

1998 Easter Floods

Final assessment by the Independent
Review Team – Volume 1

EASTER 1998 FLOODS

Volume I

**Report by the Independent Review Team to the Board of the
Environment Agency**

**Mr Peter Bye, Chairman
Dr Michael Horner, Independent Technical Advisor**

Submitted 30 September 1998

INDEPENDENT REVIEW OF THE EASTER FLOODS 1998

MEMORANDUM

30 SEPTEMBER 1998

To the Chairman and Board of the Environment Agency

Final Report

You appointed us to provide the Board with an independent assessment of the performance of the Environment Agency during the exceptional flooding that swept through large areas of central and eastern England and parts of Wales at Easter. You received a preliminary report on 31 May. We now present our final report for your consideration.

Despite the expectations of many people, especially the victims of the floods, that we could or should do more, we have kept to the tasks outlined in the Agency's terms of reference. Even those more limited objectives have tested the abilities and stamina of a two-person team. We have visited and/or studied over seventy sites that were significantly flooded, meeting with hundreds of people who were affected by the floods as victims, members of the emergency services, local government officers, elected representatives, Agency staff and interested observers. We have considered more than two hundred reports and letters expressing views and providing valuable local information. The research community has provided assistance with relevant abstracts and summaries of work in progress.

The Easter floods severely tested the defences and warning systems for which the Agency is responsible. Rivers swollen by torrential rain, not experienced in living memory in many places, overwhelmed arrangements designed for less extreme conditions. Apart from specific weaknesses cited in this report, the Agency's policies, plans, and operational arrangements are sound. As we were reminded by first-hand evidence, flood risks can be reduced but they can never be eliminated. With limited resources, protective measures for rare events must be prioritised against more immediate needs. We are satisfied that staff did their best in extreme circumstances within the limits of Agency guidelines and resources.

The Review Team has concluded, however, that there were instances of unsatisfactory planning, inadequate warnings for the public, incomplete defences, and poor co-ordination with emergency services, that fell short of the Agency's own demanding performance standards.

Environment Agency staff have responded to our requests for detailed information and explanations, arranged visits and meetings, and provided efficient administrative support. We wish to thank them all for their ready help, openness and courtesy.

We acknowledge with gratitude the assistance of officers from local authorities, police forces, fire brigades, and other emergency services who offered evidence and constructive recommendations. Our special thanks and respect are reserved for the victims of the floods and their families whose dreadful experiences illustrate the real lessons for all those who direct or deliver flood defence services.

For the sake of everybody who lives in a flood risk area, and to assist the Environment Agency to do even better in protecting people and property, we submit our detailed findings for your careful consideration and urgent action.

Peter Bye, Independent Chairman

Dr Mike Horner, Independent Technical Advisor

ACKNOWLEDGEMENTS

The purpose of this review was to assess the performance of the Environment Agency before, during and after the Easter floods. Local authorities, emergency services and other organisations also were involved, directly and indirectly in the response to the floods. We had no remit to examine their activities although they offered information and responded to our questions. They have, however, not been offered the opportunity to read a draft in order to correct any inadvertent factual errors, as this is a review commissioned by the Environment Agency.

Many individuals and organisations gave evidence or provided personal experiences that assisted the Review Team. Restrictions of space alone meant that not every item could be mentioned and some contributors have received only a routine acknowledgement for their efforts. We regret that we did not have time to provide specific and detailed replies to every contributor.

We are most grateful, nevertheless, to everyone, particularly the many victims of the floods, who met us, or who sent reports and letters. Several colleagues were asked, sometimes at short notice, to provide research, technical advice, or support. In the time available, we have tried to do justice to your generous help in this final report. Inevitably, not everyone will find the answers to all their specific questions. We have attempted an objective and balanced assessment of the evidence relevant to our terms of reference. It will be for others to judge how far we have succeeded.

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VOLUME II

ENVIRONMENT AGENCY'S FLOOD INCIDENT REPORTS

1. FINDINGS

1.1. Overview

Sustained heavy rain stretching across central England and into Wales brought rivers into flood throughout these areas on Thursday 9 April and Good Friday 1998. Rainfall varied from place to place but was exceptionally heavy and prolonged over Warwickshire, Northamptonshire and northern Oxfordshire. As a consequence, the most severe river flooding occurred in these areas with serious but lesser events elsewhere in the Agency's Anglian, Midlands, Thames and Welsh regions.

Between Maundy Thursday and Easter Day, many thousands of people were severely affected by the floodwaters. Estimates of insured and uninsured losses indicate £350m and are still rising. Whatever the final figure, one way or another those accounts will eventually be settled. The much greater personal costs of the floods will continue to be borne long after the events by the flood victims. Because experience suggests that the testimony of the victims of disasters is too soon forgotten, we have included in this report some of the vivid and sad stories recounted to us in meetings and correspondence.

The Review Team has amassed a wealth of substantive, circumstantial and anecdotal evidence about the Agency's performance at Easter. These findings and the detailed presentations in Sections 3 to 8, taken together, provide our best assessment as requested by the terms of reference. Any attempt to reduce such a complex series of circumstances to one overall evaluation is unsafe. Over simplification would not do justice either to the Environment Agency's determination to learn from experience, or to the people who provided evidence.

Those who decide, nevertheless, to draw headline conclusions from the Review, should exercise caution. First, this was not a forensic investigation and the evidence is variable in quality. Secondly, with a fixed or over-stretched budget, most improvements can only be made if other desirable projects are shelved. Thirdly, the Agency's regional teams operate with considerable autonomy within national policy frameworks so that assessments of one region's performance should not be taken as an evaluation of them all. Finally, by commissioning the review, the Agency has responsibly laid open its flood defence performance to public scrutiny and criticism. Any weaknesses should be exposed for correction, but these should be weighed against the Agency's performance across its extensive environmental portfolio.

Our findings structured in accordance with items (a) to (f) of the terms of reference are presented in Sections 1.3 to 1.7. They are summarised below.

(a) Extent and severity:

Flooding in the catchments of the Leam, Avon, Nene, Great Ouse and Cherwell was, in many places, the most severe ever recorded. The extents and severities of the flood incidents were, in general, reliably established. Consideration should be given, nonetheless, to modifying the conceptual basis for flood plain mapping, strengthening the scientific approaches and achieving greater national consistency, as explained in Section 1.3. The Agency's performance on assessing extent and severity was satisfactory.

(b) Issue of warnings:

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. A problem of fundamental importance is the unrealistic expectation arising from the way the Agency presents its warning services to the public. Attention should be given to this issue and to the other deficiencies, identified in Section 1.4, in a radically modified strategy for improving flood warning performance. The Agency's performance on issuing warnings was, on average, unsatisfactory.

(c) and (d) Emergency response:

Emergency planning and preparations by the Agency, with few exceptions, successfully ensured the operation of main river defence systems. Late issuing or absence of warnings hindered response in some places. The Agency should lead a procedural review to bring about better concerted response from all organisations and address the further weaknesses described in Section 1.5. Assessed across the affected areas, emergency response by the Agency was satisfactory in exceptionally difficult circumstances.

(e) Standards of defence:

Flood defences were generally in good order prior to Easter and there were no structural failures during the floods. At defended locations, inundation resulted from flood severities exceeding design standards hitherto regarded as adequate. Deficiencies in the condition or operation of defence systems did not cause, but may have added to, flood extents and depths. The Agency should examine the consistency of its general supervision of flood defence and the other problem issues described in Section 1.6. Although development on flood plains is now better controlled, caravan sites are exceptionally vulnerable and licensing must include arrangements for defence against and response to inundation. With several serious exceptions, Northampton in particular, the Agency's performance on standards of defence matters was satisfactory.

(f) Other factors:

The Agency should review the organisational, management and investment justification issues identified in Section 1.7 (and reinforced by the report of the Agriculture Select Committee), to establish potential for improving efficiency and effectiveness in the provision, operation and maintenance of flood warning and defence.

1.2. Experiences of flood victims

“On Good Friday 10 April 1998 I was forced to leave my home of some twenty plus years because of flooding. I am now, at the age of 78 years, having to seek alternative accommodation and deal with the many difficulties of insurance claims to rebuild and refurbish my home. The flood water, which I was told was polluted, rose rapidly to a depth of about 18”-24” and I had to be evacuated from my home by boat, this in itself caused me great distress, which added to my history of poor health caused me to suffer from shock.” Letter from Mrs E.H., Worcester

Placing on the public record the experiences of those who were worst affected is justified for itself. The ‘victims’ experiences are made even more relevant when, according to the Environment Agency’s own flood defence and warning policies, protection of life and property is the first priority. Evaluation of these experiences must be a key factor in any assessment of the Agency’s performance. They are described more fully in Section 3.4.

Five people died directly or indirectly as a result of the floods. Many people were, without warning, put in fear of death or serious injury. They lost their homes and personal possessions, suffered massive disruption to their lives and livelihoods, and some are still without permanent homes six months later. Some victims are experiencing ill health, chronic anxiety and other symptoms of traumatic stress. Some of these experiences can be attributed to weaknesses in the planning and delivery of flood defence and warning policies, and even taking into account all the mitigating circumstances described in this report, the Environment Agency did not achieve its own performance standards.

1.3. Assessing extent and severity

From the examination described in Section 4 of the Agency’s work on assessing the extent and severity of the flooding (item (a) of the terms of reference), we concluded that:-

- (1) The Easter floods were the worst on record at many locations in an area of some 5000 square kilometres, bounded by Bedford in the east, Evesham in the west, Peterborough in the north and Oxford in the south. The estimated annual probabilities are in the order of 1.3 per cent and as low as 0.6 per cent (return periods of between 75 and 170 years). Beyond this central zone of the affected area, the floods were damaging, but less exceptional, with estimated annual probabilities from 5 per cent down to 1.3 per cent (return periods of 20 to 75 years).
- (2) National guidelines on flood probability estimation should be prepared for use by the Agency and its consultants. (These should be based on the Flood Estimation Handbook that the Institute of Hydrology has under preparation).
- (3) National guidelines on computational hydraulic modelling should be prepared for use by the Agency and its consultants. (These should limit computational modelling to situations where theoretical analysis is valid and sufficient data are available for proper calibration and verification).

- (4) Alternatives to the present approach to Section 105 flood plain mapping, which take into account the hydrological and hydraulic uncertainties, should be investigated, as explained in Section 4.6.
- (5) The contract terms for the engagement of consultants on specialist computational modelling should be changed in two respects to bring them into line with those for consultants' services on other aspects of flood defence:
 - responsibility for adopting a scientifically sound approach should be placed on the consultant;
 - professional indemnity insurance should be required in an amount appropriate to the possible consequences resulting from the use of unsound science or incorrect analysis - £5m to £10m cover on an each and every claim basis would appear appropriate.
- (6) Hydrometric standards should be enhanced to ensure that:
 - raingauge coverage is adequate in key catchments;
 - the siting of flow measuring and telemetry equipment is above likely extreme (0.5 per cent annual probability - 200 years return period) flood levels;
 - at least one station in each sub-catchment, associated with a significant risk area, is capable of measuring extreme flood discharges.
- (7) External experienced professionals should be used to supervise the work of inexperienced Agency staff, where none are available in-house. The appointment of individuals as national expert advisors on an on-call basis may be appropriate for selected topics.

1.4. Issuing of flood warnings

From the examination described in Section 5 of flood warning work (item (b) of the terms of reference), we concluded that:-

- (1) The Agency is perceived (partly because of the way flood warning services are presented in its literature) as having wider ranging responsibilities than it actually performs, or is likely to be resourced to undertake in the foreseeable future. Action should be taken to establish a more realistic understanding of capability.
- (2) The majority of the people affected by the Easter floods did not receive any form of direct warning. This was because their towns and villages had not been identified as high risk defended and undefended locations. The flooding experienced was damaging and dangerous, particularly where defence systems were in place. The Agency should give urgent consideration to providing some form of warning service so that these areas are alerted when next at risk.

- (3) There are marked organisational, management and technical differences of approach to fluvial flood forecasting and warning in the regions. Greater national consistency is needed, based on best practice, in order to improve efficiency and effectiveness. Identification of current best practices and relevant research should precede progressive movement towards an optimum national approach.
- (4) Early action is required to find and introduce new and more effective ways of establishing and sustaining, at a much higher level, flood awareness and response by communities on flood plains, including:-
- Giving greater attention to the human and social aspects of warning message construction, dissemination and encouraging effective responses.
 - Establishing an alternative to the present system of colour coded warnings (indicative of the likely extent of flooding) which are wrongly interpreted by most people.
 - Adopting methods used in other countries, such as: flood markers on telegraph poles, lamp posts and buildings; reminder messages in rate notices; records of flood history in title deeds; and articles and advertisements in the media.
- (5) The principle of a series of escalating safeguards should be built into the flood monitoring procedures. These should comprise:-
- Pro-active monitoring of weather conditions, radar and forecasts on a day to day basis and throughout the day.
 - A live suite of radar display screens (one each for single site, Nimrod measured and Nimrod forecasts) where staff can regularly observe weather systems on a day to day basis.
 - Providing Duty Officers with the previous day's rainfall at the start of each day.
 - Receipt of Heavy Rainfall Warnings.
 - Telemetry monitoring of river and rainfall thresholds (measured and forecast) which initiate detailed active monitoring.
- (6) Flood forecasting data networks and telemetry should be reviewed to:-
- Improve the rainfall and riverflow stations in number, location and design for flood monitoring and forecasting.
 - Provide rainfall data in real-time to neighbouring regions.
 - Provide rainfall data in real-time to the Met Office to enhance calibration of the radar and provide Met Office and Agency staff with the same data.
 - Obtain, based on completed R&D work, real-time soil moisture data.
 - Provide soil moisture data in real-time to the Met Office.

- (7) The Agency should consider:-
- How any early awareness of severe weather recognised by the Met Office Chief Forecaster could be fed through to regions more effectively as guidance to keep a close watch on the developing situation.
 - Standardising the weather monitoring and forecasting services provided to regions (based on the best practice outlined in Section 5 and Appendix D).
 - Including, in the above arrangements: Heavy Rainfall Warnings, tailored to specific catchment and flood warning zone needs; frequent conferences with local weather centre forecasters; and training flood forecasting staff in the interpretation of meteorological information and radar data, for recognition of developing severe weather.
 - Arranging for the incorporation of flood alerts in all national and local weather forecasts, on radio and television, and also the interruption of broadcasts for issuing major incident warnings.
 - Reviewing, with the Met Office, the use of the term “local flooding”, in order to bring about better public understanding of the Agency’s responsibility for flood warning and to avoid confusion with flood alerts.
- (8) Flood forecasting models should be used more widely. Standardised recording of the key information, facilitating quick appraisal, should be introduced nationally. Modelling should be rationalised and founded on a small number of state-of-the-art techniques, relevant to the range of basic catchment characteristics found across the regions. The R&D project to compare flood forecasting models should be completed as quickly as possible.
- (9) Flood forecasting operating procedures should ensure that, in addition to using model predictions, close attention is paid to monitored flood levels. The issue of warnings will, for many years, require judgement based on all the available information. The decision not to issue a warning should not be made solely on the basis of a forecast, which does not predict the threshold.
- (10) A ‘Flood Watch’ message should be introduced, to give other agencies an early alert that conditions are developing which may require flood warnings to be issued, thereby enabling them to observe, prepare and mobilize. At Easter, this arrangement might have lessened the likelihood of staff and resources in the other agencies being unavailable at critical stages over the holiday weekend.
- (11) Consideration should be given to augmenting, or in due course replacing, the AVM system with one (such as the BT Tallis) which offers the flexibility to issue warnings to any area identified as at risk during the forecasting phase.
- (12) All caravan parks on flood plains should be directed, as part of a more stringent licensing process, to erect notices to alert visitors to the risk of flooding and the procedures to be followed in the event of a warning being issued.

- (13) Nationally consistent management procedures should require:
- effective training for Duty Officers;
 - the opening throughout critical periods of flood forecasting and warning offices;
 - the staffing levels appropriate, especially in the early stages of an event, for proper interpretation of model and other information;
 - the use of current clock time (i.e. GMT and BST in winter and summer, respectively);
 - liaison, between neighbouring regions, on developing flood threats close to common regional boundaries;
 - documentation of flood warning procedures in a nationally consistent form subject to formal quality assurance.
- (14) The Agency's *"Flood Warning Strategy for England and Wales"* (in draft and unpublished) should be re-thought to better accord with the Agency's leading position: in the light of all the lessons learnt from the Easter floods, and on the assumption that climate change will lead to flood forecasting and warning systems being activated more frequently in the future.
- (15) Further research should be commissioned to assess the potential magnitude of climate change induced increases in flood frequency and inundation.
- (16) Consideration should be given by the Agency to a flood warning partnership with the Met Office. This would exploit more fully than at present the resources, skills and public communication facilities of the two pre-eminent national organisations concerned with severe weather and its flood impacts.

1.5. Emergency response

From the examination described in Section 6 of matters relating to items (c) and (d) of the terms of reference, we concluded that:-

- (1) People in known and potential at risk areas do not understand the roles of the Agency and the other response organisations. The Agency has in the last two years taken initiatives helpful to correcting this situation. They should be sustained and augmented to promote better public knowledge, drawing on methods adopted in other developed countries.
- (2) The Agency should exploit its expertise in flood defence, taking an active role in bringing greater clarity to command and control in the combined response of all organisations to flood emergencies.
- (3) The other emergency response organisations should be encouraged to review their flood emergency planning and preparation giving particular regard to the Agency's contribution.

