Ministry of Agriculture, Fisheries and Food, which supervises flood defence, held a conference on flood warnings in order to clarify administrative roles and liaison procedures and to set down guidelines in this respect following severe floods during that year (Ministry of Agriculture, Fisheries and Food, 1968).

At the 1968 conference it was generally accepted that the technical capability for flood detection and forecasting lay with the River Authorities - the successors to the River Boards and the predecessors of the Water Authorities, the National Rivers Authority and the Environment Agency - through liaison with the Meteorological Office. It was also agreed that the River Authorities would warn the police who had the responsibility to warn the public. Local authorities would receive warnings either from the River Authorities or the police and might also warn the public. This liaison arrangement remained virtually unchanged until 1996, though precise arrangements varied locally. As Haggett (1997) notes however, at that time no one agency was given a lead role to co-ordinate activities across the function, the effect of which was to focus individual agency's activities on their area of interest and not on the performance of the system as a whole. This has inevitably resulted in inefficiencies developing across the interfaces of detection, forecasting and dissemination and response and this has had a negative impact on the integration of these elements.

Parker (1992) suggests that these informal co-operative agreements have worked well on some occasions in the past. It is evident however, that they began breaking down because of tightening resource constraints and growing concerns over legal liability. Attempts to tighten up and formalise the arrangements between organisations have been viewed very cautiously by some because of the resource and legal implications of entering into formal agreements.

In 1996, following a period of discussion with the key players, the Government decided to change arrangements by means of a Ministerial Direction under Section 5 of the Water Resources Act 1991. This requires the NRA and now the Agency to take the lead role in flood warning dissemination from the 1 September 1996 and to "take steps as appear to it to be reasonable and practicable to provide warning of any danger of flooding". Although the Ministerial Direction attempts to clarify the position with respect to flood warning dissemination, it is drafted in imprecise terms and gives the Agency a wide margin of discretion. This has implications for the introduction of integrated and consistent arrangements across the country. Nevertheless, it could be argued that the Agency would not be acting "reasonably" if it failed to introduce consistent flood warning arrangements across England and Wales.

The full text of the Ministerial Direction is reproduced below:

> "The Authority shall ensure that, with effect from 1st September 1996, there is maintained at each of its area offices, or at an alternative office designated by the Authority, a record in writing of the arrangements for the time being in effect concerning the circumstances in which the usual means by which and the persons or bodies to whom information will be transmitted (whether by the Authority or any other person or body) for the purpose of providing warning of any danger of flooding in the area for which that office has responsibility for flood defence matters.
>
> The Authority shall ensure that, before the arrangements referred to in paragraph 1 (including any significant variation in those arrangements) take effect, there is consultation with the bodies providing relevant emergency services in, and the local authorities for, the area concerned.
>
> The Authority shall take such steps as appear to it to be reasonable and practicable to provide warning of any danger of flooding in accordance with the arrangements referred to in paragraph 1 above".

Legal Liability

In recent years, and following flood warning failures, questions have been raised about the liability of authorities that are engaged in the flood forecasting and warning process. As Parker (1989) reports, there have been a number of cases brought to the civil courts that have attempted to find the agencies legally liable for inaccurate warnings or for not providing warnings at all. The specific tort law to which the agencies are most vulnerable are negligence and, to a lesser extent, liability for breach of statutory duty (Middlesex University, 1992). For example, in 1987 under the Robinson & Ors v. Cardiff City Council, Welsh Water Authority and South Glamorgan County Council case, residents claimed against the local authorities and the water authority in respect of property damage caused by a failure of the flood warning system for the River Taff in Cardiff in December, 1979. The warning system failed because of an absence of clear responsibility for disseminating warnings to the public. The Court found that both of the local authorities involved were liable for failure to warn the public. Two types of duty were specified:

> **prior duty,** that relates to the provision of reasonable steps to ensure concluded, effective and continuing flood warning provisions vis-à-vis flood endangered areas,
>
> **duty on the day**, that relates to the taking of reasonable steps to ensure communication of warnings to persons in flood endangered areas.

The Court considered that the local authorities failed to carry out both of these duties effectively and that the plaintiffs suffered damage due to the failure to issue warnings (Davies, 1987).

In 1992 Middlesex University examined in detail the legal framework governing flood warning in England and Wales and addressed the question of liability with particular reference to the then National Rivers Authority (though equally applicable to the Environment Agency). They consider that as the legislation granted only a power to the NRA to set up and operate flood warning systems, it is arguable that the NRA might not incur liability if it failed to provide any flood warning system at all. Problems might arise however, if the NRA sought to discontinue established flood warning systems without public notice. If the Authority chose to allow systems to wither away so that they became ineffective when needed they might well be deemed negligent. It might be argued that if the NRA exercised its powers and set up flood warning systems it then **assumed a duty** to operate and maintain such systems with care. The functions and responsibilities placed on the NRA by the Water Act 1989, and subsequently the Water Resources Act 1991, underline the fact that the Authority has a general duty to establish and maintain safe systems. The NRA had no coercive authority however, to require outside agencies, such as the local authorities and the police, to operate to any system it may wish to set up for flood warning purposes. Indeed, local authorities and the police have obligations to prioritise the use of their resources, obligations which they might consider override any commitment to the NRA. Nevertheless, Middlesex University suggested that the NRA would be unwise not to seek to maintain and, if necessary, improve its flood warning systems and that local authorities must be asked to continue to make an important contribution to these systems. Legal opinion also made reference to the general flood defence supervisory duty placed on the NRA. It was considered possible that this duty might place legal obligations on the NRA to provide flood warning systems. This opinion has yet to be tested in the courts.

It has already been mentioned that local authorities have sufficient power under the Local Government Act 1989 to incur expense in taking action to avert, alleviate and eradicate the danger in emerging or actual disaster situations. As Middlesex University (1992) report, they also have power given in the Civil Protection in Peacetime Act 1986 to use their civil defence resources in emergency situations. These provisions seem to be wide enough to enable local authorities both to take part in actual emergencies and in planning for them. They are only powers however, and local authorities may not be inclined to prioritise the use of these powers in relation to taking part in setting up and maintaining flood warning systems. On the other hand, the fact that they have other roles in flood defence, that might result in them incurring liability for allowing the emergency to arise in the first place (or permitting it to continue for longer than necessary), may be a considerable incentive for them to take part in the flood warning process. In practice, many local authorities produce detailed emergency plans that contain sections covering response to flooding and flood warning.

The situation of the police is more complex. As Middlesex University (1992) mention, their primary common law function is keeping the peace, however, a custom has grown up for the police to take overall command in emergencies. There has been litigation concerning the duty of the police to citizens in the performance of their duties. All cases have failed to establish that the police have any general duty to protect individual members of the public. Thus it seems unlikely that members of the public could attach liability to the police for negligent failure to act in respect of either flood warning or other emergency procedures related to flooding. It also seems improbable that the Environment Agency could get anything in the nature of an enforceable contractual commitment from the police to partake in emergency procedures.

The situation in the United States may point the way to future public attitudes in this country. As Drabek (1986) notes, there is a growing propensity to seek compensation through litigation in the United States if another party can be held responsible. There are signs that issues of liability pertaining to warning issuance or actions taken during an emergency will be introduced with increasing frequency in the American court system. Peoples' perceptions of natural hazards are changing and there is a tendency not to see them solely as acts of God. It is likely that such views will become more prevalent in England and Wales in years to come.

The institutional framework in England and Wales prior to September 1996

In England and Wales the principal national government department responsible for overseeing and supervising flood defence matters and determining flood defence policy is the Ministry of Agriculture, Fisheries and Food (MAFF). MAFF actively encourages the adoption of flood forecasting and warning schemes by allocating grants for the installation of flood monitoring equipment. The Department of the Environment, Transport and the Regions (DETR) also has a role through its supervision of the planning process and in Wales the National Assembly of Wales takes many of the executive decisions in relation to flood defence. At the regional level, flood defence on "main rivers" (the principal arterial rivers and their major tributaries) is the responsibility of the Environment Agency. The Agency is a non-departmental public body that has eight regional units that in turn are subdivided into twenty-six operational areas, all of which are based upon river catchment boundaries. The Agency is responsible for flood defence planning, implementation and monitoring and has a remit for both fluvial and sea flood defence. At the local level, local authorities (district and borough councils) have certain responsibilities for flood defence on some of the smaller non-main tributaries or "ordinary watercourses". In some rural areas farmers' co-operatives, known as Internal Drainage Boards, have powers to exercise general supervision over all matters relating to land drainage within defined internal drainage districts.

In the flood forecasting and warning chain of agencies, the Meteorological Office is often the first to be involved, providing a forecast of conditions that might lead to flooding. The Met. Office has agreements to provide the Environment Agency and other customers with warnings of heavy rainfall or sea conditions that may lead to flooding. It operates and maintains the Storm Tide Forecasting Service and the UK Weather Radar Network (jointly owned by the Met. Office and the Environment Agency) and provides tidal alerts, radar and satellite data to the Agency's Flood Warning Centres. Increasingly, the Environment Agency has demanded more quantitative precipitation forecasts, especially in urban areas, in addition to the more routine synoptic forecasts (e.g. Nimrod and the GANDOLF thunderstorm warning system). The Environment Agency has a key role in the flood forecasting and warning process and prior to 1996 this covered the following activities:

- the operation and maintenance of rainfall and river flow measurement networks
- rainfall and flow forecasting using models of varying complexity
- issuing flood warnings to the police for onward transmission to the general public, other emergency services, local authorities, utility companies, etc.
- recording the extent and impact of flooding
- operation of river control structures and securing flood defences
- ensuring watercourses are free of obstruction
- providing assistance to other agencies
- holding post-event evaluations

These roles were mainly restricted to main rivers, although the Agency has permissive powers to operate flood warning systems on any river.

In England and Wales the police have historically been an important agency within the flood warning dissemination chain. Although they do not have a statutory responsibility to pass on flood warnings received from the Environment Agency to the public or any other body, in practice they respond to emergency situations such as flooding. Prior to September 1996 their role was not only in emergency response and traffic management but also in warning dissemination and public notification. Because of the general lack of statutory duties on any authority to provide flood warnings, however, the police focused increasingly upon their legal position if warning arrangements failed for any reason. The police resisted attempts by the Environment Agency to establish more formal agreements to disseminate flood warnings and in general, the informal arrangements that had been in place since the 1960's were steadily breaking down. An example of this is in London where in recent years the Environment Agency has improved the identification of properties at risk and hence the ability to offer more targeted public warnings. The police were concerned that once information of this type was formally accepted they would be obliged to warn the identified properties whenever a flood warning was issued for the area concerned. The police were not willing to offer such a commitment in case they became legally liable if warning arrangements failed due to other operational pressures and accordingly refused to incorporate the property information into their operational procedures.