- (4) In partnership with the Agency, these organisations should also be encouraged to undertake comprehensive logistical assessment of materials and equipment that may be required for flood emergencies.
- (5) The adequacy of liaison with local authorities - county, unitary, borough and district - on the generalities of flood warning and defence in their areas should be examined and strengthened where necessary.
- (6) Flood emergency planners, in all organisations, should be encouraged to consider the experiences of flood victims when re-appraising response procedures.
- (7) The Agency should seek to achieve national consistency in its dealings with the other organisations, particularly with those whose territories span regional boundaries.
- (8) Agency staff should improve their understanding of command and control in the other organisations.
- (9) Greater emphasis should be given in the future to testing response activity, interfacing and co-operation, with extreme event scenarios.
- (10) Agency procedures should be clear and consistent in relation to staff attendance at police strategic and tactical controls.
- (11) The Agency should take an active role alongside local authorities and voluntary organisations in improving advice to the public on recovering from flood experiences.
- (12) The Agency should seek to achieve a higher profile in the national and local media at the time of flooding and give emphasis to sympathetic and candid explanations as well as stressing achievements.
- (13) Better control and co-ordination of press releases should be introduced within and between regions and with other agencies to ensure accurate and consistent explanations of flood emergencies.

1.6. Standards of defence

From the examination described in Section 7 of standards of defence issues relating to main river (item (e) of the terms of reference), we concluded that:-

- (1) Defence systems were generally in good order at Easter.
- (2) Flooding at most if not all defended locations resulted from flood characteristics more extreme than those the systems were designed to defend against.
- (3) Some elements of the defences at Northampton were missing due to actions by others, or in poor condition. Flooding would have occurred irrespective of these deficiencies because of the extreme conditions but it may have been less extensive and severe.

- (4) There were instances of inappropriate application of mechanical equipment or non operation due to maintenance. It is possible that flooding would, nonetheless, have occurred at the locations in question (which include the Blanquettes Estate in Worcester) because of the extreme conditions but less extensively and severely.
- (5) There appear to have been no structural failures of defences.
- (6) The Agency should give greater attention to its general supervision and enforcement roles. At Northampton, the prior correction of deficient works in the ownership of others, and action to restore ordinary watercourses to proper condition, may have resulted in less damaging flooding.
- (7) The Agency should consider whether enhancing the nature conservation value of watercourses without compensating flood defence action is increasing upstream urban flood risks.
- (8) Imprudent development in flood risk areas is the fundamental reason for most of the damage experienced at Easter. In the majority of situations, the property dates from the mid 1900s or earlier. During the current decade, planning authorities appear to have properly responded to the advice given by the Agency (and previously the NRA) as a statutory consultee. The Agency should be prepared to assert and defend, vigorously, its advice.
- (9) Past disregard for the advice of the Agency's predecessors against caravan park developments and extensions had serious consequences at Easter. These large sites situated by rivers with minimal warning and evacuation arrangements provided the most severe risk of loss of life. More stringent licensing conditions with requirements for flood risk advice with warning and evacuation instructions, are essential.
- (10) Consideration should be given by the Agency to:
 - the technical, environmental and administrative feasibility of water supply and canal reservoirs being operated for the benefit of flood control.
 - the introduction of a factor of safety into flood defence design to account for the anticipated effect of climate change on flood frequency and severity.
- (11) Underlying standards of flood protection were appropriate prior to Easter but should be re-examined taking account of the resulting changed understandings of risk and having regard to climate change implications.
- (12) Most members of the public do not understand why some rivers and watercourses are described as *main river*, or the significance of this term in determining whether the Agency is able to provide flood defence. Until and unless the Agency's flood defence powers relate to any river or watercourse, greater attention should be given to promoting awareness of the roles and responsibilities of all the relevant organisations, as described in Appendix A

1.7. Management issues

We have considered management issues as part of our response to item (f) of the terms of reference and on the basis of the plan for the second phase of the Review.

The aspects of management referred to here emerged as issues during the Review. They are stated briefly, because in-depth consideration was beyond the scope of the terms of reference.

We acknowledge in Section 8 that the Agency appropriately manages flood defence in the context of holistic environmental management.

Following much organisational change in the recent past, we emphasise the importance of a period of stability and consolidation. We conclude, nonetheless, that in order to gain most from the Easter flood experience, these measures should be considered:-

- (1) Increasing the importance and strength of the flood defence management line from the level of national head of service down, in order to permit more authoritative direction of the function and bring about greater national consistency.
- (2) Surveying flood defence assets more frequently and cheaply but to a lesser level of detail which acknowledges that decline in assumed protection standards can result from the removal of elements or the rapid deterioration of earthwork sections in particular.
- (3) Establishing specific individual accountability at regional or area head of flood defence levels for the effectiveness and preparedness of all elements of flood warning and defence associated with main river. Formal inspections should be regularly made and personally approved by the accountable officer as confirming the adequacy of the states of the systems in relation to defined key performance criteria. Resources appropriate for managing flood warning and defence on this basis should be made available to the accountable officers.
- (4) Ensuring that flood warning and emergency response activities are led at all times and at all stages during the period of a flood emergency by senior staff experienced in the function and trained in crisis management.
- (5) Centralising flood warning and defence technical specialisms regionally (or nationally) in order to improve efficiency, effectiveness and national consistency by developing excellence through the concentration of specialist resources.
- (6) Amending the Project Appraisal Guidance Notes (PAGN) methodology for justifying flood warning and defence investments, to account for social, environmental and political considerations. This is primarily an issue for MAFF and the Welsh Office but Agency encouragement and advice would seem appropriate.
- (7) Adopting with greater urgency and applying to all regions, R&D programme outputs which are accepted as beneficial to flood warning and defence.

Some further problematic issues concern:-

- a) The lack of opportunity for middle and senior level flood defence managers to give sufficient attention to:
 - liaising informally with their counterparts in local authorities on matters such as: the state of ordinary watercourses; the condition of flood defence works not owned by the Agency; and joint preparedness for flood emergencies;
 - liaising, similarly, with the police and the fire and rescue services on flood emergency preparedness;
 - directing and co-ordinating the use of consultants;
 - ensuring the sound application of new technology;
 - informally auditing, from the standpoint of long experience, the adequacy of the approach to delivering warning and defence services.
- b) The scarcity of senior staff with advanced academic training and qualifications in hydrology, open channel hydraulics and computational hydrologic and hydraulic modelling.

Our broader conclusions on the management of flood defence are those we offered in evidence to the Select Committee:-

- (1) *Rationalisation of the Agency's flood defence committee structure - one RFDC per region without local or advisory committees would appear appropriate.*
- (2) *Removal of regional ring fencing of revenue to permit resources to be used flexibly in the context of national priorities.*
- (3) *Creation of a national flood defence committee with authority to direct the regional committees and allocate resources.*
- (4) *Replacement of scheme specific grant aid from MAFF and WO with block grants.*
- (5) *Redefinition of the Agency's policy on enforcement in respect of ordinary watercourses to bring about more effective action by riparian owners or local authorities.*
- (6) *Strengthening the Agency's position in relation to preventing new development in flood plains. Securing substantial funding from developers, for compensatory works for the hydrological consequences, in extreme flood conditions, of any green field developments, whether in or above the flood plain. These measures might in addition encourage brown site redevelopment, as opposed to green field new developments, with resulting environmental benefits.*
- (7) *Giving the Agency powers to require information from owners of existing flood defence structures and a system of statutory improvement notices to ensure the proper maintenance of such structures.*

1.8. Northampton, Leamington Spa, Kidlington, Skenfrith and Talgarth

As required by the plan for the final phase of the Review, special consideration has been given to the floods at Northampton, Leamington, Kidlington and Skenfrith because they were the most serious incidents in each of the four Agency regions affected at Easter. In addition, these locations are examples of the three categories of urban development on confirmed or potential flood plain land associated with main river; namely, areas:

- known to be at risk and defended (Northampton);
- known to be at risk but undefended (Skenfrith);
- not known to be at risk (Leamington and Kidlington).

Talgarth has been selected for special reference because it flooded from an ordinary watercourse and not main river.

The reports by the Agency on flooding at these four sites are included in Volume II. From the information they provide and understanding we have gained from discussions with the Agency, other organisations and the public, our opinions on these incidents may be summarised as follows.

(1) Northampton

The town has a long history of flooding from the main river reaches of the River Nene and its tributaries, but defences built in the 1940s successfully provided protection prior to Easter.

Flood defence engineers were uncertain about the adequacy of the defences in the 1980s and provision was made in the medium term capital programme for an improvement scheme but hydrological and hydraulic studies did not confirm deficiency and the proposal was dropped.

Based on the computational modelling studies in the 1980s and early 1990s, the defences were considered to protect the town up to the 100 years return period standard. However, the hydraulic computer model was established using data from a flood with an estimated return period 18 years. The reliability of this model when simulating the 100 years return period event is, therefore, uncertain and this must reflect in the confidence that can be placed on the conclusion from the studies about the town's standard of protection. Irrespective of this element of doubt, flooding at Easter was inevitable because the return period appears to have been well in excess of 100 years.

Investment plans established by the Flood Warning Strategy 1997-2001 included provision for improving the telemetry linked rainfall and river flow monitoring system covering the catchments upstream of the town, but had not been implemented before Easter.

Arrangements for direct warnings to the public were not in place at Easter because of the assessed low risk due to the presence of the defences and the Agency's policy to use its limited resources to warn areas at greater risk.

Northampton Borough Council (NBC) in a submission has stated that prior to March 1992 the Council had an Agreement with Anglian Water Authority in which NBC was responsible for flood warning to areas of St James' End and Cotton End. It would appear that these arrangements did not pass to the NRA on its formation and incorrectly remained with Anglian Water as part of the Sewerage Agency Agreement. One part of the agreement required the passing of advanced warnings of heavy rainfall to NBC, the Council would then monitor river levels and erect various barriers. Development in the 1980's appears to have removed the need for these barriers. The Agency was unaware of the agreement and the previous arrangement to pass Heavy Rainfall Warnings to NBC.

Effective interfacing between the Agency, the Borough Council and the emergency organisations was not achieved because all concerned were unprepared for an extreme event, particularly at the start of the holiday weekend.

Flood forecasting at Easter was handicapped by the inadequacies of the existing telemetry linked rainfall and river flow monitoring system. Insufficient rainfall information masked the severity of the event and flow measuring stations, not designed for flood monitoring, were overwhelmed. The forecasting models in use were developed nearly 20 years ago to study flood defence standards, and they are unsuitable for the purpose of forecasting extreme events. Forecasting did not take into account that reservoirs, upstream of the town, were full prior to the storm. The lack of drawdown at these reservoirs significantly influenced the run-off response to rainfall. As a consequence of these factors, forecasting was inaccurate.

It is evident that some lengths of the defence system were missing or in poor condition prior to Easter. The consequence of these defence deficiencies would have been the earlier onset of flooding and, possibly, more extensive and deeper inundation than would otherwise have occurred.

The flood defence walls and embankments were substantially overtopped and the poor condition of some ordinary watercourses and drainage systems within the defended areas probably added to the duration, extent and depth of flooding. Approximately 2500 properties, mainly houses, were inundated.

The apparent unsatisfactory states of the main river defences and ordinary watercourses raise questions about the Agency's attention to its general supervision and enforcement duties and powers.

Several thousand people were rapidly affected during darkness in the late evening and night of 9/10 April. The flooding cut off power supplies and there was little or no time for action to lessen damage. There were two fatalities; one from a houseboat in daylight hours. Flooding of the Borough's main depot and the roads contributed to the difficulties of the authorities attempting to respond to the emergency.

There were physical obstructions on the town reach of the river at Easter, which had the potential to heighten flood levels. One resulted from the partial blockage, for a period during the early stages, of a major bridge by a semi-submerged houseboat. The others related to maintenance work, commenced by the Agency's contractors prior to Easter, on two sluice structures. Conclusive evidence on the effects of these obstructions is not available, but it would appear that the boat may have been a factor of consequence and that the sluice works were probably not.

Wet weather in the months and weeks before Easter resulted in water supply impounding reservoirs upstream of the town being full prior to the storm. Hence, their alleviating effect was insignificant but there appears to be no basis for suggesting that the reservoirs operated in a manner worsening flood conditions. Discharges did occur from the canal system and were unavoidable because of the volume of inflow. However, there were no breaches of canal embankments and the small amounts of the discharges relative to river flows would have had negligible effect on the flooding.

Substantial post-war development at Northampton has been accompanied by the construction of flood detention reservoirs. These storages appear to have operated effectively during the early stages of the flood, prior to being overwhelmed, due to storm severity exceeding the criteria for their design.

There has been comment about the suddenness with which floodwater drained away. This was a feature of many of the flooding incidents across England and Wales. It evidently resulted from a rapid cessation of heavy rainfall and consequent steep fall in flood discharges from peak rates.

Hydrology and hydraulic studies made since Easter suggest that the annual probability of the Easter event is less than 1 per cent and perhaps as low as 0.7 per cent (between 100 and 150 years return period). There is uncertainty about these estimates because of the lack of reliable recorded data. They are, however, accepted by the Review Team as the best estimates available.

On-going investigations undertaken or commissioned by the Agency have the objectives of remedying revealed deficiencies in the warning, emergency response and defence arrangements relating to the town, and establishing the feasibility of improvements.

(2) Leamington Spa

The Agency was unaware of any history of extensive flooding at Leamington Spa and there are no flood defences.

The town has developed on land to both sides of the River Leam which is designated as main river. Much of the developed area is well above the river and, therefore, not vulnerable to river flooding.

Public gardens occupy low riverside land in the centre of the town. Adjacent to the gardens, there are long established residential and commercial areas some of which are only marginally higher. The vulnerability of these areas to flooding was exposed at Easter.

A study to establish flood plain extent within the town was commissioned by the Agency in 1997 and scheduled for completion at around Easter. This work was then extended to take account of information on the Easter floods. The flood levels determined by computational modelling for the critical reach in the town centre do not, however, correspond closely to the recorded data on the Easter and an earlier lesser flood.

The explanation for these discrepancies seems likely to be the complexity of flow behaviour at flood discharges in the town reach. There are bridge and weir structures of unusual form, some in close proximity, as well as complicated variations in channel and flood plain geometries and surfaces. In these circumstances, the validity of the theoretically and empirically based hydraulic concepts in the model programs are questionable.

Because of the steepness of the valley side, away from and to the north of the river, flood plain extent is insensitive to changes in flood water level. This is demonstrated by comparison of the flood plain limit, established by modelling the estimated Easter flood hydrograph, with the actual observed and measured inundation extent. Although modelled peak flow levels along the critical reach differ from those recorded, by between about 0.5m and 0.8m, modelled and actual extents are similar. On the south side, there were insufficient topographic data to sensibly locate the modelled extent. However, the gradient of the developed land towards the river is not steep and appears to be such that depth discrepancies in the order of the above would be misleading about flood plain extent.

Warwick District and Warwickshire County Councils were evidently not aware of the Agency's investigation of flood risk in the town.

The discharge at the peak of the Easter flood was the highest since 1968 when flow monitoring stations were established on the Leam. Flow forecasting at Easter, as a consequence, relied on understandings of flood hydrology gained from lesser events which built up more slowly. This basis proved unreliable in the more severe conditions at Easter, but warnings were, nonetheless, given for the Leam basin several hours in advance of flooding in the town.

The agreed arrangement for direct warnings to the nine properties in the town centre, which were covered by the Agency's service, involved alerting Warwick District Council by Automatic Voice Messaging (AVM). The agreement then required the Council to warn the people in these properties.

The Agency has explained that an error in the pre-programming of the AVM system resulted in amber and red alerts failing to be communicated to the Council, and, hence, to the residents.

General warnings of flooding were broadcast by local radio stations and back-up information was available from the FLOODCALL service.

As a result, some people may have been able to mitigate the effects of the flooding which commenced in the early hours of 10 April. It seems likely, however, that the vast majority were totally surprised by and unprepared for the polluted and silt laden water which entered their properties. With many having basements used as living accommodation, risk to life was real but, thankfully, no fatalities occurred.

Analyses since Easter have revealed that in the Leam and immediately adjacent catchments flood events of exceptional severity were experienced. A probability of occurrence of 0.6 per cent per annum (return period greater than 175 years) appears a valid estimate for the Leam at Leamington Spa.

There is no evidence to suggest that motorway construction or the operation of other water systems in the catchment - the Grand Union Canal and Draycote Water reservoir - adversely influenced the severity of the flooding.

The number of properties that flooded in the morning of 10 April 1998 is assessed by the Agency as approximately 400. Most appear to date from the early 1900s or before. Although the Agency had no knowledge of the majority having flooded previously, it seems that extreme but somewhat less severe floods occurred in 1900, 1920, 1932, 1939, and 1947.

The Agency is currently examining the feasibility of a protection scheme for the town. Expansion of the warning service is also under investigation. Frequent auditing of the AVM system to reduce the likelihood of programming errors preventing the delivery of warnings in the future, has been introduced. Warning thresholds have been reviewed and the AVM service offered to all residents affected at Easter.

(3) Kidlington

The River Cherwell is a major tributary of the Thames. It flows more or less north to south from above Banbury down to Oxford where it joins the Thames. The reach from Banbury to the Thames confluence is designated as main river. Kidlington is on the west bank of the Cherwell about 6km from Oxford. Development is predominantly housing. The older parts of this large village are on marginally higher ground in a landscape that is essentially flat.

Prior to Easter, the Agency's awareness of flood vulnerability derived from knowledge gained over 40 years or so by its predecessors. This supported the conclusion that the risk areas were not extensive and included few properties. However, in the evening of 10 April 1998, the peak of the flood wave, moving down the Cherwell basin from above Banbury, passed through the Kidlington reach. The known risk locations as well as much larger areas were inundated and flood water entered over 90 properties, mainly houses, in the majority of cases without any form of direct warning.