Because local authorities have powers to undertake flood mitigation works on ordinary watercourses, district and borough councils have permissive powers that extend to flood warning for such rivers. In practice, local authorities rarely operate flood warning systems. Apart from passing on flood warnings to the public in some cases, the role of the local authorities is mainly in the areas of public awareness, public defence, social services and post event clear-up operations. Although local authorities have powers to incur expenditure to avert, alleviate or eradicate the danger emerging from a flood, they have not been given an unambiguous statutory duty to prepare for and respond to peacetime emergencies such as floods. They find it increasingly difficult to find resources to prepare for flooding once funds have been allocated to their statutory duties in other areas. Just prior to September 1996, the Environment Agency had asked local authorities to confirm their role in flood warning response, but had experienced difficulty in gaining agreements because of the ambiguous legal position, and because local authorities feared legal liability being placed upon them.

There was no general agreement about how the mass media fitted into the emergency management communication process by carrying news and information about hazards such as flooding. The strengths of the media, namely their independence from government or other agencies and their ability to attract large audiences which regard them as reasonably credible information sources (Burkhart, 1991), were not fully appreciated. As a consequence, prior to 1996 the media's role in disseminating flood warning messages to the public was minimal, with at most some local ad-hoc arrangements in place. For significant flood events most of the agencies involved would issue press statements to the media, but mostly after flooding had occurred and without co-ordination. There was no concerted effort to involve the media and to win their confidence and at times this invariably resulted "in the needless arousal of the media's watchdog role of looking into possible wrongdoing and waste" (Burkhart, 1991).

Arrangements in the Thames Region prior to September 1996

In the Thames Region the importance of flood warning was given particular impetus as a consequence of the serious floods that occurred in 1968 when there was considerable damage to property in the Mole and Wey catchments, in the lower reaches of the Thames and in south London. As elsewhere in England and Wales, the institutional arrangements that have been in operation in the region were established in December of that year at the special MAFF conference convened in response to those floods. Essentially the detection and forecasting of floods has been carried out by the Environment Agency and its predecessors at varying levels of sophistication since 1968. Until 1974 this was undertaken in the Thames catchment by three different authorities, namely Thames Conservancy, Lee Conservancy and the Greater London Council (GLC). It was not until 1986 that this fragmented arrangement was addressed and the flood forecasting function for the entire Thames basin was integrated under one organisation, the Thames Water Authority. Since this time flood detection and forecasting has been operated for the catchment by the Thames Water Authority (until 1989), the National Rivers Authority (1989 to 1996) and now the Environment Agency.

In general terms, flood warning notices were issued by the flood forecasting agency (in its various guises) to the police. Typically, the warning message provided details of the river catchment likely to be affected, the warning severity, the local authority area in which flooding may occur and the places in those areas that are particularly at risk. On receipt of a warning it had been custom and practice for the police to disseminate notices to their own staff, the relevant local authorities and other emergency services, and ultimately the general public at risk of flooding. In some areas however, the local authority carried out the role of public warning through the operation of flood warden schemes. Indeed, in the London catchments formerly administered by the GLC, the arrangements for warning dissemination were changed following flooding in 1977, with the riparian London Borough Councils taking on the police's role of public warning (Haggett, 1981) (see Figure A3.1). The Thames Water Authority reversed this policy in 1986 however, following discussions with the Metropolitan

Police and the London Boroughs). From 1986 the Thames Water Authority issued direct warnings to just the 12 police forces in its area and relied totally on the police to onwardly transmit these messages to all other relevant organisations (see Figure 4..2, Chapter 4). Thames Water kept no record of the organisations that ultimately received its warnings from the police and considered that once the police had been notified its job was done.
One of the inherent difficulties with these arrangements was that there was a communication chain over which no one authority had control or a responsibility to ensure operational effectiveness, and this inevitably provided opportunities for misinterpretation and delay. The unclear statutory position and confusion over roles and responsibilities added to the air of uncertainty. In an attempt to minimise the effects of these and other difficulties, the Environment Agency and its predecessors attempted to improve inter-agency liaison in the Thames Region over a number of years. This was tackled in two main ways:

1. by holding annual seminars for police and local authorities to remind them of the flood warning arrangements in their local area

2. by producing detailed flood warning procedures which set out why and how warnings are issued to organisations and the public.

Although in general these initiatives assisted in the inter-agency liaison process, confusion still existed regarding public warning arrangements and concern over legal liability had become an increasingly important issue. In 1990 the National Rivers Authority attempted to clarify the roles and responsibilities of the key players in the Thames Region so as to allay confusion. The NRA's flood warning procedures were reformatted (NRA, 1990) to better present the arrangements and roles of all parties based on the understanding of the Authority. The NRA insisted that it was not attempting to impose duties on either the police or local authorities it was merely trying to better summarise arrangements based on existing practice. The NRA argued that as these arrangements had not been challenged in the past, it was reasonable for it to assume that they had the agreement of all concerned. The NRA circulated the revised procedures and gave notice that they would be discussed at their annual flood warning seminars during that year.

A number of local authorities, at county and district level, and police forces reacted strongly to the NRA's initiative, especially in Hertfordshire and Berkshire. There were two main concerns articulated by Hertfordshire County Council in 1991;

a) "that the document produced by the NRA lays down and implies duties and responsibilities upon the police and local authorities which have no statutory basis, and although they may previously have been assumed, their continued viability was open to question."

b) "that such a document with the profound legal, financial and resource implications implied to the parties mentioned within, should have been produced without the prior consent of the aforementioned parties." The annually held flood warning seminars were considered to be an inappropriate forum for consulting on a document such as flood warning procedures.