The flooding in the Cherwell valley generally was of a severity matched only in the post war period by the 1947 flood, which is a benchmark event for most rivers in England and Wales.

The magnitude of the flood wave at Easter was such that it inundated large areas of developed and rural flood plain throughout the Cherwell valley. Unprecedented flooding at Banbury and smaller developed areas in the upper reaches preceded that at Kidlington. In these circumstances, it is considered that suggestions which have been made about discharges, from the reservoirs and the Oxford Canal, being of significance to flooding at Kidlington, are unfounded. This is because no structural failures, resulting in the release of contained water from the canal or reservoirs, occurred and, hence, these water systems could have had no marked influence.

Similarly, construction of the M40 motorway in the last decade or so, although marginally increasing the paved area of the catchment, would not have had any measurable effect on flooding from rain of exceptional intensity and duration falling on saturated ground.

A minor road as well as the A34 and A40 cut across the Cherwell valley below Kidlington - the first immediately downstream of the village. The bridges carrying these roads over the river (including a bypass channel in the case of the minor road) appear appropriately sized for flood flows. The presence of these roads, at elevations above the general levels of the flood plain, must, nonetheless, increase water levels to some extent when the valley is inundated.

The Agency maintains the channels of the Cherwell (and other main rivers) with the proper regard for nature conservation required by the legislation under which it operates. This necessitates the acceptance of tree and other vegetation growth on river banks and shoaling in the channel bed, to a greater degree than would have been the case when hydraulic efficiency was the primary criterion.

It has been suggested that the lighter, more environmentally considerate, approach to maintenance could have caused or significantly contributed to the flood at Kidlington. The argument is not wholly accepted because rainfall and river flow statistics, as well as the exceptional flood impacts throughout the Cherwell and adjacent catchments, support the conclusion that the truly exceptional severity of the storm was the dominating factor. However, heavier maintenance may reduce vulnerability with less extreme flood flows.

Flood warnings were issued at Easter in accordance with the procedures in place. But 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. Flood plain extents on the Kidlington reach of the Cherwell had not been investigated prior to Easter by detailed hydrological and hydraulic studies. However, as part of an exploratory exercise on indicative flood plain mapping, simplified analyses had been made and revealed vulnerability in extreme circumstances, although with the risk area crudely defined.

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

The Agency has expressed the view that the probability of the Easter flood at Kidlington being equalled or exceeded in any one year is about 1 per cent (that is, 100 years return period). It is evident, however, that lack of reliable flow data at appropriate locations in the catchment create uncertainty about the reliability of this estimate.

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.

Improvement of the flood warning system to provide coverage to Kidlington is reported by the Agency to be under consideration..

Investigations by the clerk (who is an engineer) to the Gosford and Water Eaton Parish Council, into the river, ditch and surface water drainage systems, have contributed substantially to the understanding of the responsible authorities about flood alleviation measures justifying consideration.

(4) Skenfrith

Skenfrith is in a scenic, hilly area of the lower Wye catchment. This historic village is located on the west bank of the River Monnow (designated as main river) some 16 kms upstream of its confluence with the Wye. The village has developed over an area of the flood plain that is clearly defined by steeply sloping ground on both sides of the valley. There are no flood defence works at Skenfrith.

There is a high weir associated with an old (but still operational) corn mill at the downstream end of the village reach. Immediately below the weir, a multi arch bridge carries the primary valley road over the river and across the valley at a slightly higher level than adjacent areas of flood plain.

Norton Brook is an ordinary watercourse (within the district of the local internal drainage board) which skirts the upstream side of the village and runs on to join the Monnow above the mill weir.

The understanding of events at Easter gained from: the Agency's report; site inspection; and discussions with Agency and Monmouthshire County Council staff and villagers, including the flood warden, may be summarised as follows.

There is a long history of frequent flooding - it would seem at a mean interval of between 10 and 20 years. Frequent flooding might well extend back to the dates when the mill weir and the road bridge were constructed since both would have been detrimental in terms of the flood risk to upstream areas of the flood plain.

The Agency's predecessor, the NRA, investigated the feasibility of a flood defence scheme, but the project concept examined could not be justified economically and no work was undertaken. The Norton Brook has been improved and maintained to a good standard over the years by the internal drainage board, primarily for land drainage purposes. The village's piped surface water drainage systems are of questionable adequacy. Minor improvement works have, however, been undertaken and further upgrading is under consideration by the County Council.

During the afternoon and early evening of 9 April 1998, the Agency issued colour coded warnings in accordance with procedures, including to the village flood warden. The timings in relation to the minimum lead time target of two hours, appear to have been appropriate for yellow, and somewhat late for amber. However, the red warning was given after property flooding had commenced, initially from local sources, and was of no value since the flood warden and the residents had already taken last minute action to protect themselves.

The initial flooding of properties, roads and open areas appears to have been associated with flows directly off adjacent high land, surface water drainage inadequacies and overspill from Norton Brook. Subsequent property flooding was due to high levels in the Monnow. Twenty-one properties were inundated to depths of up to half a metre.

The flood at Easter was the second highest in a record of water level marks at the corn mill extending back to a flood in 1928. The flow rate may, however, have been less than the second highest because roadworks undertaken around 1960 appear to have altered the carriageway geometry in ways which could have increased flood levels. The Agency's assessment of Easter flood probability is 5 per cent in any year (20 years return period) and this is considered to be of the right order.

Emergency response work by the County included the provision of sandbags an hour or so before the first properties flooded. Earlier provision would have benefited some residents but with widespread flooding of the valley roads throughout the area and delayed warnings, nothing better could have been achieved. The Agency maintained a watch on defences lower down the Monnow as well as on bridge and other structures. Interfacing between the Agency and the County Council was well founded on adequate procedures and good personal contacts.

The Agency is intending to look again at the feasibility of flood protection measures and the appraisal of options might usefully include consideration of alterations to road levels and flood relief arches.

Warning thresholds have now been lowered to achieve greater lead times and the AVM service offered to all residents.

Talgarth

Talgarth is a village in the north western foothills of the Black Mountains. The village has developed around the Afon Ennig and an unnamed tributary, neither designated as main river.

There appears to have been no recent history of serious flooding. Accordingly, prior to Easter, Talgarth was not considered to be at risk and there are no flood defences or warning arrangements.

Development, mainly housing, has occurred over decades if not centuries and there is little modern construction. Some properties are close to, or hard against, the watercourses. The village reaches are crossed by a number of road and foot bridges.

The catchment to Talgarth is rural and hilly. The village reaches of the Ennig and its tributary have steep overall gradients with boulder strewn pool and riffle features and a series of waterfalls. The valley sides above and through the village slope steeply to the watercourses. The absence of broad flood plain areas is typical of the upper reaches of a river system. No reservoirs or other water systems which could influence flood hydrology are evident in the catchment.

Main river and risk considerations apart, effective warning is precluded by the rapid response of the Ennig to rainfall on the small and steep catchment to Talgarth. As a consequence, this community must rely on general forecasts of severe weather in the locality, intense convective storms in particular, for their awareness of possible flooding.

Heavy rain over the northern slopes of the Black Mountains on 8 and 9 April resulted in flood flows in the upper reaches of this part of the Wye system. There are no hydrometric records specific to the Afon Ennig and, therefore, probability cannot be directly assessed. However, consideration of data relating to the downstream system suggests that probability is in the order of 3 per cent (return period of 30 years) for the Easter flood discharge being equalled or exceeded in any one year.

Such a flood does not rank as extreme and the explanation for the flooding experienced would appear to be a moderately large flow rate combined with substantial blockages at several bridges. The likelihood of repetition is uncertain but may not be high.

From eyewitness descriptions, it appears that a fallen tree, carried down by the flood, partially blocked the waterway at the road bridge on the upstream side of the village. The resulting water level caused flooding to properties alongside the bridge and flow down the road running into the village, inundating buildings, mainly houses. Further blockages at another road bridge and two footbridges within the village, evidently resulted in more overspill into the streets and buildings. Over-land flow off the steep hillsides appears to have added to discharges down the roads and the flooding in the village.

The event was dangerous, and no doubt frightening for the community, because of the high velocities of flows down the steep village roads and the torrents in the watercourse channels. Also, some properties were flooded to depths well in excess of one metre. It is understood that a total of twenty-six houses and ancillary buildings were affected with many severely flooded.

In the difficult and dangerous circumstances of this event, little could have been done to lessen the impact of the flooding. However, it is evident that Powys County Council's emergency planning and highways and direct services departments took some action with support from the Environment Agency. The work undertaken after the flood to clear obstructions and otherwise restore the watercourse channels was important for reducing the risk of flooding in the event of further storms.

The vulnerability to flooding demonstrated on 9 April at Talgarth is common to many towns and villages on the upper reaches of the river systems in Wales and England. The actual experience of flooding is, however, rare but potentially dangerous at many of these locations.

Flood alleviation schemes for such situations may involve construction to provide singly or in combination: trap, deflector or screen devices for intercepting boulders, gravel, timber and trash, swept down by flood flows; channel works to alter flow characteristics so that flood levels are reduced; and flood walls or embankments.

With or without flood alleviation works, flood risk is lessened by regular maintenance to control tree and bush growth on watercourse banks and to remove gravel accumulations and boulders from critical sections.

It is beyond the scope of the Review to consider the technicalities and economics of flood protection for Talgarth if, indeed, any action is called for, given the likely low annual probability of a re-occurrence of the Easter event. Furthermore, the powers and responsibilities of the local authority and the riparian owners interlink and cannot be clarified for a specific location in this wide ranging exercise. Because the Afon Ennig is not main river, the Environment Agency cannot use its powers to undertake a flood defence scheme.

1.9. Recommendations of the Agriculture Select Committee

In the later stages of the Review the Agriculture Select Committee published its report and recommendations on flood and coastal defence. The Select Committee covered a broader canvas than ours, although we were pleased to note that we had arrived independently at similar conclusions on fluvial flood defence.

Specifically, we support the Select Committee's recommendations for legislative and organisational rationalisation, integrating flood defence requirements with the planning system, public information on flood risks, and improved flood warning dissemination.

2. INTRODUCTION

2.1. Easter 1998

Many people were disappointed by the wet weather over the Easter weekend this year. The heavy rain spoiled holiday trips, sporting events and other outdoor activities. Thousands of other people suffered more than temporary inconvenience. Their homes and places of work were flooded, causing disruption, fear and loss scarcely imaginable to those outside the affected areas. Tragically five people died, apparently as a consequence of the flooding.

Floods causing widespread damage and loss of life are, thankfully, rare in Britain. The moderate climate is a helpful factor but, in addition, flood defences constructed over many decades succeed in protecting vulnerable areas from all but the most extreme storms.

In England and Wales, it is on average perhaps ten or twenty years between floods which, at some coastal or inland location, can be classed as disasters on the national scale.

Such events in recent times include the East Coast tidal inundation and the Lynmouth and Lynton flood in the 1950s. The coastal floods in NW England and at Towyn in North Wales were exceptional in the 1970s and 1980s. Prior to Easter this year, the benchmark event on nearly all major river systems was the 1947 flood. However, in some places Easter 1998 flood levels exceeded those of 1947.

Close examination of damaging floods is essential to establish whether there are lessons relevant to dealing more effectively with equivalent or more extreme events in the future. The Review responds to the Agency's recognition that, in addition to its own investigations, an appraisal made independently should assist in learning from the Easter experience.

2.2. Environment Agency

In England and Wales, the Agency has permissive powers for the provision, operation and maintenance of flood defence on certain rivers and watercourses described as *main river* within the overall policy framework established by MAFF and the Welsh Office. The Agency's role is not, however, all embracing because local authorities and internal drainage boards are also empowered to provide flood protection in some circumstances. These organisations, together with the police, fire and rescue services and, on occasion, the military, join with the Agency in responding to flooding as a major civil emergency. Appendix A - Flood Defence in England and Wales - describes the legal, administrative and technical background to the flood defence activities of the Agency and the other organisations.

Gaining wider public recognition as the lead organisation on flood warning and defence is challenging for the Agency because:

- it was formed only two years ago;
- the police were the authority most prominent in providing flood warnings to the public prior to September 1996;
- there were three major reorganisations of the water industry in the preceding twenty-two years as well as frequently changing and regionally dissimilar arrangements for flood warning and defence;
- the word “catchment”, “river” or “water” is absent in the name of the responsible organisation (i.e. the Agency) for the first time since the 1930s when river flood related public services commenced.

2.3. Terms of reference for the Independent Review

The terms of reference given to the Review Team by the Agency are:-

For those parts of Anglian, Midlands, Thames and Welsh Regions affected around Easter 1998 to:-

- a) establish the extent and severity of the flooding events;*
- b) examine the appropriateness and effectiveness of the issue of flood warning both for properties known to be at risk and those not previously known to be at risk;*
- c) examine the appropriateness and effectiveness of implementation of the flood emergency response procedures, including the response of third parties;*
- d) review the appropriateness and effectiveness of the Agency's interface and co-operation with other public bodies and the media;*
- e) address the effectiveness and appropriateness of the current standards applying to flood defences in these areas. This should include the effectiveness of the planning liaison process with regard to development in the flood plain;*
- f) consider any other relevant factors.*

With regard to reporting, part 5 of the terms of reference states:-

Two reports are required. A preliminary report should be produced by 31 May 1998. The Review Team is required to give priority in its preliminary reporting to addressing the effectiveness of flood warning arrangements and the Agency's emergency response measures [(a-c) in the Terms of Reference, as well as (d) with regard to warning and emergency response].

The final report should address all points of the terms of reference comprehensively, thus covering in the round, the effectiveness and appropriateness of the underlying level of flood protection in the areas affected by the Easter floods. The Review Group should complete its final report by 30 September 1998.

The preliminary report should be made in public, to the Agency Board, who will publish it with any appropriate comment.

Term (a) above has been interpreted as requiring appraisal of the adequacy of the Agency's work in establishing extent and severity, and not as an instruction to replicate this activity.

2.4. Preliminary report

The brief for the Preliminary Report was to provide an initial assessment of the Agency's preparedness for severe flooding, its performance during the floods and its actions after the events. The key question centred around the appropriateness and effectiveness of the Agency's actions.

In the report dated 31 May 1998, the Review Team summarised their findings as follows.

The Easter floods resulted from unusually intense and prolonged rainfall on catchments already saturated from a preceding period of wet weather. The preliminary evidence supports the assertion that, in most areas, these floods were more severe than the widespread flooding experienced in 1947. There were differences, which may be significant, in the cases of the two events. The 1998 floods originated from very high rainfall over a short time, whilst those in 1947 resulted from prolonged rain falling on snow covered and frozen catchments, causing slower river response.

The evidence gathered and analysed by the review team for this report is not sufficient to permit a definitive assessment of the overall performance of the Environment Agency before and during the Easter floods. The team will offer a measured judgement of all-round performance in its final report. Any evaluation of performance by the review team will place relative successes or failures firmly in the context of a rare occurrence that developed with exceptional speed and intensity. The relationship with investment in flood defence infrastructure and dedicated staff over the years will be considered. The team will wish to recognise also that responsibility for dealing with major emergencies that threaten life and property is shared with other public services.

The team's scanning of the available documents indicates that there is in place a framework of strategies, policies and operational plans. In the context of the Agency's own high standard, strategic preparation and operational delivery of warnings appears to be an area of relative weakness, particularly in low risk locations, although considerable progress has been made since the Agency was given the lead role for this activity in September 1996.

With the limits of their resources and in the face of exceptional events, Agency staff responded satisfactorily to the floods in most areas. In some places they must be given credit for excellent work alongside the emergency services. There were unsolicited accounts of individuals and teams working long hours and in dangerous conditions to protect people and property.

Evidence from several of the flooded areas visited by the review team confirms the Agency's report that estimates of the extent of flooding, warning systems and co-operation with the emergency services worked well in many instances. There is evidence in some locations, however, of unsatisfactory forecasting and warning dissemination, apparent slow reaction to events, confusion and misunderstanding amongst the public caught up in the floods and unsatisfactory liaison between Agency staff and emergency services.

The review teams provisional assessment is that the exceptional intensity and speed of development of the Easter 1998 floods may have been a significant factor in those areas where performance fell short of the Agency's targets. Forecasting may have been disadvantaged because there was no prior experience of comparable flood hydrology. Telemetry systems and forecasting models of proven soundness in less exceptional conditions were evidently required to operate beyond their reliability limits. In consequence, planned preparation and dissemination of warnings may have been unavoidably disrupted.

For each of the four regions that experienced flooding, the review team identified the location most seriously affected by the floods where questions about the adequacy of flood defences, telemetric systems and forecasting models, warning systems, major incident planning and related matters require urgent investigation and concerted action by all the relevant agencies. They are Northampton, Anglian Region, Leamington, Midlands Region; Kidlington, Thames Region; and Skenfrith, Welsh Region. For reasons explained in the report, these locations are proposed for in-depth studies in the second phase of the review.

Responding to lessons from studies of specific locations, whatever strengths and weaknesses are identified, may amount to dealing with symptoms rather than causes. In the second phase, the review team proposes to initiate analyses of five strategic issues. These are: the management arrangements for the flood defence function; flood warning, dissemination and response; emergency planning for major floods; flood defence investment plans; and control of development in the flood plains.

2.5. Final report

The terms of reference are responded to in full in this final report on the basis of the approach outlined in the preliminary report:-

The approach suggested is based on investigating the circumstances and events surrounding the urban flooding incidents in the listed catchments, at one of two levels of detail. This will involve subjecting some to wide-ranging and in-depth study with the remainder appraised comprehensively but in less detail.

It is proposed that the wide-ranging and in-depth investigations should be made in relation to:-

- (1) Northampton, Anglian Region, where there is a defence system and main river flooding affected over 2000 properties.*
- (2) Skenfrith, Welsh Region, where an undefended area known to be at risk was flooded, in part, from main river, affecting about 30 properties.*
- (3) Leamington, Midlands Region, where town areas not previously thought to be at risk were flooded affecting approximately 300 properties.*
- (4) Kidlington, Thames Region, where an area not previously thought to be at risk was flooded, affecting up to 150 properties.*
- (5) Talgarth, Welsh Region, is the incident suggested for the investigation of flooding from an ordinary watercourse.*

Responding to lessons from studies of specific locations, whatever strengths and weaknesses are identified, may amount to dealing with symptoms rather than causes. In the second phase, the review team proposes, therefore, to initiate analyses of five strategic issues:

- (1) the management arrangements for the flood defence function;*
- (2) flood warning, dissemination and response;*
- (3) emergency planning for major floods;*
- (4) flood defence investment plans;*
- (5) control of development in the flood plain.*

Evidence for responding to the terms of reference on the basis outlined above has been acquired principally from examination of the Agency's activities during the event and investigation of the many flooding incidents experienced across the four regions affected at Easter.

The maps overleaf show:

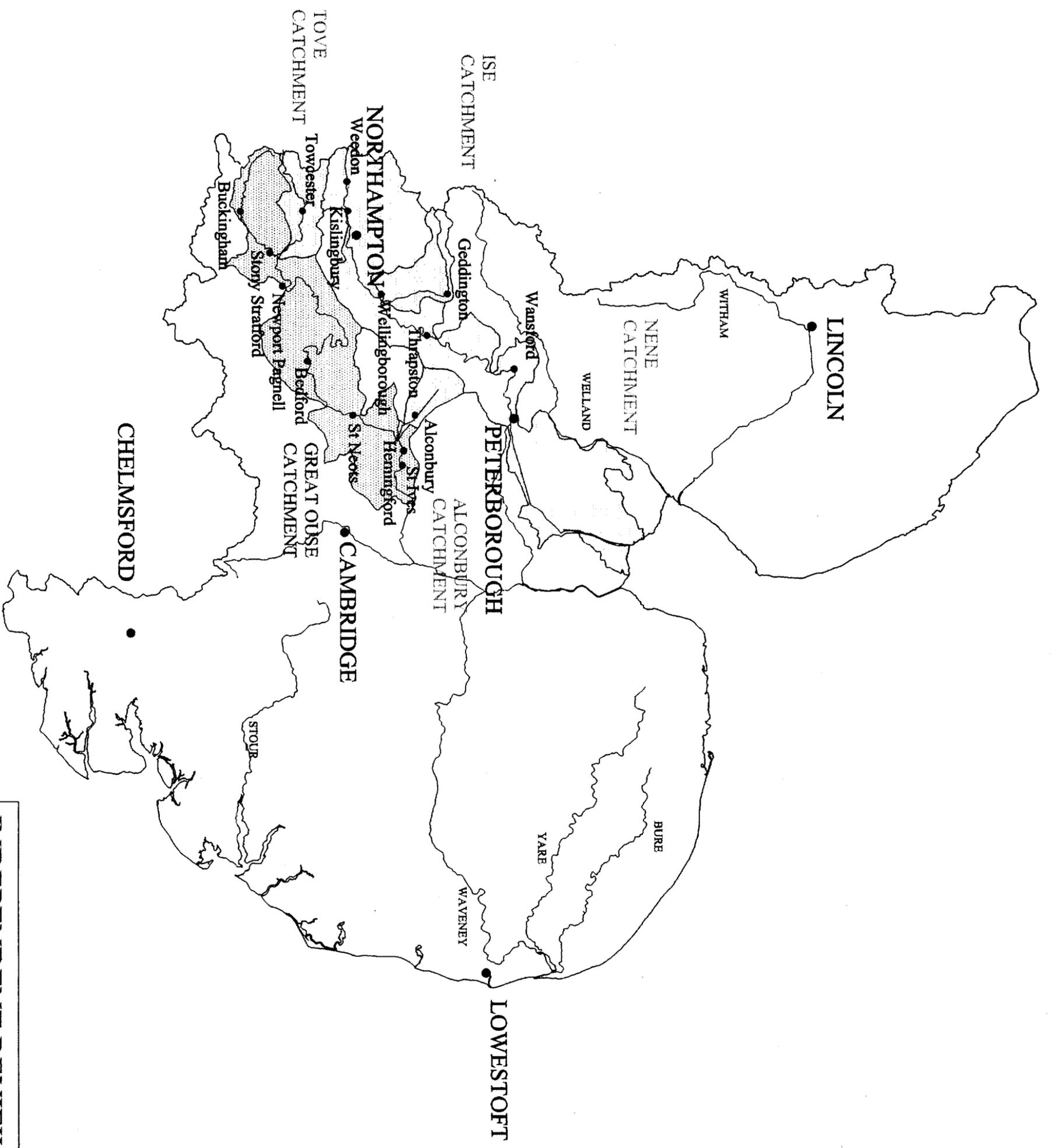
- the Agency's regional structure and the four regions affected by the Easter floods;
- the catchments in the Anglian, Midlands, Thames and Welsh regions which experienced extreme flood conditions.



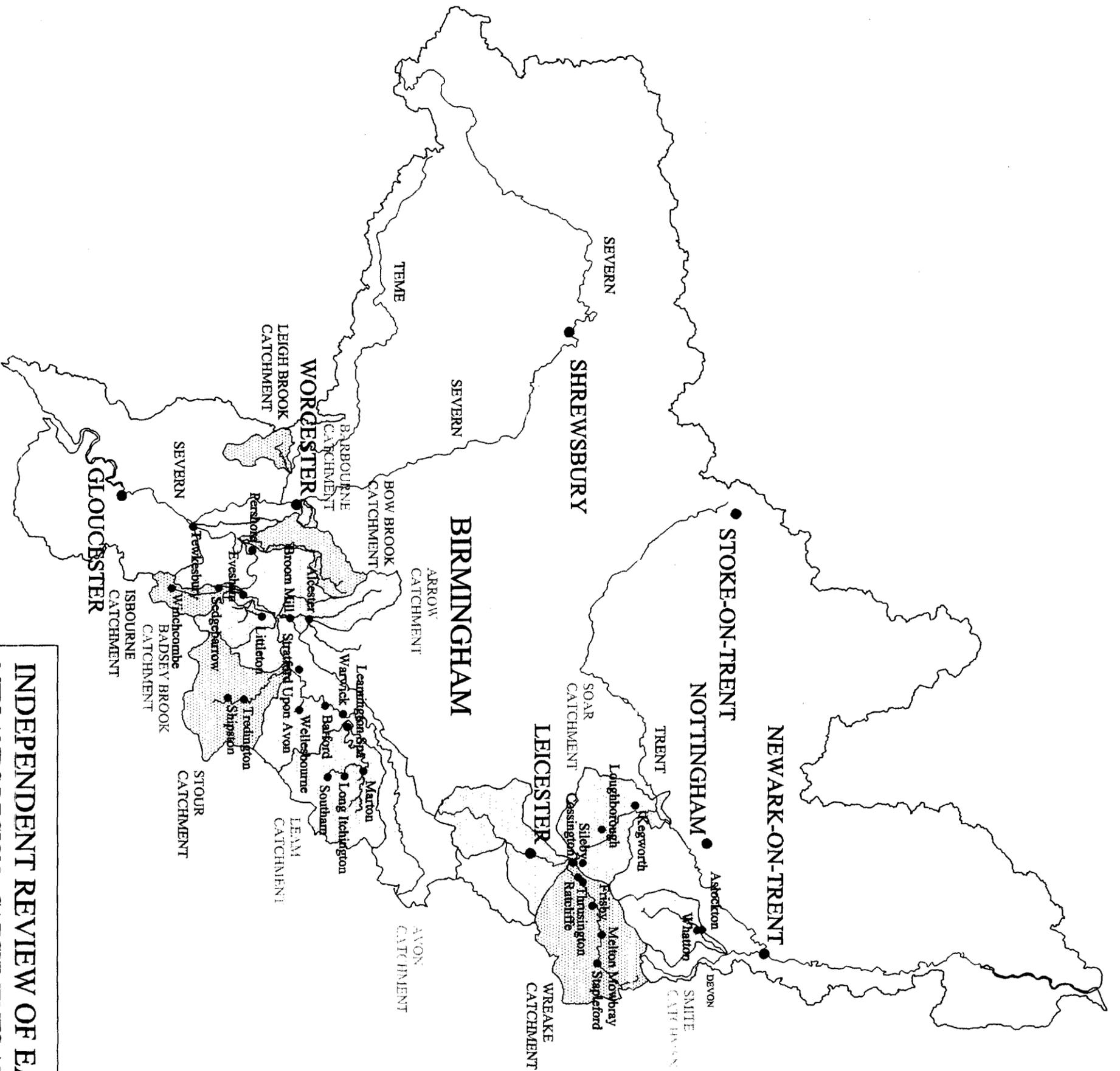
**INDEPENDENT REVIEW OF
EASTER FLOODS 1998
ENVIRONMENT AGENCY REGIONS**

Regions affected shown in red.

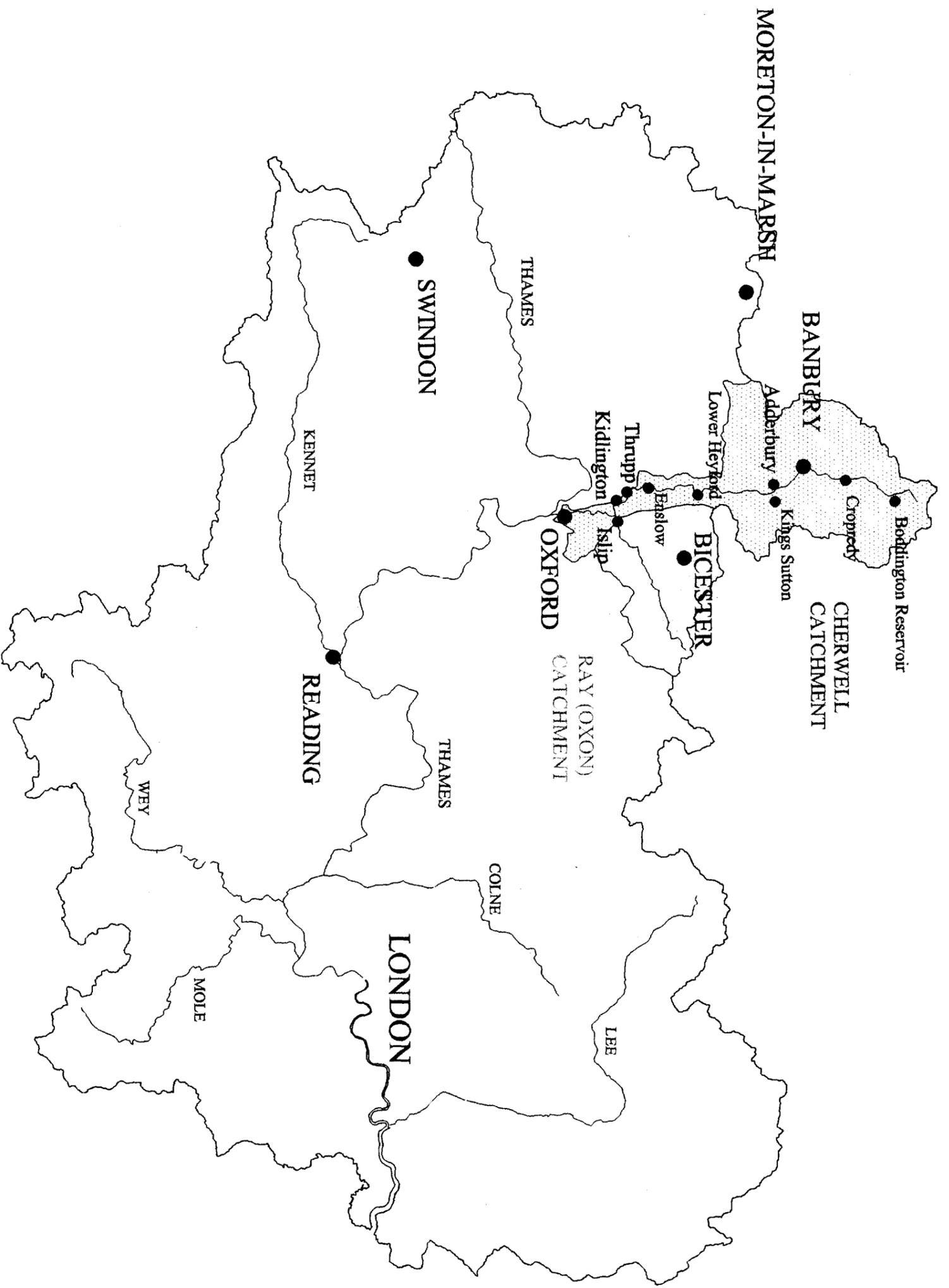
September 1998



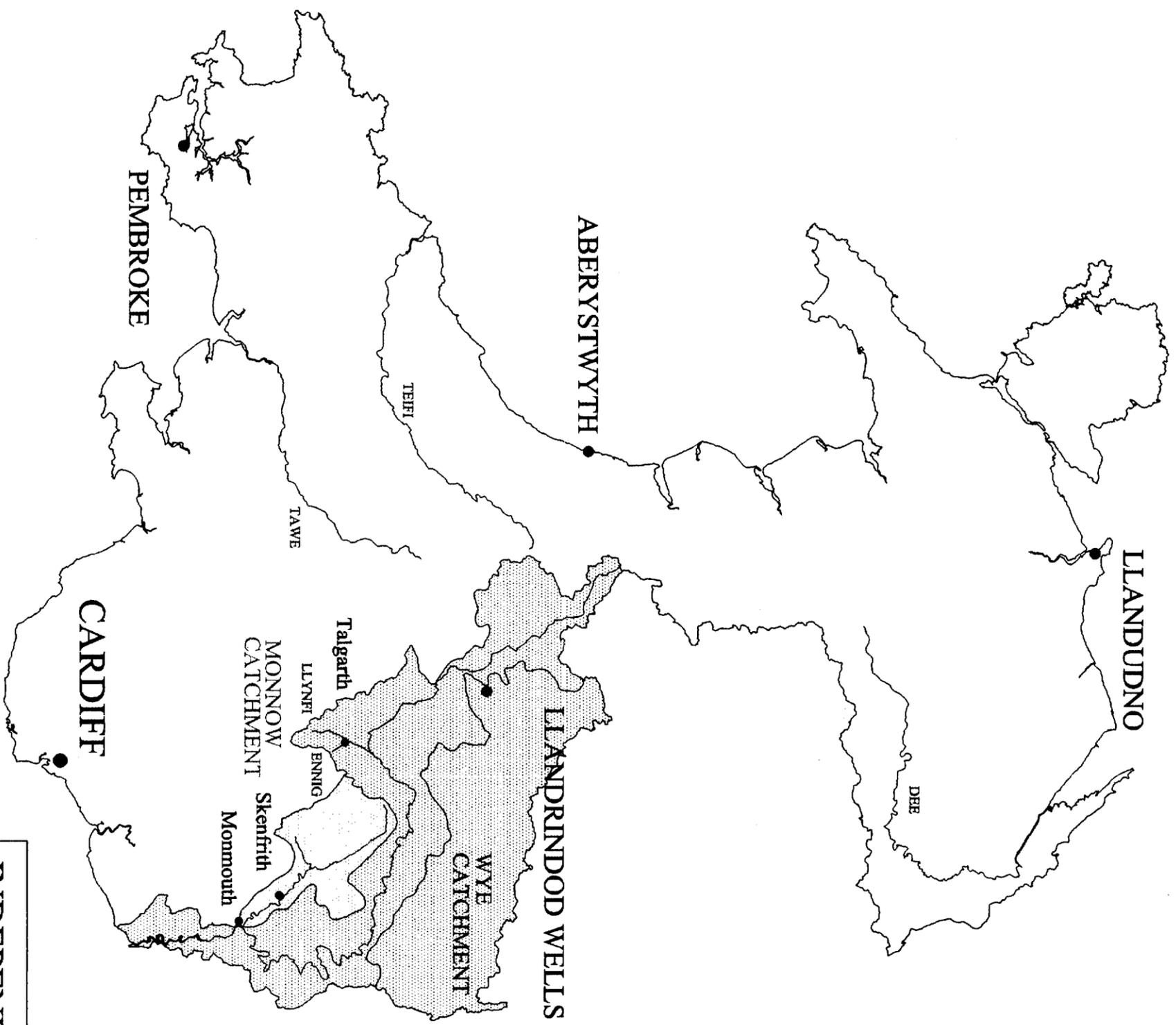
INDEPENDENT REVIEW OF EASTER FLOODS 1998
ANGLIAN REGION - CATCHMENTS AFFECTED



**INDEPENDENT REVIEW OF EASTER FLOODS 1998
MIDLANDS REGION - CATCHMENTS AFFECTED**



INDEPENDENT REVIEW OF EASTER FLOODS 1998
THAMES REGION - CATCHMENTS AFFECTED



**INDEPENDENT REVIEW OF EASTER FLOODS 1998
ENVIRONMENT AGENCY WALES - CATCHMENTS AFFECTED**

Much of the information required for the review has been obtained from the Agency's own post-event studies. In order to avoid duplication of effort, such information has been examined by the Review Team prior to its acceptance for their purposes. Additional information has been requested and obtained through the Agency from the organisation's staff and consultants and also by direct contact with other bodies.