Several district councils wrote to the NRA in 1990/91 and challenged the right of the Authority to set out the roles and responsibilities of other agencies in their procedure document and questioned the legal basis on which this was undertaken. The NRA's assertion that it was articulating current practice was not excepted. It was felt that the arrangements agreed in 1968 were no longer valid and did not take into account the severe financial and resource restrictions now placed on local authorities and the increasing risk of litigation following the "Cardiff Judgement".

At this time there was an attempt at a national level to clarify the respective roles of the NRA and police. The Director of Operations of the NRA wrote to all chief constables in August 1991 and stated that the role of the NRA was "to make forecasts, to advise, to monitor and to implement flood defence operational activities on the ground". The role of the police was "to disseminate warnings to the public on receipt of such advice from the NRA". Guidance was taken from the "Government Response to the Third Report of the Welsh Affairs Committee, Session 1989/90: The Breach of the Sea Defences of 26/27 February along the North Wales coast". The chief constables were given the opportunity to give their response to these definitions.

Following a period of protracted discussion between a number of police forces, local authorities and the NRA at a regional and national level, several authorities gave notice that they would be raising the issue with the relevant government departments. They generally felt that they were unable to resolve the matter with the NRA to their satisfaction. The NRA maintained that it had a responsibility to help clarify arrangements and ensure that the whole flood warning dissemination process worked properly. If, however, local authorities wished to challenge current practices due to resource constraints, then the NRA made it clear that it would encourage government intervention to resolve the issue. A number of authorities, notably Hertfordshire County Council, subsequently pressed the Government for a resolution of this matter which in turn gave weight to the establishment of the MAFF working group to re-examine the whole question of flood warning dissemination in England and Wales.

The institutional arrangements post September 1996

In 1993, the Ministry of Agriculture, Fisheries and Food (MAFF) identified a number of difficulties with the existing arrangements for disseminating flood warnings. The four main areas of concern were;

1. resourcing difficulties for the police and some local authorities lead in some cases to a desire to reduce involvement in the transmission of flood warnings

2. a realisation that the general public was confused about the roles and responsibilities of the various bodies involved and that they generally had a low level of awareness of flood risks

3. some evidence that development in flood plains is exacerbating storm water run-off thus increasing the need for accurate and timely river flood warnings

4. evidence that in a significant number of cases flood warnings can fail to reach those for whom they are intended, suggesting that new technologies and new methods of dissemination need to be explored.

In an attempt to address these issues and review the operation of the present arrangements, MAFF convened a national working group, known as the Flood Warning Procedures Group (FWPG). A number of organisations were represented including, the Welsh Office, the Home Office, the NRA, the police and each of the local authority's national associations. The FWPG was tasked primarily with considering ways in which the dissemination of warnings could be improved. It was judged that this could be achieved by; clarifying roles and responsibilities, simplifying the chain of communication, and through the use of technology.

The key recommendations of this Group affecting institutional and legal arrangements are set out below, along with an assessment of their likely impact on future integration of flood warning systems, and where further work is needed.

Designation of a lead agency

One of the first conclusions made by the FWPG was that one agency should take the lead role in relation to flood warning arrangements. This recommendation is likely to have a positive effect on integration in that one agency will be able to co-ordinate planning and management activities across the function and with all involved parties. However, the Group experienced some difficulty in agreeing which agency should take on this role. The unclear statutory framework, the vulnerability to litigation and the economic cost all mitigated against an early decision on this matter. Nevertheless, a revised national system was proposed and the newly formed Environment Agency was given the lead role (see Figure 4.3, Chapter 4). This was felt to be a sensible arrangement as the Agency already had a general supervisory duty for all matters relating to flood defence in England and Wales. Its powers were considered to be flexible under present legislation and could be used in ways that would suit local circumstances and had the potential to fit in with contingency plans worked out with local authorities, the police and others. It should be noted however, that the Agency was not provided with additional financial resources to carry out this role and had to re-prioritise its existing flood defence programme to enable these arrangements to be implemented. It could be argued that the Agency's senior management was not fully briefed as to the potential risks of taking on such a role without adequate resources. These risks were fully exposed during the Easter 1998 floods.

Changes to legal arrangements

It was judged by MAFF that the proposed arrangements would not require a change to primary legislation and that this could be formalised by means of a direction from Ministers. Accordingly, in 1996 the NRA was issued with a Ministerial Direction by MAFF and the Welsh Office under Section 5 of the Water Resources Act 1991. The Direction instructs the NRA and now the Environment Agency to exercise its permissive powers in relation to flood warning provision without placing a specific duty on the Agency. Specifically, the Direction requires the Agency to maintain records in writing of the arrangements by which flood warnings are disseminated and for these records to be drafted in consultation with local authorities and the emergency services. It also requires the Agency to take steps as appear "reasonable and practicable" to provide flood warnings in accordance with the written plans. The Direction has been given however, within the context of the existing institutional arrangements and, as has been discussed in Chapter 4, these are seriously fragmented in a number of areas. There has been no attempt to fundamentally change these arrangements to minimise fragmentation and facilitate integration.

Nevertheless, the Ministerial Direction is likely to have a positive influence on integration but this must be tempered by the contextual situation in which it has been issued. Although statutory duties are not conferred on any organisation however, the Direction does attempt to clarify the role and responsibilities of the lead agency and by doing so gives that agency a greater degree of legitimisation with the other authorities involved in the process. An obligation is also placed on the Environment Agency to clarify the roles and responsibilities of other organisations in a written plan, which in practice may be difficult to achieve. The Agency can only accomplish this through negotiation, a process its predecessor authorities have attempted in the past with mixed success. Although the Agency will have the final say in relation to the content of the plan, it will not have the right to impose any duties on other organisations who will be working to their own operational agendas. To help facilitate inter-agency liaison the FWPG drafted "Circulars of Understanding" that have been forwarded to each local authority and police force in England and Wales. The Circulars attempt to clarify the principles of the new working arrangements as agreed and recommended by the FWPG and set out the roles and responsibilities of the key players. It remains to be seen, therefore, how individual organisations will react to these arrangements and whether they will have the anticipated positive influence on integration.

Institutional liaison

As was mentioned in Chapter two, to encourage the likelihood of integration and co-operation between organisations, it is important to have in place processes and mechanisms to facilitate bargaining, negotiating and mediating. Inter-organisational liaison groups have often been lacking in the flood warning field with the result that organisations have not been fully aware of the actions of others which can lead to misunderstanding and suspicion. With this in mind, the FWPG reached agreement on the respective roles of the Agency, police and local authorities and circulars were issued by the Association of Chief Police Officers and by the Local Government Association in 1996 containing the following working arrangements:

1. The Agency will in partnership with the police and local authorities ensure plans are in place to disseminate flood warning messages to the public, businesses and other statutory bodies and will take the lead role in arranging for the dissemination to take place.

2. The police and local authorities will, in consultation with the Agency at local level, ensure plans are in place to respond when flooding occurs in known flood risk locations.

3. Proposals will not affect the arrangements that currently exist for taking action when flooding occurs. The police and local authorities will continue to exercise their existing role as explained in the Home Office publication "Dealing with Disaster".

4. Adopt the agreed framework that reiterates the need for police and local authority involvement in flood warning dissemination where there is a pressing locally agreed need to do so.

The Home Office publication, Dealing with Disaster (Home Office, 1997), embodies the current government guidance on disaster response. It advocates an integrated approach to planning and management of major incidents in which, without rigid prescription of specific roles, the relevant institutions can plan and act together. A flexible use of all available resources is encouraged with effective pre-planning and clear command and control throughout a major incident. In outline every organisation, including the utilities, British Waterways, and the media, is responsible for preparing effective plans for responding to disasters within the limits of its own responsibilities and resources. The arrangements described in this document and the agreements referred to above, comprise the framework in which organisations are supposed to operate during floods.

The success of any nationally agreed procedure lies in its perception and implementation at the local level. The requirement to have written flood warning plans in place will encourage organisations to consult and liaise in a more formal manner and this will be bolstered by the establishment of consultative fora for each county and metropolitan area in England and Wales for this purpose. The Environment Agency has actively set out how it expects to approach this issue through the establishment of Flood Warning Planning Groups. It has issued instructions to each of its regions to ensure that all local authorities and emergency services are invited to attend these groups and are actively encouraged to attend. A standardised list of other operational organisations has been drawn-up and it is a requirement that these authorities are also invited to the planning groups. Because the number of organisations that have a role to play in flood warning activities is so large and arrangements are so fragmented, it places a significant demand on those within the Agency tasked to undertake liaison work. A more integrated institutional system would place fewer demands on the lead agency and would be significantly easier to administer.

Nevertheless, these new liaison arrangements are likely to be beneficial to integration. Success is dependent however, on the co-operation of the agencies involved and recognition and acceptance of the Environment Agency's lead role, particularly at the local level. Difficulties may arise when the Agency attempts to clarify the roles and responsibilities of the individual organisations involved in flood warning dissemination. Different authorities will almost inevitably have objectives which conflict with those of the Agency and it is important that a balance is struck between obtaining clarity of objectives and building in flexibility. Some organisations, for instance, may not place particular priority on fluvial flooding alongside other potential emergencies. It is not desirable to unreasonably constrain organisations and some careful generalisation in objectives may be needed to resolve this issue. The danger here is that if flexibility and generalisation are taken too far then plans become ineffective and confusion and misunderstanding will remain.

Political commitment and organisational climate

For an integrated approach to succeed there needs to be a strong political commitment to the policy, backed-up by the instillation of a positive climate and culture within the organisations directly involved in its implementation. It is true to say that previous attempts to introduce a more integrated approach to flood warning, instigated by the National Rivers Authority, have suffered from a lack of such commitment and a rather parochial attitude by other organisations.

The difference with the new arrangements is that on this occasion the pressure for change has come from a government department. Indeed, MAFF have elevated the provision of "adequate and cost-effective flood warning systems" to the highest priority (MAFF, 1993). It has indicated that this project should be funded before other flood defence work and has agreed to grant-aid a significant amount of the expenditure at a special rate of 50% for a limited period. The test will be whether this degree of commitment will continue in the longer term. The relationship and degree of influence that MAFF has with other organisations involved in the response to flooding however, is particularly diffuse. The commitment of other key government departments to a policy of integration in flood response is not so resolute and this will influence the reaction of organisations such as the police and local authorities to such a policy.

With regard to organisational climate and culture, the degree of dedication shows signs of variation. Both MAFF and senior management in the Environment Agency have given firm backing to the introduction of an integrated flood warning system in England and Wales and have sent positive signals to those within the organisation responsible for its implementation. A national project group has been instigated and a national project manager appointed to oversee implementation and ensure consistency between the eight regions. This is to be further supported by the establishment of a National Flood Warning Centre by the Agency in 2000.