In Section 3, the Easter weather and the forecasts in the preceding days are described. The impacts of the floods on people are then explained. Consideration is given to the key aspects of the terms of reference in Sections 4, 5, 6 and 7, prior to comment on management and organisational matters in Section 8.

At the Review Team's request, the Agency has identified and prepared summary tables on all incidents affecting property. The Agency has then drafted reports on these incidents, having regard to methodologies for the detailed and ordinary studies suggested by the Team.

The flood incident reports are presented in Volume II.

With the objective of reporting clearly and succinctly, detailed information underpinning the comments, conclusions and recommendations given in this report is provided in appendices rather than in the main sections of the document.

2.6. Review standpoints

The independent status of the Review has allowed consideration of the Agency's performance, in providing and operating flood defence and warning, from positions different to those readily taken by its own in-house studies. This has created scope for the Review to complement the Agency's own learning from the Easter floods.

The Agency's declared customer commitments, visions, aims, objectives and plans suggest many standpoints appropriate to an external appraisal. More are evident from the legislation and statutory guidance applying to the Agency's functions. However, time and resource constraints have restricted the number that could be adopted to those offering the potential to contribute most significantly. The Review has, therefore, responded to the terms of reference from the following four of the numerous possible standpoints.

- (1) What were the impacts of the Easter floods on people?
- (2) How were the interests of the public served by the Agency's actions before, during and after the floods?
- (3) How were the interests of local authorities, the police and emergency organisations served by the Agency's actions before, during and after the floods?
- (4) How effectively has the Agency responded in its flood defence and warning work to statutory guidance requiring operation on the basis of sound science, value for money, holistic environmental management and national consistency?

2.7. Policy and operational context

The context for policy and operation of flood warning and defence is complicated legally, administratively and technically. It is, however, important to reviewing the Easter floods in accordance with the terms of reference. For this reason, an appreciation of the policy and operational context is provided in Appendix A - Flood Defence in England and Wales - under the headings:-

- Historic background
- Relevant organisations and their inter-related roles
- Legal background
- Environment Agency responsibilities
- Internal drainage board and local authority responsibilities
- Flood risk management
- Climate change and rainfall variability
- Environment Agency strategies, procedures and public information

2.8. Formal submissions to the Review

The Review Team is grateful for and has had regard to in conducting the Review, the following submissions.

- Flood Forecasting, Warning and Response System - Professor D J Parker, Flood Hazard Research Centre, Middlesex University (see Appendix C).
- Model Meteorological Service for Flood Detection, Forecast, Warning and Response - The Meteorological Office (see Appendix D).
- Social Issues in Warning Systems Response - Dr Maureen Fordham, Department of Geography, Anglia Polytechnic University (see Appendix G).

3. EASTER WEATHER AND FLOODS

3.1. Brief description

The start of April 1998 was very unsettled over the whole of the UK. In the first week, 20 to 30 mm of rain fell over the Midlands. The month as a whole was exceptionally wet, the Royal Meteorological Society's *'Weather Log'* reports monthly rainfall values over England and Wales of between 1.6 and 3.2 times the monthly average.

By Tuesday 7 April, a cool northerly airflow covered the UK and an area of low pressure formed near Iceland. On 8 April, this depression moved south across the UK, and with more than 10mm of rainfall, catchments became very wet and close to field capacity (soil moisture deficits were below 10mm).

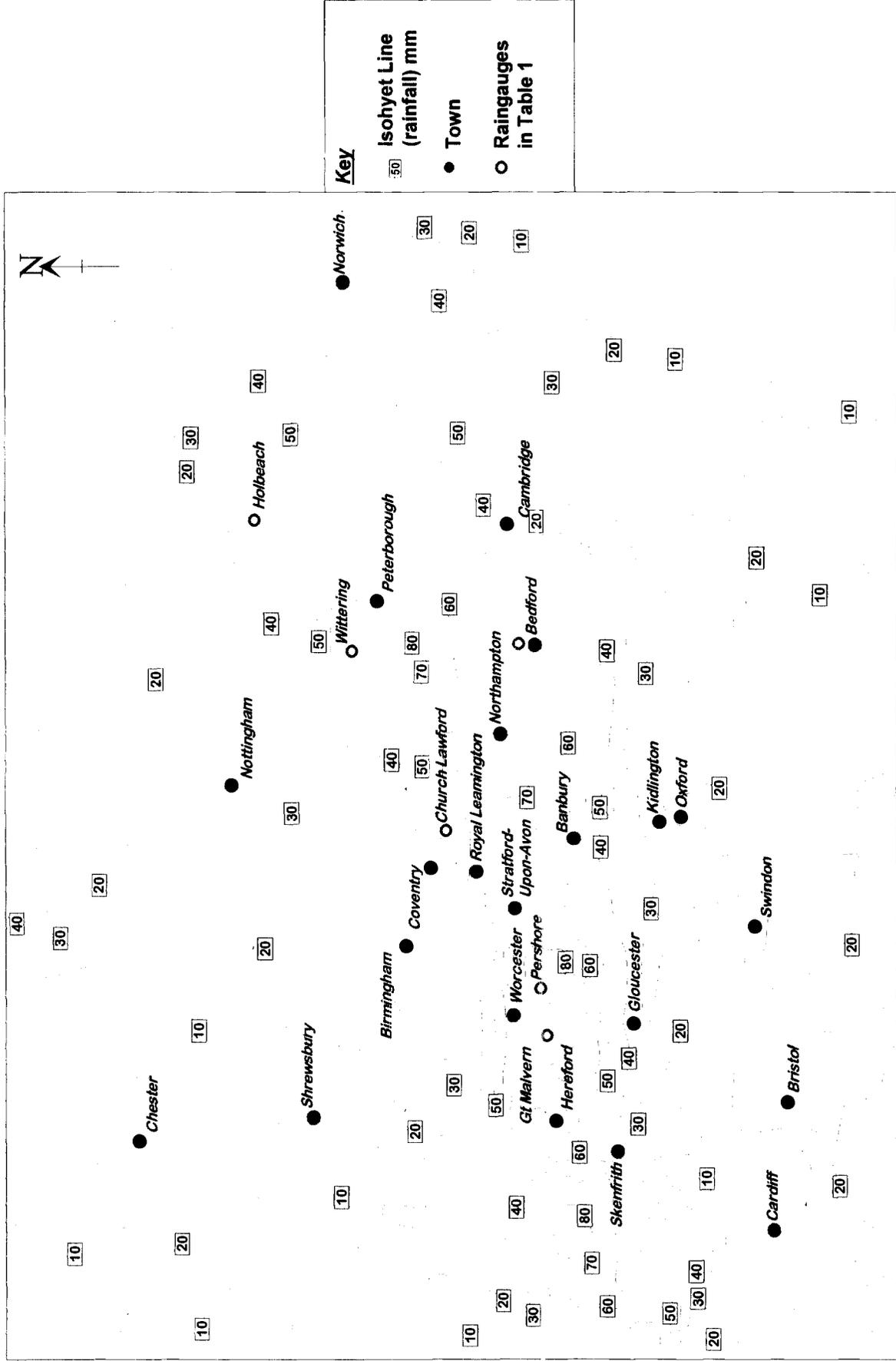
The low had two frontal systems associated with it:-

- A front to its north which marked the boundary of very cold air over northern UK which moved slowly south.
- An occlusion around the low which marked the boundary with warmer air advected north on the eastern flank of the low; this front moved slowly north.

As the southern front moved to the north across southern England on Thursday 9 April, thunderstorms broke out widely ahead of it. These thunderstorms added further intense bursts of convective rain to the pre-existing frontal rainband over central England and Wales. As these two fronts merged, they created a slow moving and intense frontal zone. This resulted in prolonged and heavy rain across central England and into Wales.

Most of the rain fell in a band between 50 km and 100 km wide and about 300 km long, stretching in an east north easterly direction from the Black Mountains in south Wales to north Cambridgeshire. The rain in central England, which led to the most serious flooding, was largely due to the dynamics of the slow moving fronts rather than active thunderstorm cells. The highest recorded totals for the 48 hours were 90 mm near Pershore and 97 mm near Peterborough. The Map below, based on information supplied by the Met Office, shows the rainfall over the 48 hours from 09.00 on Thursday 9 April.

Rainfall for 48 hours ending 09:00 10th April 1998



Based on map and data provided by the Met. Office

The Met Office has provided in the table below an analysis, from their hourly gauges, of total rainfall.

Table 1 - Periods of maximum rainfall

	Start time	Stop time	Period	Rainfall (mm)	Average Rate of rainfall (mm/hr)
Pershore	0600/9th	1900/9 th	14 hr	76.6	5.5
Great Malvern	0600/9th	1900/9 th	14 hr	64.9	4.6
Church Lawford	1100/9th	2100/9 th	11 hr	46.8	4.3
Wittering	1400/9th	1100/10th	22 hr	59.6	2.7
Bedford	1100/9th	2300/9 th	13 hr	37.4	2.9
Holbeach	1600/9th	0700/10th	16 hr	31.6	2.0
Note: The rainfall period has been taken as extending from the first hour with 1 mm or more rain to the last hour with 1 mm or more.					

The persistent, heavy rain on nearly saturated ground caused the rivers to rise at record rates, about twice as fast as previously experienced, to levels as high or higher than any on record. The speed and intensity of the flooding was therefore without precedent in many areas.

3.2. Weather forecasts arrangements

Weather forecasts, based on the best available techniques, are important for establishing states of readiness in the organisations responsible for warnings and responding to flooding. They, also, alert the communities at risk. Consideration follows, therefore, of the arrangements made by the Agency for the receipt of weather forecast information.

Weather forecast services are provided to the Agency by two organisations under term contracts. The Met Office provides differing forms of service to all the Agency regions and the Weather Department Ltd supplies forecasts to the Midlands Region.

Details of the Met Office services to each of the eight Agency regions are tabulated in Section 5.5 and reveal diversity and inconsistency.

Forecasts:

Anglian and Thames receive detailed 5-day forecasts twice weekly with a 10-day ahead outlook. Thames Region also receive a routine fax update daily at 16.00 hours; this covers the expected weather overnight. Some regions purchase a consultancy service and Thames' procedures encourage Duty Officers to discuss, at any time, the weather prospects with local weather centre forecasters.

Welsh Region does not have a contract for the supply of routine forecasts or the Nimrod rainfall forecasts. Twice weekly, it purchases the publicly available 5-day forecasts from the Met Office's Met FAX service and, when rainfall is anticipated, this is obtained daily.

Midlands Region does not receive any routine contracted forecast or warning service from the Met Office. Its routine forecast services are purchased from the Weather Department Ltd., who issue a 10-day ahead forecast daily at 16.00 hours giving rainfall amounts for the next 2 days and daily forecasts for the next 5 days. Midlands has an arrangement for Duty Officers to discuss, when necessary, with the Weather Department Ltd. the daily forecast issued at 16.00 hours.

Warnings:

There are three main types of warning from the Met Office:

- 1) Heavy Rainfall Warnings go direct from Local Weather Centres to Agency regions.
- 2) Severe Weather Warnings go to local authorities direct from Local Weather Centres and to Bracknell for reissue.
- 3) Public Met Service Severe Weather Warnings issued by the National Meteorological Centre (NMC) at Bracknell go to the Thames Barrier.

Heavy Rainfall Warnings can provide advance notification of the likelihood of flood generating rainfall ahead of telemetry alerts of actual heavy rainfall and create useful extra time to monitor the developing situation. All Agency regions except Midlands have arrangements to receive Heavy Rainfall Warnings when Agency defined criteria are forecast to be exceeded. These warnings are issued by Met Office Local Weather Centres to regions directly at any time, day or night.

Midlands Region receives revised rainfall forecasts from the Weather Department Ltd. when defined criteria change, these are issued only up to 23.00 hours. Midlands Region also depends upon Nimrod forecasts and alarms from its network of telemetry raingauges when threshold amounts are exceeded. The Region does not see a need for Heavy Rainfall Warnings. The only warnings that Midlands Region receives from the Met Office are those issued by NMC and sent via the Thames Barrier.

All Regions are recipients of the National Severe Weather Warning Service through the cascade point at the Thames Barrier. Flash messages may originate from the NMC or Local Weather Centre offices. Local Weather Centre Flash Messages are sent to local authorities, police and fire brigades, etc., but not to the Agency. These also go to the NMC, who in turn redistribute them to the Thames Barrier, from where they are passed to appropriate Agency regional communication centres, and on to Duty Officers.

3.3. Easter weather forecasts

It is understood from the Met Office that their Chief Forecaster issued national guidance which identified:-

- *Severe weather for Easter as early as 4 April.*
- *Heavy rain in forecasts for 9 April from early in the week.*
- *Risk of flooding in forecasts from 8 April.*

His discussion of hazards and uncertainties issued at 15.00 hours on 8 April stated:-

“Frontal rain over Wales, Midlands and Southwest England over next 48 hours gives large rainfall accumulations, in excess of 25 mm with peaks of over 50mm in 48 hours over Welsh mountains. Timely warnings to water authorities should be considered”.

His guidance issued at 16.00 hours on 8 April;

“heavy precipitation...has left river levels high...ground saturated...high risk of flooding”.

The national media script stated;

“rain will be prolonged and heavy at times in a band from Southwest England to East Anglia including South Wales, most of the Midlands and southern England”.

The BBC TV forecasts at 21.30 hours on 8 April and at 13.30 hours the following day both contained Weather Warnings and clearly identified “persistent”, “heavy” and “stationary bands” of rain.

The Met Office has supplied details of the forecasts and warnings issued to the Agency and of Severe Weather Warnings; the details are summarised in Appendix B. The forecast information supplied to the Agency lost the impact given in the guidance and did not communicate the potential for significant rainfall as strongly. Two examples illustrate this:-

- The routine twice weekly forecasts issued to Anglian did not emphasise the magnitude of the rainfall for the second half of the week.
- No Heavy Rainfall Warning was issued for southern Wales even though guidance from the Chief Forecaster identified the possibility of 50mm over the Welsh mountains.

The Weather Department Ltd forecasts, summarised in Appendix B, also gave no indication of severe weather or of exceptional rainfall in the following advice:-

- 8 April - occluded front will bring some heavy rain at times, 6-15mm.
- 9 April - occluded front likely to cross the region, outbreaks of rain - some of these heavy, 9 - 20mm.

Anglian and Thames received Heavy Rainfall Warnings from the Met Office at 15.50 hours on Wednesday and at 03.44 hours on Thursday respectively:-

- Anglian - Heavy rain locally greater than 20mm, persistent rain later tonight greater than 20mm, heavy rain expected to continue tomorrow.
- Thames - Slow moving rain band developing, sustained heavy rainfall may result in 20 - 30mm in next 24 hours more especially over high ground.

The more general National Severe Weather Warnings, forecast heavy rain to the south of the area subsequently affected.

3.4. Impacts on people

During the Easter weekend 1998, five people lost their lives directly or indirectly as a result of the flooding. Some 4500 families lost their homes and possessions to the floodwaters. A rough estimate of the cost of the insured losses resulting from the Easter floods, according to the Association of British Insurers, is £300m. Uninsured losses could significantly increase that figure possibly by a further £50m. Even these calculations may prove to be an underestimate when the accounts are closed, but at least it may be assumed that eventually the insured losses will be settled. By far and away the greatest price, however, will continue to be paid, without expectation of early settlement, by the flood victims. These very personal costs are essentially subjective and much more difficult to quantify although no less real in their consequences. The fear of death or injury, loss of confidence, ill health and chronic anxiety will persist for many of the victims long after damage to houses and possessions has been repaired. In this section an attempt is made to convey the experiences that the flood victims vividly recounted in meetings and in correspondence.

Experience suggests that the testimony of the victims of these major disasters is too soon forgotten by those not directly involved. In reviewing the Easter floods, their testimony has been sampled at first hand and from hundreds of letters. If the primary purpose of flood defence, according to the Environment Agency's mission statement, is to protect lives and property then the experiences of those people caught up in the floods must be a key factor in any assessment of performance. More importantly many flood victims have explained their belief that the Agency has listened more attentively to local authorities and other public bodies than it has to them. This is one opportunity for them to place on the record some of their real life stories.

From the flood victims met in groups or as individuals, the predominant reactions some three months after Easter were bewilderment and anger. They were shocked that their lives could have been so devastated by floodwater sweeping away their homes and personal possessions without adequate protection, and angry that this could have happened to them without warning. The questions most frequently asked were "why did this happen to us?" and "could it happen again?" Issues of individual or corporate liability and compensation were raised, although the extraordinary efforts required just putting normal everyday lives together again was draining the physical and emotional energies of many victims.

This sense of exhaustion and loss of purpose was especially noticeable amongst the residents of St James and Far Cotton in Northampton. There, polluted water swept through 2500 properties in two poorer communities at night without warning, causing acute fear of death by drowning or injury and widespread distress. Treasured personal mementoes were destroyed together with essential domestic equipment and furnishings, much of which was not insured. The security of homes assembled over many years was shattered in a terrifying hour or two of cold, wet, pitch-blackness.

From many distressing stories of irreplaceable losses and chronic disruptions, only a few can be used here as illustrations. For example a young mother recounted her anxiety as the fast rising water flooded the first real home of her married life and forced her to entrust her young daughter to a complete stranger during the rescue. She and her husband had just fifteen minutes to move their most valuable possessions upstairs and, in the understandable panic, all their wedding photographs and earliest pictures of their daughter were lost. The experiences of the floods and the daily struggles with insurers, banks, builders and employers that followed and are continuing have placed exceptional strains on the family. The mother's principal concern, however, was how she would tell her daughter as she grew up that she had no photographs of her babyhood.