In other organisations a rather less positive climate is common. This situation is not helped by the fact that MAFF, despite its many pronouncements for the need for integration, has very little influence with these organisations to deliver such a policy. This is illustrated by the fact that the police are actively trying to disengage themselves from the responsibilities of flood warning dissemination and are looking to off-load as many activities as possible to the Environment Agency. Surrey police for instance, gave notice that they wished to withdraw from **all** flood warning dissemination activities, including warning their own police stations! They reconsidered this position after discussions with the Environment Agency and subsequently fell in line with national agreements. In general, the local authorities have a more positive approach to the new arrangements. Concern over legal liability, which is still upper-most in the minds of the police, has lessened in the local authorities. There is almost a sense of relief that the Environment Agency is taking the lead role and by implication putting itself in the front line with regard to legal liability. The local authorities seem to be more comfortable in a supporting role and are generally approaching this position in a positive way. Many county councils for instance are co-ordinating liaison with the district councils and actively helping the Agency in the drawing up of flood warning plans.

Implications for legal liability

As discussed above and in Chapter 4, concern over the question of organisational liability has hindered inter-agency co-operation in recent years and ultimately the furtherance of integration. To minimise the effects of perceived liability on integration it is important that the organisations involved clarify their position and tailor their policies accordingly.

Following the issuance of the Ministerial Direction, the Environment Agency has sought legal opinion on the question of liability, the main conclusions of which are likely to be relevant to other organisations involved in the process (Environment Agency, 1996c);

1. there is a judicial reluctance to impose a common law duty of care on an authority exercising a statutory discretion.

2. the Agency has the power to provide and operate flood warning systems and general powers to do anything that in its opinion may facilitate carrying out its flood defence functions. Because of the general nature of these powers it is hard to envisage circumstances in which a successful challenge would be made if the Agency failed to forecast or disseminate flood warnings, unless it could be proved that it had acted in a negligent manner.

3. only in exceptional circumstances where particular arrangements have been established and a particular relationship exists between the Agency and a member of the public in relation to flood warnings, may a duty of care be found to exist. It is unlikely that giving broadcast warnings or warnings over a loud hailer or public address system or siren warnings would be enough to establish such a relationship. However, direct dial telephoning and any direct contact (such as knocking on peoples doors) may be enough to establish a duty of care, particularly in areas of repeated flooding where a pattern of such direct contact has been established

4. the Ministerial Direction does not give rise to a cause of action where one would not otherwise have existed. The most that it could do would be to colour the approach that a court might take on whether a common law duty of care existed and whether there had been negligence. However the requirement to provide warning of the danger of flooding is in such general terms that in practice it is difficult to see how it could have this effect.

5. the Direction covers three matters - the maintenance of records of the arrangements for flood warnings, consultation on proposed arrangements with emergency services and local authorities, and the Agency's duty to take steps to provide warnings in accordance with these arrangements. No requirement is imposed as to what the arrangements should include, and there is no requirement to make arrangements which are not reasonable and practicable and resource limitations would be material in this respect. The form and content of the records is a matter for the Agency and there is no requirement that the arrangements should be consistent across the country nor that there should be a warning prediction capability of uniform standard in all areas. In all these respects the Agency has a discretion.

The Environment Agency has acknowledged the risks identified above and has decided to pursue its current policy of providing an enhanced flood warning service from September 1996. Other authorities have also sought legal opinion on this issue and their response is varied. There is still a general nervousness with respect to legal liability and this is motivating the police in particular to distance themselves from public warning arrangements. However, many police forces and local authorities believe they have a moral duty to assist the public in times of flood and judge that in-action in such circumstances could be as, or even more litigious than action that is ruled to have failed in some way. Norfolk Police for instance have decided to continue to offer a public warning service on receipt of RED flood warnings from the Agency, and will disseminate warnings to local authorities and utilities as before. It is also clear that the Environment Agency's new role will go someway to reduce their fears of legal liability and thereby ease the process of integration.

Implementation of the new arrangements in the Thames Region

The implementation of the new arrangements began in October 1995 with initial discussions with the police and local authorities (see Figure A3.2). Some difficulty was experienced in getting the police to formulate a clear policy with respect to flood warning. It was clear that this issue was not a high priority especially with their senior management and with a number of forces it took several attempts before a policy statement could be obtained. It also proved difficult to acquire specific written details of the current warning arrangements from each of the 13 forces in the Thames catchment. Some forces stated that they did not issue public warnings even though police involvement in previous flood events was well documented. Others indicated that ad-hoc warning arrangements were in existence but they were unable to supply specific details of properties warned. When particulars were forthcoming and subsequently checked many of the contact details were out-of-date and a number of recipients indicated that they rarely received warnings if at all. In general therefore, the police seemed keen to pass warning responsibilities to the Environment Agency but were unable or unwilling to supply sufficient information to make this transfer easy. This underlined the poor state of public warning arrangements in the Thames Region.