An elderly widow in poor health, who had not been affected by the worst of the 1947 floods in Northampton, told how she was moved by the Police from her bungalow to her daughter-in-law's home as the floods approached the town. Not suspecting that this time the floods would reach her bungalow, she left everything where it was. When she returned two days later her home was in ruins. The shattering effect on the physical and mental health of that frail lady, who had lost every memento of her life and marriage prior to the flood as well as her home, may not easily be accounted for in any subsequent cost-benefit calculations. Such domestic tragedies, which may be dismissed as unfortunate and unavoidable by some observers, were repeated in hundreds of homes across Northampton and surrounding areas.

On the other hand, a retired man with connections in the building trade was insistent that flooding could not be prevented, that people should be insured against such risks, and individuals really ought to fend for themselves and their families, as he was doing. His views were not typical of those we received during this review.

On a pleasant estate on the outskirts of Worcester *"83 homes were completely ruined and the occupants devastated by the mess and the total disruption"* according to the chairman of the newly formed residents association. Fifty letters from the residents eloquently described the drastic disturbances to normal lives and the filthy conditions left in the wake of the floodwaters.

"It had been very traumatic seeing our home and all the others devastated. The smell from the water was awful, just like a cesspit. Even some 5 weeks afterwards trying to get everything sorted out, work to be organised and the endless list of things that were lost in the flood. I wouldn't like anyone to have to go through this experience again."

"We are also severely critical of the lack of response from the local authorities. From the time we were alerted at 2am to the time we had to wade out with our two children in four foot of water at 9.30am seven and a half hours later, we did not see anyone and no information of any kind was given. Following the event no information has been made available on health and hygiene precautions or possible pollution effects. To date we have only received one leaflet telling us to wash our hands and wear rubber gloves!"

"We have two children and for the past three weeks we have had to endure very basic facilities having lost all our household contents downstairs. The floors have had to be stripped down to the bare concrete and the plaster removed from the walls...and we are having to live with the constant noise of four dehumidifiers and air movers."

These residents were quite clear that theirs was not "*a natural flood*." They believed that the speed of the on-set of the flood and its rapid departure proved that someone (probably employed by the Agency) had opened or closed sluice gates that resulted in their homes being flooded. This feeling that the extent of the disaster could only be explained by human error or negligence - an understandable reaction to the events - was strongly expressed in letters and public meetings in most of the flooded communities across central England. In some places, such as Kidlington in Oxfordshire, Parish Councils, community groups, or individuals have prepared elaborate investigations with detailed analyses running to hundreds of pages. Some of these reports have demonstrated considerable technical competence and excellent use of local knowledge.

As often happens when communities have suffered in extreme events, new leaders, lobby groups, and self-help support arrangements have emerged around the most seriously flooded sites. In Leamington, both St Mary's Church and the Old Town Council, amongst others, have provided pro-active leadership and lobbying. In Northampton, the churches in St James and Far Cotton have provided invaluable emotional and material support to the victims whilst new residents associations have combined to exert local and national democratic pressure for improvements to flood defence in the town.

These new community initiatives arising from the devastation of the Easter floods, often working alongside Members of Parliament and local councillors, represent, for the most part, a healthy determination to prevent any recurrences and to return life to normality. This "*Dunkirk Spirit*", as it was described on many occasions, is heartening and constructive. It should not be allowed to diminish the grievous suffering experienced by many very vulnerable people during and since the floods, people who probably do not wish or who do not have the means to engage in community actions.

4. EXTENT AND SEVERITY

4.1. Purpose of assessment

The primary purposes for the Agency's work on extent and severity are concerned with its: provision and operation of flood warning and defence; advisory role on development planning; and general supervision of flood defence. In short, the work is fundamental to management of the function.

Development related advice given by the Agency reflects the organisation's commitment to a sustainable environment. The World Commission on Environment and Development defined sustainable development as that which "*meets the needs of the present without compromising the ability of future generations to meet their own needs*". This definition is self evidently relevant to the importance of defining, in order to preserve them, flood plains as undeveloped areas, and to managing flood risk in relation to those parts that have been developed.

The Government has estimated that an additional 4.4 million new homes will be required by the year 2016. The Agency has pointed out that this represents an urban expansion equal to four times the size of Birmingham, and that pressure for development on flood plains will grow as a consequence. Furthermore, the expansion of impermeable paved areas, whether on or above flood plains, will increase flood risk generally.

4.2. Approach

Identifying flood plain extent is a prerequisite for operating in accordance with the Agency's declared policy and practice. Observing and recording the inundation caused by an extreme flood is the most reliable means of identification. With the analysis of recorded hydrological data, this approach affords an appreciation of flood plain limits at an estimated low probability.

If there is no information on actual flooding, hydraulic modelling combined with precise topographical surveying, is an alternative or additional method of defining a flood plain. Physical hydraulic modelling is rarely appropriate because of the high cost, but computational modelling is more economic. The latter is reliable providing flow behaviour is not too complex and good quality data are available for model proving.

Flood plain maps for a river basin may be based on a single recorded event, or they may be composites of more than one event, either recorded or modelled.

It will be appreciated, therefore, that the Easter floods afforded a rare opportunity for the Agency to gain understandings of flood vulnerability which could enhance its operational advisory and supervisory activities. Consideration follows as to whether, from the standpoints taken by the Review, proper advantage has been taken of this opportunity.

4.3. Recording extents

In addition to conventional surveys, photographs and videos (taken from the ground and air), press reports and anecdotal evidence have all been used to advantage. Information of value has been given by other organisations, local authorities in particular, and the people whose homes and workplaces were affected.

There appear to be no guidelines or procedures issued nationally or regionally relating to establishing and recording the extent of a major flood. However, custom and practice appears to have afforded soundly based work at most of the locations of main river related flooding.

4.4. Flood severity estimation

The assessment of the probability of a flood is not straightforward. The measurement of flow is particularly difficult for very large floods when rivers are flowing across fields, down roads and through peoples homes. A large flood may, as happened at Easter, drown the recording equipment and prevent measurement of flow and rainfall.

The calculation of severity statistics is complex. The Institute of Hydrology developed a range of standard procedures in the Flood Studies Report (FSR). The FSR is the authoritative guide to flood estimation for the UK. Supplementary reports have provided updated guidance. The techniques take account of the length and type of data available and are the result of the comprehensive and extensive studies undertaken 30 years ago using all suitable rainfall and runoff data. The Institute are currently producing a new Flood Estimation Handbook, which will be published next year.

Studies of severity have not been undertaken directly as a part of the Review because these would have replicated work being carried out by the Agency or its consultants. However, the adequacy of this work has been appraised, and independent guidance sought from experts at the Institute of Hydrology on the appropriateness and application of the different methodologies.

A complementary approach, to analysing flood flows, is to study the rainfall data. This can be more straight forward than the assessment of river flows as there are more and longer records of rainfall. However, probabilities assessed from rainfall and those from river flow, rarely, if ever coincide. The hydrological cycle is a complex process, rain falling on a catchment may be intercepted by vegetation, absorbed by the soil, infiltrate into sub-strata, impound in reservoirs, lakes and ponds etc.. This means that the rate and amount of rainfall converted into river flow on a catchment changes from storm to storm as a result of the antecedent conditions. There is, therefore, no simple relationship between rainfall and runoff and, consequently, no direct correspondence between the severity of the causative event (rainfall) and its consequence (river flow / flooding).

One of the particular features of the Easter floods was that the catchments were already very wet and reservoirs full from the above average rainfall in and before March and the heavy rainfall in the first week of April. As a consequence, there was a reduced capacity to absorb rainfall and a greater proportion of the rainfall than normal was quickly converted into runoff causing rivers to rise very rapidly.

Rainfall severity:

All the analyses of rainfall data, both by the Agency and the Met Office, have used the methods developed for FSR. The Met Office has a rigorous data quality control process and their assessment of severity, which is quoted below, has been undertaken on quality controlled data.

Table 2:-Rainfall totals over various periods

	Highest 1hr total	Highest 2hr total	Highest 3hr total	Highest 6hr total	Highest 12hr total
Pershore	10.4	20.6	28.0	49.0	73.2
Great Malvern	10.0	17.1	23.9	39.0	61.4
Church Lawford	11.4	17.2	24.8	39.6	47.2
Wittering	6.4	11.2	15.2	24.2	41.6
Bedford	6.2	12.0	15.0	19.2	36.4
Holbeach	6.4	9.2	11.8	21.6	26.8
The highest rainfall totals in mm recorded during the event for periods of 1, 2, 3, 6, and 12 hours are given for each Met Office station					

The highest daily totals for this event are over 60 mm in places near Stratford-upon-Avon and rise to over 70 mm near Peterborough. Such totals as these are very rare in April; they are more commonly associated with convective storms in summer. The highest April daily totals in the Midlands during the 30 year period from 1961 ranged from 24 to 42 mm. Over the year as a whole in the Midlands, a 24 hour rainfall total of around 75 mm has a 1 per cent probability. Most of the rain on this occasion appears to have fallen in a period ranging from about 14 hours at Pershore to about 22 hours at Wittering. The probability for 77mm rainfall in 14 hours at Pershore is much less than 1 per cent.

Flood severity:

During this event, no situation has been identified where the peak flow was measured to a high accuracy with absolute confidence. In Anglian Region, the flow stations designed for low flows were quite unsuitable for flood flow measurement. Estimates of flow have been made using hydraulic analysis, but for one site the range embraced an upper flow estimate over twice the lower. In many locations, the level equipment could not record the highest part of the flood. In Midlands and Thames Regions, flow stations were visited soon after the peak flow had passed and current meter gaugings taken, which enabled the peak flows to be estimated with moderate confidence.

There is only a single situation - Leamington - where a long data set on past floods has been subjected to appraisal, the history of flooding investigated, and a comprehensive frequency analysis undertaken.

At another site, the conclusion has been that the flood severity can only be estimated from point rainfall in the middle reaches of the catchment as no gauges were located in the headwaters. Consequently, the true severity of the flood generating rainfall over the uplands cannot be assessed.

An alternative approach has been used in some cases, namely to compare the actual flows with those produced for 1 per cent probability floods in modelling and design studies. However, it is considered that caution is required with this approach. Reservations about computational hydraulic modelling are discussed elsewhere. There is also a danger of perpetuating errors, by using the results from previous probability analyses, which may themselves be based upon estimates, when assessing both the flow and its severity for the Easter flood.

In view of the foregoing, the majority of the estimates of severity need to be heavily qualified. The best estimates for the special study sites follow.

R Nene - Northampton

The lack of a reliable measurement on the Nene upstream of Northampton and problems in estimating flows, make it difficult to ascribe a severity to the flood. (Estimates of peak flow are in the range 170 - 200 cumecs.) Comparison with earlier studies indicates an event with less than 1 per cent annual probability of being equalled or exceeded (return period longer than 100 years).

A number of gauges were unable to record the full extent of the rainfall and the available data does not indicate the true severity. The most extreme rainfall recorded upstream of Northampton has been estimated to have 2 per cent annual probability (50 years return period). It is reasonable to conclude that a complete set of data would have indicated more extreme conditions.

R Leam - Leamington

Data for Leamington have been subjected to detailed scrutiny, including a survey of historic floods from as early as 1735. The flow was physically measured about 0.02 metres below the peak. The Easter 1998 flood is the highest known, its severity has been assessed as having a 0.57 per cent annual probability (175 years return period). The floods in 1932 and 1900 have been determined as the next highest this century, with 1932 levels only marginally lower than at Easter.

The most extreme rainfall event measured by the Agency was 68.5mm in 15 hours which has a less than 1 per cent annual probability (longer than 100 years return period). This is consistent with Met Office data and the analysis for Pershore.

R Cherwell - Kidlington (and Banbury)

Only data from the Banbury flow gauging station were assessed as suitable for direct analysis. The peak flow has been estimated from data collected on site. Estimates made by the Agency indicate less than 1 per cent annual probability (100 years return period or longer). On the Lower Cherwell, a current meter gauging of flow was made at Marston Ferry Road Bridge in Oxford (this is downstream of the confluence with the River Ray) close to the time of the peak. This flow was 5 per cent greater than the 1 per cent annual probability design flow for the bridge crossing, supporting the assessment of flow at Banbury.

The Agency estimate that rainfall for any duration had a 2 per cent or greater annual probability (50 years return period or longer). The most extreme event reliably recorded was 57.8mm in 12 hours (2.6 per cent annual probability - 40 years return period). However, one rain gauge was reported to be 1.5 metres under the flood water and it is reasonable to conclude it would have measured a more extreme event had it continued to operate.

R Monnow - Skenfrith

The most extreme rainfall was 73 mm in 24 hours with a 3 per cent annual probability. The peak flow was of similar magnitude to three others experienced over the last 49 years. Flood frequency analysis concluded that the 1998 event has a 3 per cent annual probability (30 years return period).

4.5. Section 105 flood plain mapping

The Agency's publication "*Policy and Practice for the Protection of Flood Plains*" explains the Agency's policy objectives and the associated environmental and sustainable development issues. Powers and responsibilities at government, Agency and local authority levels are described together with the related instruction and guidance. The Agency's specific flood plain policies are stated and explained, and the concluding section outlines how these are put into practice. The advisory nature of the Agency's involvement with the responsible local planning authorities is explained in relation to both development plans and individual development proposals.

Section 105(2) of the Water Resources Act 1991 requires the Agency (as the successor to the NRA) to undertake surveys for the purpose of defining flood risk areas. Considerable work has been undertaken on these surveys, but with approaches and rates of progress differing between regions, the exercise is far from complete nationally.

Guidance to planning authorities concerning the requirement for consideration of flood risk is given in the Department of the Environment Circular 30/92, Welsh Office Circular 68/92 and MAFF Circular FD 1/92 and MAFF's "Strategy for Flood and Coastal Defence in England and Wales". The Agency's policy and practice publication accords with the guidance criteria.

The objective, in relation to non-tidal rivers of the Section 105 surveys, is to define flood plain limits associated with a 1 per cent annual probability (return period of 100 years). Recognising that there are uncertainties in the hydrological and hydraulic analyses determining flood plain definitions, Circular 30/92 declares that surveys should be regarded as *---indicative rather than specific---*. This acknowledgement of imprecision underlies the requirement for planning authorities to consult the Agency on specific applications.

The objective of defining flood plain extents for events of 1 per cent probability does not accord well with the Circular's requirement for indicative rather than specific definition. Furthermore, there are uncertainties associated with flood plain mapping arising from the limitations of flood hydrology and hydraulic concepts and theory, as well as the possible effects of climate change. These uncertainties justify questioning the scientific soundness of the Agency's current response to Section 105(2) of the 1991 Act. The answer initially evident is that it is not sound in some situations and that the defined extents are often no more than crude estimates. This occurs particularly where hydraulically complex urban reaches have been computationally modelled, whereas the assignment of a specific return period implies a spurious notion of precision.

A flawed technical basis to the computational modelling approach to flood plain mapping may be masked by the presence of steeply sloping valley sides at the flood plain boundaries associated with extreme conditions. As a consequence, a mapping study may appear, at first sight, to justify the modelling approach. Closer examination could reveal, however, inaccuracies due to a situation which is too complex hydraulically for reliable analysis by computational means.

In situations where valley sides are less distinct, large errors in flow depth prediction would, of course, be reflected in substantially inaccurate positioning of the flood plain boundary.

With regard to the computational modelling of long rural reaches with occasional and hydraulically simple structures, the evidence from Easter, although somewhat subjective, is that flood plains in these situations are defined with reasonable accuracy.

4.6. Indicative mapping of flood potential

The foregoing comments lead to the conclusion that flood plains should be defined, indicatively, in a manner that acknowledges the hydrological and hydraulic uncertainties. The conceptual framework on land slip potential and development planning, produced for the Welsh Office, is an approach that could be applicable to flood potential. Recent work by the Institute of Hydrology on a computer generated flood risk map, together with research on topographical and soil science based methods would also appear to merit consideration. The main features of an alternative approach incorporating aspects of the foregoing would involve:-

- the Agency advising planning authorities of flood potential on the basis of maps showing:
 - (a) **known flood risk areas**, defended and undefended, established from recorded events;
 - (b) **possible flood risk areas** established by approximate modelling of topography, soil characteristics or arbitrary methods.
- Developers being required to take full responsibility for confirming flood risk at proposed sites as well as the implications for vulnerable upstream and downstream areas.

4.7. Contractual obligations of consultants

The numbers of experienced specialists on flood hydrology and hydraulics employed in the Agency's regions, are less than they were in the predecessor organisations. The Agency is, as a result, more dependent on consultants for providing expertise in these fields and exercising their judgement about the soundness of the technical approach.

It would seem prudent for the Agency to better reflect these circumstances in the contract terms for the appointment of consultants, by framing the contracts for flood hydrology and hydraulic studies, so that:

- the required study outputs are fully and unambiguously identified;
- responsibility for applying sound science and correct technology to achieve the outputs, rests fully with the consultant and is not reduced by a constraining specification;
- the consultant provides and maintains professional indemnity insurance sufficient in scope and amount in relation to damage claims which could arise from negligent performance through failure to provide soundly based services (£5m to £10m professional indemnity insurance on an each and every claim basis would be appropriate and in line with cover for flood defence design and contract management services).

By commissioning work in this way, there would be less likelihood, for example, of the Agency bearing the cost and liability consequences of the misapplication of computational hydraulic modelling. It would, in addition, encourage consultants to respond to their increased risk by introducing greater expertise into modelling work which might otherwise be mechanistic.

4.8. Interests of the public and other authorities

The extent and severity issue is relevant to the public in terms of the contributions made to flood plain development planning, flood warning, flood risk management and the provision of defences. It is considered that these interests have, in the main, been adequately met by the assessments of the Easter flooding.