The local authorities on the other hand are more positive and willing to work in close liaison with the Agency to make the new arrangements work effectively. The county councils, possibly keen to establish a role in the process, have helped co-ordinate liaison with the district and borough councils. This generally worked well but with two notable exceptions. In Berkshire, the move towards unitary status for the districts meant that the county council had lost its authority and the previously close relationship had become strained. With the abolition of Berkshire County Council, liaison activities across the County are now co-ordinated by a lead district council. In London, the already unitary London Boroughs value their independence and resent any interference with their affairs. So when the London Fire and Civil Defence Authority (LFCDA), again seeking a role, volunteered to assist the Environment Agency with liaison it was met with some hostility from the boroughs and was not pursued and a possible process for organisational integration was lost. The London Boroughs have arranged themselves into 5 emergency planning groups that now form the basis for liaison on flood warning matters with the Agency. This is in contrast to other counties where a single flood warning planning group has been established.

Figure A3.1: Non-tidal flood warning arrangements for the London Excluded Area (after Haggett, 1981).

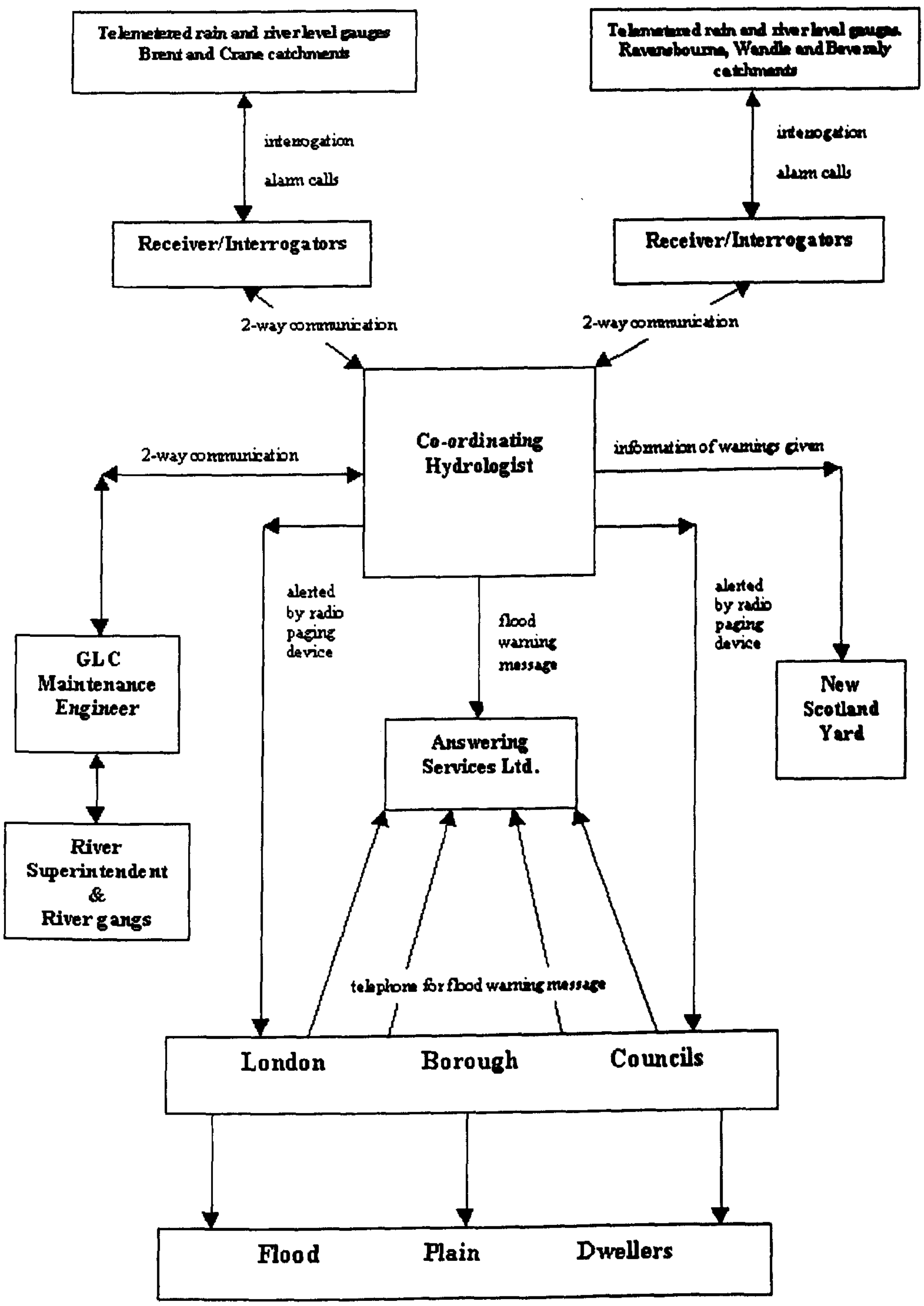
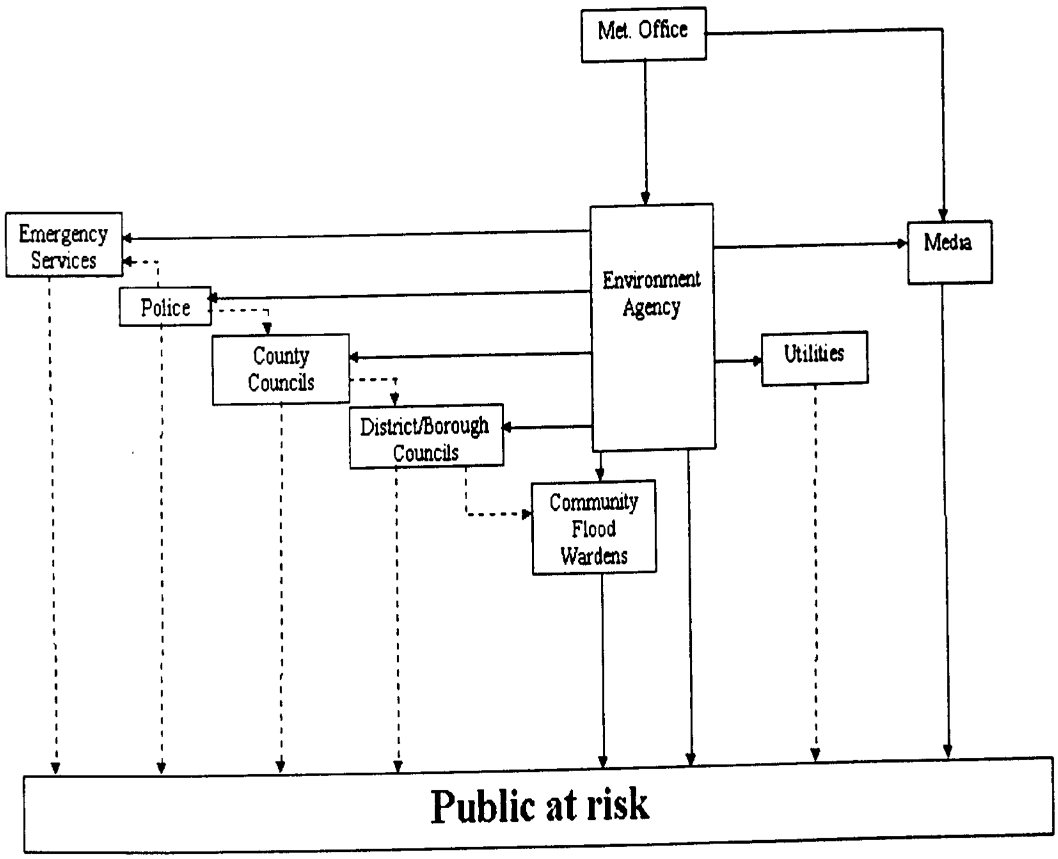


Figure A3.2: Flood warning arrangements in the Thames catchment post September 1996.



APPENDIX 4

Appendix 4: Flood duty officer questionnaire

Name:...

Age: 20-25....., 25-30....., 30-35....., 35-40....., 40-45....., 45-50....., 50+.....

What is the best method for minimising possible inconsistencies between the service offered by individual flood duty staff? Please rank these options.

1. Regular informal meetings to discuss issues
2. Formal training sessions
3. Multi-agency exercises
4. Use of expert systems
5. Better understanding of the needs of warning recipients
6. Standardised actions formally written down
7. Consistent instruction
8. Work shadowing with other duty officers to understand how they act in given situations
9. Other – please specify..
   ....
   ....

Rank: ...../, .../, .../, .../, .../, .../, .../, .../

As a duty officer you may be presented with information in which you may have low confidence (e.g. an extreme rainfall measurement/forecast or rapidly rising river level at just one station). In this situation do you:

1. Dismiss the information as being wrong or incorrect and take no further action.
2. Act immediately on the information presented, despite its uncertainty, to ensure the issue of a timely warning
3. Delay action until the situation becomes clearer
4. Proactively seek confirmation from another source and only act when you are certain
5. Other – please specify..
   ....
   ....

Answer:...

Your intuition as a duty officer may be at odds with the environmental information that is being presented to you via the detection system. It might not "feel right". In these circumstances do you:

1. Dismiss your feelings and only act on the factual information presented to you
2. Go with your intuition and reject the information presented to you and take no further action
3. Delay action until the situation becomes clearer and you are more certain (wait until you see "the whites of its eyes"!)
4. Proactively seek confirmation from another source and only act when you get confirmation
5. Other – please specify...
   ....
   ....

Answer:..

You are in a situation where a colleague considers that your interpretation of events is incorrect and suggests a different course of action than you were going to take. Do you:

1. Ignore what you colleague says and stick to what you think is the right course of action.
2. Bow to your colleagues better judgement and follow his/her advice
3. Seek the advice of a third party
4. Other – please specify...
   ....
   ....

Answer:..

When you are considering issuing a flood warning what is uppermost in your mind:

1. Getting the warning out in time
2. Getting the location (reach) of the warning correct
3. Concern about issuing a false warning/ your future credibility
4. Ensuring that the warning gets to the public at risk
5. Ensuring that the warning recipients understand the message and act appropriately
6. Other – please specify...
   ....
   ....

Answer:..

Do you think the format of flood warning messages sent to the public and response agencies should be:

1. Standardised for all recipients to ensure consistency and ease of delivery
2. Variable and tailored to reflect the range of different audiences and community groups
3. Other – please specify...
....
....

Answer:...

What information do you think the public most wants in a flood warning message?

1. Time of the onset of flooding
2. How long will the flooding last
3. Information on what to do
4. How severe will the flooding be
5. The depth of flooding
6. Where can they get sandbags
7. How long will flooding last
8. Is this warning real
9. Is evacuation necessary
10. Where to go for help

Please rank the options:

Rank: ...../, .../, .../, .../, .../, .../, .../, .../,...../, .../

Which approach to public warning are you most comfortable with?

1. A technology-based warning dissemination system capable of relaying consistent, pre-recorded and standardised messages, with a monitoring system capable of recording when messages where issued, to whom and whether they were received or not.

2. A community-based warning dissemination system that is reliant on local people passing on verbal warnings to their neighbours and friends, with a monitoring system dependent on feedback from the community.

Answer ....

Thank you for you co-operation.