The quality of the Agency's advice to planning authorities is improved by the understanding gained of flood behaviour at Easter. Similarly, future interfacing with the emergency services in the event of comparable flooding will be more effective as a result of these understandings. The publication *Policy and Practice for the Protection of Flood Plains* comprehensively and clearly explains the context for post flood extent and severity work. The Agency's performance has been good from this standpoint.

4.9. Attention to statutory guidance

Requirement to operate on the basis of sound science:

The estimation of flood probabilities has been variable in method and standard. Although generally scientifically well founded, inconsistency of approach, duplication between in-house and consultants and lack of direction by experienced flood hydrologists, are detrimental features.

There are examples of the use of computer packages where data have been wrongly analysed and it appears that the work was inadequately supervised by more experienced staff. Consequently, some preliminary analyses produced immediately after the flood were invalid. It is evident also that in certain cases the arrangements for measuring flows are inadequate and prevent the application of sound science.

For the reasons explained in Section 4.7, the application of computational hydraulic modelling is scientifically unsound on certain, usually urban, river reaches and erroneous flood plain definition may result.

Requirement for value for money:

Efficiency is evident in most aspects of extent and severity work, but would be enhanced by standardising procedures and conducting hydraulic studies with greater regard to approaches acknowledging flow complexity.

Value for money in connection with Section 105 flood plain mapping is at best unproven because it is unclear whether complex expensive approaches are a better basis for development planning than simpler and cheaper methods acknowledging approximation in the scientific techniques employed.

Requirement for holistic environmental management:

The Agency's work properly contributes to the attainment of this aspect of statutory guidance.

Achieving national consistency:

The absence of standard national guidelines for the various aspects of extent and severity work is not encouraging consistency. Also, Section 105 flood plain mapping appears to be variable in standard.

5. FLOOD WARNING

5.1. Purpose

In essence, the purpose of flood warning is to provide advice which permits those people vulnerable to impending flooding to take actions which lessen the consequences of inundation, should it be experienced. In literature for the public, the Agency states that it *---operates a flood warning system across much of England and Wales. From September 1 1996 it will take the lead role in passing warnings to people who are at risk, so that they can take action to protect themselves and their properties.*

Warnings are required by:

- people who live, work or are temporarily in the areas at risk;
- organisations with responsibilities for responding to the flooding before and after its onset.

For people living and working in flood risk areas, it would appear from independent surveys, commissioned by the Agency, that their expectations in respect of warnings are for:

- confirmation of the flood risk;
- awareness of the arrangements for the issue of warnings;
- receipt of warnings sufficiently in advance of flooding - at least 2 hours - to permit effective action to protect themselves and their property;
- appreciation of the likely severity and timing of flooding from onset to cessation;
- communication links facilitating discussion about and updating on, an issued warning.

People temporarily in the risk areas include those at caravan sites and in boats. The Easter flood tragically demonstrated the magnitude of the risks and the devastating effects on caravans and boats. Whilst the needs of these people are similar to those above for individuals living and working in the risk areas, greater emphasis should be placed on prior awareness and the effective communication of strongly worded warnings prompting rapid evacuation.

The needs of the emergency response organisations are essentially the same as those of the public but with information specific to their functions and earlier warning to enable them to prepare and mobilise.

5.2. Approach

On 1 September 1996, the Agency took on the lead role from the police for disseminating flood warnings based on arrangements existing at that time. Prior to this date, the Agency and its predecessors had taken the initiative in preparing warnings of flooding from rivers and watercourses designated as main river, with the police playing the key part in the dissemination of warnings to the public.

The role now performed by the Agency covers:

- receiving weather forecasts and interpreting the potential for flooding;
- monitoring rainfall, river and tidal conditions;
- forecasting and monitoring floods;
- interpreting the likely impacts of floods on identified 'at risk' areas;
- constructing and communicating messages about likely impending flooding to people in the identified risk areas and to the emergency response organisations;
- alerting local authorities of impending flooding to areas previously identified as serious flood risk hazards.

The Agency's power to provide and operate flood warning systems is permissive and not a statutory duty. The Ministerial direction given to the NRA in March 1996 and now applying to the Agency relates to the manner in which flood warning is to be provided when this power is exercised. The Agency's fluvial flood warning services apply to flooding from rivers and watercourses designated as main river, and not to flooding from other reaches of the natural drainage systems, commonly referred to as ordinary watercourses. However, there is no legal restriction preventing the Agency from providing and operating a warning service for any location.

The Agency issues warnings in two ways:-

- Directly to the communities at risk using local flood wardens, sirens and/or telephone calls - mainly automatic voice messaging (AVM) - or through the police.
- Through the media - local radio, teletext and weather forecasts (but not always in the main national radio and television weather forecasts).

Additional information on the flood condition of rivers and status of warnings is available from FLOODCALL - a 24 hour 'dial and listen' recorded information service provided by the Agency for England and Wales.

With regard to the AVM service, some people in at risk areas decline the offer of connection, and coverage of vulnerable communities may be incomplete as a consequence.

Irrespective of the manner of issuing, all warnings are colour coded:-

- | | |
|----------|---|
| Yellow - | warning of flooding to some low lying farmland and roads. |
| Amber - | warning of flooding to isolated properties, roads and large areas of farmland. |
| Red - | warning of serious flooding affecting many properties, roads and large areas of farmland. |

The Agency's document " *Flood Warning Strategy for England and Wales 1997/1998 to 2001/02*" is at final draft stage. The strategy establishes plans for improving the warning services currently provided and the intention is that future capital expenditure programmes will feature the identified projects and expenditures.

In support of the Agency's principal aim for flood defence - *to provide effective defence and warning systems to protect people and property against flooding from rivers and the sea* - specific objectives and targets are set out in strategy and policy documentation. The key commitments relating to fluvial flood warning may be summarised as:

- providing accurate warnings;
- issuing warnings at least two hours before flooding commences;
- achieving a success rate for the receipt of warnings of 65 per cent in 1998 and 80 per cent in 2001 in those areas where a service operates.

The Agency commendably commissions independent surveys in order to objectively investigate the public's attitude towards, and satisfaction with, flood warning services, and to assess the degree to which its objectives are attained. To date, these surveys are of:-

- A nationally representative sample of about 900 adults in England and Wales.
- Approximately 950 properties randomly selected from 180,000 defined by the Agency as located in flood risk areas.
- Samples of properties in areas affected by flooding.

A survey of the Easter floods is understood to be in progress but the findings have not been available in time for consideration by the Review.

5.3. Warning system principles

Research by the Flood Hazard Research Centre (FHRC) at Middlesex University and best practice in other countries has identified the importance of adopting a total systems approach to flood warning in the form of a Flood Forecasting, Warning and Response System (FFWRS). This approach has been well developed in Australia where the production of "*Flood Warning: an Australians Guide*" has been used to describe a set of 'best practices' and inform all those involved, in many different agencies, about the design and operation of flood warning systems. The World Meteorological Organisation also used the same approach for improving flood warning dissemination in Bangladesh and both of these examples have been drawn upon by the Review.

The principal components of an integrated FFWRS are:-

- **Forecasting**
Monitoring, data measurement and collection and modelling.
- **Interpretation**
Identifying the impacts of forecast river levels and constructing messages.
- **Dissemination**
Distributing and communicating warnings.
- **Response**
Achieving action to minimise the impacts of flooding.
- **Review**
Evaluating, updating and developing improved and more effective services.

It is important to keep a clear distinction between *forecasting* (i.e. predictions of river flows), *impacts* (i.e. extent of flooding) and *warnings*, namely the message advising of the flood risk.

In the submission to the Review from the FHRC, the results of the Centre’s research in the UK is summarised. The main finding was that flood warning dissemination frequently failed to reach, in a timely manner, a large proportion of the target flood plain population. It is stated that the principle challenge in flood warning lies not so much with the science of forecasting and modelling, but with the ‘social and behavioural science’ of risk communication and warning recipient response. Also, that many of the problems faced by the Agency at Easter are well recognised but still need to be addressed by improved policies and procedures.

The FHRC submission to the Review is summarised in Appendix C.

5.4. Optimum weather forecast arrangements

At the request of the Review Team, the Met Office has advised on what it regards as the model weather information service which would best support fluvial flood warning. The model adds value to some data already collected by the Agency’s real-time transmission to the Met Office for use in their systems to improve rainfall forecasts. Another valuable gain would be a better, common understanding of the prevailing weather conditions. Two of the most advanced flood forecasting systems overseas (in Australia and USA), are fully integrated within the meteorological service and benefit from direct consultations and shared data sources.

The service proposed by the Met Office is described in Appendix D.

5.5. Flood forecasting

The Review enquiries have revealed that some organisational and technical issues may have inhibited the issue of effective warnings.

The lack of organisational similarity between regions appears unhelpful for the attainment of high and nationally consistent forecasting standards. The arrangements for the four regions affected at Easter are:-

Table 3 - Issue of flood forecastings/warnings - variation in regional arrangements

Region	Flood Forecasting		Issue of Warnings	
	Region	Area	Region	Area
Anglian		X		X
Midlands	X			X
Thames	X		X	
Wales		X		X

In all regions, the primary information for forecasting comprises data from: telemetry linked rain gauges and river level/flow stations; weather radar; and (except Welsh) numerical rainfall forecasts from the Met Office. Not every region is able to access the rainfall data collected by neighbouring regions' telemetry systems. Access to data across the boundaries of the three English regions would have provided a more comprehensive picture of the common critical rainfall event, which caused the flooding at Leamington, Northampton, Banbury and Kidlington. Flow and rainfall information is supplemented in some regions by other climatological variables and data sets. Weather forecast services are provided by the Met Office to the Agency's regions as follows.

Table 4:-Routine Met Office Services to Environment Agency Regions for Fluvial Flood Forecasting

	Welsh	Thames	S.West	Southern	Midlands	N.West	N.East	Anglian
1	X	X	X	X	X	X	X	X
2		X	X	X	X	X	X	X
3		X						
4							X	X
5	X	X	X	X	X	X	X	X
6						X		X
7		X				X		X
8				X				
9		@	X	X		X	#	
10	X	X	X	X		X	X	X
11		X	X	X		X	X	X
12	X	X	X	X	X	X		X
13		X						
14		X	X					
15			X					

Notes: # Transfer direct to Agency by PC to PC link for Yorkshire Areas only @ For overnight weather
 Midlands obtain items 8,9 and 11 from Weather Department Ltd.
 All regions receive Flash Warnings of Severe Weather via Thames Barrier

One of the regions unaffected at Easter considers it advantageous to hold a daily conference (regardless of weather conditions) between their Duty Officer and the local weather centre forecasters at around 17.00hrs. Other regions (apart from Thames) prefer to rely upon ad-hoc conferences when judged necessary by the Flood Warning Duty Officer.

The justification for frequent contact is that:-

- (1) Agency Duty Officers establish first hand the nature of the overnight weather and gain a full appreciation of any uncertainties which face Met Office forecasters.
- (2) Agency staff can indicate to forecasters when catchment conditions are sensitive to further rainfall and indicate critical amounts.
- (3) Dialogue develops an understanding of each others tasks and a strong working relationship is established.
- (4) This relationship is useful during severe weather and flood events when both groups may be working under pressure.

Flood flow forecasting relies upon upstream flow, or rainfall over the catchment, or a combination of both, and in some cases these may be supplemented by the numerical forecasting of rainfall to give a longer lead time. The simplest form of flow forecasting relies upon a correlation between an upstream level measurement and that at the point of risk. Transfer function models use simple mathematical relationships to convert rainfall into flow, whilst the most sophisticated models involve a computationally complex conceptual model to represent the physical process of the catchment.

Transfer function models are typically used where lead times are short and the catchment processes can be represented by a few parameters. Conceptual models are used on larger complex catchments in which individual sub catchments may not all behave in the same way or receive the same rainfall and must be individually represented.

All forms of model are used by the Agency and the explanations for the varying approaches appear to be historic rather than rationally related to differing catchment conditions and forecasting requirements. The Agency has recognised this and has initiated an R&D project to compare different flood forecasting models for a range of catchment types. The project will produce a guide to which models work best and in what circumstances.

Two of the four regions incorporate radar data into their forecasting models. Midlands are evaluating the incorporation of 6-hour ahead rainfall forecasts from the Met Office Nimrod system. Thames use a short term rainfall prediction system developed by the Institute of Hydrology in addition to the qualitative use of Nimrod forecasts and are assessing another Met Office system - GANDOLF - to predict severe convective rainfall.

Forecasting in Midlands Region relies mainly upon conceptual models, which have been developed in house over many years. Anglian Region use transfer function models, often based on unit hydrographs developed in the early 1980s, coupled with level to level correlations. Welsh Region has a conceptual model for the Wye, but, in the main, relies upon upstream river levels as the trigger to issue warnings. Thames Region have a range of modelling techniques. In the case of the River Cherwell and forecasts relevant to Banbury and Kidlington, models have been developed but are not yet operational. Hence, no flow or level forecasts were made at Easter and warnings were issued on the basis of the exceedence of thresholds on monitored river levels.

The models used on the River Nene were developed nearly 20 years ago as part of a modelling exercise to study flood defence design standards and are inappropriate for the forecast of extreme floods. They do not explicitly take account of reservoirs in one sub-catchment or of the hydraulic response of the other sub-catchment at very high flows and these inadequacies are enhanced by poor measurement of high flows. Further weaknesses in relation to the upper reaches of the Nene appear to have arisen because of sparse rain gauge coverage and flow stations which were bypassed by high flows and failed at an early stage due to the submergence of equipment.

In all four regions, a major factor affecting ability to give timely warnings was the exceptionally rapid rates of rise of the rivers, due to the fast response of the catchment caused by the saturated ground and heavy rainfall. The catchments were already very wet following above average rainfall in March and the rainfall in the previous week. As a result, there was little or no capacity for the ground to absorb rainfall and a higher proportion than normal was quickly converted to runoff. These rapid rises were not forecast in any region.

Forecasting models had not been calibrated for fast response conditions, as no prior data were available. In one case, the models consistently predicted the time of the peak 6 to 7 hours after it occurred but had been predicting the peak level to within 0.2 metres for more than 7 hours ahead.

Calibrating models to forecast events more extreme than those hitherto experienced always presents a problem as the required data are unavailable. Nevertheless, it is important to anticipate that events more extreme than those already experienced will occur. One way of dealing with this is to test the models with extreme values of artificial input data and to study the model outputs to see if the forecasts are credible. This requires experience and judgement but is worthwhile to lessen the chance, on some future occasion, of model under performance as experienced at Easter.

Regions have different timetables for the running of forecasting models. At one extreme a region, which did not experience the Easter floods, has simple models running automatically after every 15 minute telemetry data scan, whilst Midlands Region runs its complex models routinely once per day and then initiates more frequent operation during a flood event.

In Midlands Region, logistical considerations limit forecasting model runs to a maximum of once per hour because data are produced for a large number of sites. The forecasting duty officer was working from home overnight on 9/10 April in two regions and would have benefited from assistance and the full range of office facilities to monitor river levels and assess forecasts.

The need to have streamlined data presentation was identified in the NRA research reports produced by Dr C T Marshall. In 1991, he stated “ *It is important to ensure that duty staff are not presented with more information than they can assimilate and act upon at peak times.* ” In 1996, he drew parallels between flood warning and avionics, in particular TCAS traffic and collision avoidance system as both deal with comparatively rare events. TCAS processes complicated information and presents just the necessary amount of information for warnings and advice on actions.

5.6. Warning chronologies

The chronologies in Appendix E have been prepared of the monitoring, forecasting and warning activities of the Agency for the four special study sites. They provide an overview of the weather information available to duty flood forecasters and of the progression of the event. The information collected has highlighted different practices and operating arrangements across the four regions. They identify a number of procedural matters which require attention and provide a basis for identifying opportunities to develop best practices for the enhancement of future forecasting and warning performance. They also confirm many of the issues highlighted in the Flood Warning: Baseline Survey of February 1997, a selection of which are reproduced in Appendix F.

The use of warning times expressed in GMT rather than BST, was another problem causing confusion in one region.

The flood event may be considered to have started when the first Heavy Rainfall Warning was issued to Anglian Region by the Met Office at 15.50 on Wednesday 8 April. Thames received one at 03.44 on Thursday. The initial alarm in Midlands was raised when their Duty Officer was alerted at 07.27 on Thursday 9 April by the results of the routine daily forecast model run, based on data collected at 07.00; this forecast a Yellow flood threshold. Welsh Region did not receive any Heavy Rainfall Warnings and began active monitoring at 10.00 on Thursday 9 April.

Summaries of the chronologies for the special study sites are as follows:

Northampton:

- 11.59 09/04 - 20 mm rainfall reported by telemetry alarm
- 15.30 09/04 - Flood control Room opened
- 15.45 09/04 - First Amber warning issued on R Nene
- 16.25 09/04 - First Red warning issued on R Nene
- 17.00 09/04 - Hourly forecasting of flows commenced
- 23.00 09/04 - 109 cumecs predicted (cf Red warning trigger of 125cumecs)
- 00.00 10/04 - First reports of flooding in Northampton
- 07.00 10/04 - Agency advised by Emergency Planning Officer of evacuation

Leamington:

- 08.00 09/04 - Area office commenced flood warning operations
- 08.30 09/04 - Flood forecasting commenced in Regional office
- 09.38 09/04 - 18mm rainfall reported by telemetry alarm
- 11.00 09/04 - Model run predicts Yellow threshold at 23.30 and Red “overnight”
- 15.00 09/04 - Model run predicts Yellow threshold at 16.30 and Red “overnight”
- 15.54 09/04 - Yellow warning issued
- 17.00 09/04 - Model run shows Amber threshold already exceeded
- 17.02 09/04 - Amber warning issued
- 18.00 09/04 - Flood forecasting duty officer operating from home
- 23.00 09/04 - Model run predicts Red threshold at 06.30 10/04
- 23.18 09/04 - Red warning issued
- 00.00 10/04 - Red threshold exceeded at Eathorpe gauge
- 04.30 10/04 - First report of flooding in Leamington

Kidlington:

- 08.30 09/04 - River Control Room opened at Regional office
- 10.30 09/04 - Yellow warnings issued for R Cherwell reaches 1 & 2
- 15.10 09/04 - First report of flooding in Cherwell catchment
- 17.00 09/04 - Amber warning issued for R Cherwell reach 1 (Banbury)
- 18.30 09/04 - River Control Room closed (Duty Officer operating from home)
- 22.30 09/04 - Amber warning issued for R Cherwell reach 2 (Kidlington)
Red warning issued for R Cherwell reach 1 (Banbury)
- 03.00 10/04 - Estimated peak level in Banbury
- 09.30 10/04 - River Control Room opened at Regional office
- 14.45 10/04 - Red warning issued for R Cherwell reach 2 (Kidlington)
- 18.30 10/04 - First report of flooding in Kidlington

Skenfrith:

- 10.00 09/04 - Duty Officer begins active monitoring
- 14.05 09/04 - Yellow warning issued for R Monnow (Monmouth & Skenfrith)
- 15.30 09/04 - First report of flooding (from surface water) at Skenfrith
- 18.28 09/04 - Amber warning issued for R Monnow (Monmouth & Skenfrith)
- 19.00 09/04 - Further flooding of property
- 19.11 09/04 - Red warning issued for R Monnow (Monmouth & Skenfrith)

The full chronologies confirm that the events developed quickly and that significant amounts of rain had fallen overnight on 8/9 April. The rainfall for the previous day is not always automatically available to some forecasting Duty Officers, unless it exceeds a predetermined threshold amount. This rainfall information may only have been available if the Duty Officer initiated a poll of the telemetry.

It would appear that the true severities may not have been fully appreciated, even though indicative information was potentially available. It is a recognised feature of human nature that the initial response to emergencies is to play down the severity early in an event and this appears to have been the case. It is apparent, with hindsight, that there should have been a greater sense of urgency together with the fuller deployment of resources on 9 April for flood monitoring and forecasting.

Procedures for logging and disseminating weather warnings issued by the Met Office are deficient. It has not been possible to audit trail some messages within the Agency. There can be a lengthy chain and when occurring this needs to be shortened to remove delay and the opportunity for messages to be lost.

Due to the way Severe Weather Warnings are transmitted to regions, the potential for confusion arises from the Agency and local authorities not receiving the same weather warnings. This was a concern to the emergency planners in one county.

The Agency has arrangements with the Met Office for the issuing of Amber and Red warnings to Local Weather Centres for use in regional radio and TV weather forecasts. The Agency may also, when it is considered appropriate, issue these to the BBC Weather Centre and to International Weather Productions (for ITV). This would usually be when flooding is likely to be widespread or serious. It is apparent that there were inconsistencies between regions on when to utilise national broadcasts. Only red warnings issued by Thames Region were sent direct to the BBC and those from other regions when requested by the broadcasters.

The Met Office, at their own discretion, use "local flooding" in BBC forecasts when heavy rainfall is forecast that is likely to lead to ponding on fields, roads etc. They say that this frequently leads to phone calls to the BBC Weather Centre and the callers think that the Met Office has responsibilities for all flood warning. The term "local flooding" may be inappropriate and some other phrase should be considered.

The state of the rivers at the end of the working day on 9 April was sufficiently threatening to continue flood forecasting duties in the office. However, flood forecasting was carried on "at home" in Midlands and Thames Regions overnight on the 9/10 April when the Leam and the Cherwell were approaching their peaks at Leamington and Kidlington. The Anglian and Welsh regions were fully operational from area offices overnight. The facilities available in offices offer superior communication and information display capabilities, allowing additional support staff to run models, interpret data and disseminate results. In Thames region, where there is no AVM system in place for Banbury and Kidlington, warnings were also issued from home and staff were managing the flood from five different locations, some within the same office complex. As a result, there appear to have been difficulties in communicating and sharing information.

In Anglian, criteria have been established for the circumstances in which flood forecasting must be performed from the office and Welsh has identified the flood room manpower requirements for three escalating levels of flood incidents.

5.7. Interests of the public and other authorities

The two principal criteria determining how well the interests of the public were served by the issue of warnings concern:-

- (1) The prior awareness by the public of flood risk and warning arrangements.
- (2) The effectiveness of warnings in lessening damage and suffering.

Consideration follows of the public's interests from these standpoints.

(1) Prior awareness

All inland urban conurbations in England and Wales extend to some degree over the flood plains of rivers and streams. The major reaches of these natural drainage systems have remained visible in open channels whilst tributaries have often been culverted or hidden in the midst of buildings.

Urbanisation has often been accompanied by measures such as river channel hydraulic improvements, flood walls or embankments to contain flood flows, undertaken at the time of development or following floods. It is, as a consequence, typically decades between actual flood experiences. Risk awareness tends to diminish quickly after a flood and is further eroded by the movement of people into and away from homes and jobs in the vulnerable areas.

Overcoming the normal lack of awareness and consequent apathy is a challenge for the Agency in its lead role on flood warning.

The majority of people affected by the Easter floods do not appear to have been aware of either their vulnerability or the Agency's warning services. Accordingly, the public's interests were not well served in these respects.

The damaging and dangerous flooding of caravan sites was well reported over Easter. The remarkable absence of fatalities appears to have been due to the courage, skill and facilities of the rescue services together with a measure of good fortune. It is evident that on most sites the awareness of flood risk of people using caravans, was negligible. The issue of caravan site vulnerability is addressed in the joint Department of the Environment, Ministry of Agriculture, Fisheries and Food and Welsh Office circular on "*Development and Flood Risk*" dated December 1992. The circular includes the statement "*Where permission is granted, and there is a risk of flooding, a planning condition should require the erection of suitable permanent warning notices*". The case for extending this requirement to all sites is strong on the evidence of Easter.

(2) Effectiveness of warnings

The majority of people whose homes and work places were flooded at Easter received no form of alert directly from the Agency. This was because their towns and villages had not been categorised as high risk defended or undefended locations. These locations were, as a consequence, not given coverage at the initial stage of the phased strategy for providing an effective national warning service.

However, the Agency succeeded reasonably well at Easter in issuing warnings in accordance with its policy to directly alert people in those high risk areas where, prior to September 1996, the police had been responsible for dissemination. This was an achievement in view of the short time available for designing and introducing the new arrangements. Furthermore, the warnings issued were, in the main, two or more hours in advance of flooding and the proportion received was in excess of 65 per cent. In short, the declared objectives and targets were met.

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 the 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 per cent of calls made by the public connected to the message box and the majority of callers did not, therefore, obtain any information.

Warnings through the media - some local radio stations, teletext and weather forecasts - appear to have been helpful but they did not achieve the degree of awareness required to significantly lessen the impending suffering and damage. The full participation of radio and television with programme interruption would seem necessary for more worthwhile benefit.

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 extent definitions to which the colours relate. The interests of the public are not well served by warnings given on the colour coded basis.

Regarding the interests of the public on caravan and camping sites and mobile home parks, as early as 1982, DoE, MAFF and the Welsh Office referred in a circular to the desirability of including in site licences a condition requiring the display of warning notices about flood risk and giving advice about any warning system. Attention was also drawn to the need to address this in Dr Marshall's R&D report (201/2/SW) for the NRA in 1991. It is understood that warning notices are found at sites in Europe and they are undoubtedly necessary in this country.

There are, as a consequence of the foregoing, contradictory responses to the question of how well the interests of the public were met at Easter by the Agency's warning services. The aspects of this dichotomy are:-

- by operating in accordance with its pre-defined plans and procedures, the Agency addressed the interests of the public moderately well;
- through failing to communicate directly with most of the people who suffered, the Agency failed to properly protect the public.

With regard to the latter response, it should be borne in mind that the Agency's limited staff and other resources must be deployed to provide warning services in numerous catchments, across large regions and throughout England and Wales. It should be acknowledged also that in the two years since the Agency was formed a flood warning improvement strategy has been prepared and a five year implementation programme commenced.

Public dissatisfaction is, nonetheless, understandable in view of the failure to directly alert the majority.

It is explained at Section 1.8 that prior to 1992 there was an arrangement between Northampton Borough Council and the Agency's predecessor Anglian Water Authority which prompted a flood watch operation. It is clearly regrettable that this arrangement appears to have lapsed without the agreement of any of the parties directly or indirectly concerned with flood warning. The Flood Warning Plan identifies flooding in Northampton as a major incident with flood warnings limited to passing warnings to the police and local authorities and broadcasts on local radio.

The coincidence of the floods with the start of the Easter weekend exposed particularly low preparedness in all organisations for dealing with the emergency that developed. It appears that the interests of other authorities would have been better served if some form of standby alert had been given by the Agency on the basis of its consideration of severe weather and Nimrod based forecasts.

Application of the PAGN methodology to justify capital investment is commented on in Section 8.7. The view expressed is that the approach should be modified to account appropriately for unquantifiable social, environmental and political considerations and a line of investigation to establish a broader based methodology is suggested. 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.

5.8. Attention to statutory guidance

Requirement to operate on the basis of sound science:

A wide variation in the technical approach to flood forecasting has been identified across the four regions. In only a few cases, the science used is at the leading edge, for example the use of radar derived rainfall data and forecasts to predict flows. In others, there are out-of-date techniques in need of updating or replacement.

Requirement for value for money:

No value for money matters are evident.

Requirement for holistic environmental management:

The issue of warnings is not relevant to this aspect of statutory guidance.

Achieving national consistency:

It will be readily evident from the foregoing that there is substantial inconsistency between regions on most, if not all management, organisational and technical facets of the issue of warnings.

The Agency's "*Flood Warning Strategy for England and Wales 1997-8 to 2001-2*" (unpublished) affords a framework for achieving greater national consistency. However, it appears to inadequately measure up to the Agency's declared lead position and because of its drafting in 1997, the lessons from Easter on consistency and other matters are not addressed.

6. EMERGENCY RESPONSE

6.1. Policy background

The floods that struck central England and mid Wales at Easter 1998 fulfilled the definition of a disaster or major incident as described in the Home Office publication *Dealing with Disaster* (3rd ed.,1997). "In the context of civil protection a useful working definition of a disaster is any event (happening with or without warning) causing or threatening death or injury, damage to property or to the environment or disruption to the community, which because of the scale of its effects cannot be dealt with by the emergency services or local authorities as part of their day-to-day activities."

Dealing with Disaster embodies the current government guidance on disaster response. It describes an approach to integrated planning and management of major incidents in which, without rigid prescription of specific roles, the emergency services and other bodies can plan and act together. All local authorities, government departments and agencies have accepted the framework together with its principles and definitions. The spirit of the guidance, embodying best practice, is that of flexible use of all available resources with effective pre-planning and clear command and control throughout the major incident.

For the purposes of this report it is not necessary to describe the framework and guidance in detail. 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 principal local authority (often the county council) in an area seeks to co-ordinate emergency planning, relying where necessary on powers derived generally from civil defence legislation as updated by Home Office Circulars ES3/93 and ES5/93. The emergency services (police, fire, ambulance, and coastguard) have their own specific roles and plans. In addition the police assume command of the integrated strategic, tactical, and operational activities during a major incident. In most areas of the country there are formal co-ordinating groups that seek to ensure co-ordinated planning, training, and execution of plans in a disaster.

In addition, the Environment Agency and the Local Government Association have a Memorandum of Understanding outlining the framework within which their interface will operate. One of the technical protocols attached to the Memorandum deals with flood defence including civil emergencies and flood warning dissemination. A revised version of the protocol was agreed in August 1998.

6.2. Responsibilities of the Environment Agency

In *Dealing with Disaster* (p.7) the role of the Environment Agency is described as follows: "The Environment Agency (EA) has primary responsibility for the protection of water, land and air in England and Wales...The EA has key responsibilities for maintaining and operating flood defences on rivers and coastlines. These responsibilities cover direct, remedial action to prevent and mitigate the effects of the incident, to provide specialist advice, to give warnings to those likely to be affected, to monitor the effects of an incident and to investigate its causes".

Meetings of the Flood Warning Procedures Group, led by MAFF and comprising the local authority associations, Association of Chief Police Officers, Welsh Office, Home Office, and National Rivers Authority, reached agreement on implementation in July 1995. Circulars issued by the Association of Chief Police Officers and by the Local Authority Associations in 1996 included these working arrangements:-

ROLES OF POLICE AND LOCAL AUTHORITIES

1. NRA/EA 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 NRA/EA 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 as detailed on the attached table (note- tables not attached) which 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 arrangements described in the Home Office publication, expanded by the considerations above and by agreements reached during local planning for emergencies, comprise the framework for the responses to the Easter floods.

6.3. Military assistance for major incidents

Dealing with Disasters describes (pp 12-14) Ministry of Defence arrangements for Military Aid to the Civil Community (MACC). In broad terms there are three categories only one of which, Category A, is relevant to the circumstances described in this report. Category A is defined as *assistance to the civil authorities in dealing with an emergency such as a natural disaster or major incident.*

The Home Office guidance (paragraph 2.31) explains that *service personnel and material are not earmarked or put on standby to meet any civil emergency or other task. Consequently, although civil authorities may produce contingency plans in conjunction with Service Headquarters and units, such plans do not guarantee that a Service response will necessarily be available.*

Most local authority emergency planning teams and emergency services have excellent local links with service units in their areas. This liaison was demonstrated to good effects during the Easter floods. However, contact from Headquarters Land Command requested correction of the implication in the Preliminary Report (Paragraph 8.1) that pre-planned military assistance is available to the Environment Agency. It is not, except under the MACC arrangements and then only at the request of the civil authorities and when operational and training commitments permit.

Although it is not a direct concern of this report, it may be worth noting when considering improvements to flood emergency response that there is no longer any significant military presence in some areas. In addition, as service resources are stretched by economies and increased responsibilities, civil aid availability and responsiveness may further decrease.

6.4. General assessment of major incident management during the Easter floods

The floods affected substantially some seventy locations across large areas of England and Wales. The emergency responses engaged, amongst others, personnel from police forces, fire and rescue services, ambulance services, and local authorities. The Environment Agency deployed staff on flood defence duties across its Anglian, Midlands, Thames, and Welsh Regions. The Review Team had no remit to study in close detail the activities of local authorities and emergency services. Detailed evaluation of every incident was ruled out, in any case, by limitations of time. An overall assessment, with reference to specific locations for illustrations of particular points, is offered here. The primary focus is the performance of the Agency.

6.5. Planning and preparation

Planning and preparation procedures for major incidents are in place across England and Wales with local authorities and emergency services collaborating well. The Agency's role in flood defence, forecasting, and warning is understood and incorporated in generic major incident and specific flooding plans. There was disputed evidence in some localities, for example Northampton, that the Agency had not consulted local authorities about flood warning dissemination plans. The majority opinion, however, supported by a survey by the Local Government Association in 1997, was that relationships between local authorities and the Agency were good or excellent.

There were suggestions, nevertheless, that fluvial flooding was not seen as a particular priority alongside other potential emergencies. Exercises based on serious or extreme flooding scenarios were very infrequent or had not occurred. This may explain why Agency staff were not used effectively at strategic or tactical level in some locations. Before the experiences and lessons of the Easter floods are forgotten, all the organisations involved should review their planning and preparation with particular regard to the contribution of the Environment Agency.

All organisations with responsibilities in major incidents should review arrangements for supply, storage, and distribution of essential rescue equipment from boats to sandbags. There was evidence that improvisation rather than pre-planning was the rule. This is not surprising given reductions in public expenditure and the problems of maintaining stocks for relatively rare events. Even so, in preparation for the next floods or other extreme events, a comprehensive logistical assessment would be timely.

The Environment Agency may have satisfactory links with county councils but its liaison with unitary, borough, and district authorities appears patchy. Building and rebuilding those links requires urgent attention.

6.6. Initial response

In most locations, the floods struck with a speed and severity unprecedented in the last fifty years or more. The peak impact in many places, and particularly in the largest and most populated sites at Northampton and Leamington, was in the dark early hours of Good Friday. Floodwater was deep, fast flowing and very cold. Those who have not undertaken search and rescue operations in such conditions or held command under the pressure of unpredictable events with lives at risk might with hindsight find fault with the emergency response.

There were specific criticisms from victims on lack of warnings, delays in rescue attempts, poor communications, absence of essential security, health and safety information, and apparent lack of co-ordination between emergency services and local authorities. On the other hand, there was enthusiastic praise for the courage and good humour of fire-fighters, police, and volunteers involved in many rescues, often putting their own lives at risk.

Major incident planners and commanders should take careful account of the experiences of flood victims. In Northampton, the most seriously affected urban community, one victim spoke for many (and not only in that town) when he described the appearance of poor co-ordination and lack of assistance as he waded away from his flooded home as '*like being in a third world country*'. His evaluation was perhaps influenced by hours spent waiting for rescue in cold and contaminated water. No doubt the police and fire service personnel he accuses of ignoring his plight knew what they were doing and were attending to other priorities. Even so, attention to the acute needs of severely shocked victims for basic information and reassurance should be an important factor in planning and response by all agencies.

During the initial response, Environment Agency staff appear to have contributed well to the major incident teams in most locations. At incident sites, employees carried out flood patrols, made temporary repairs to defences, removed obstructions from waterways, and assisted with rescues and protection of properties. At Easter, the Agency's response capabilities were fully stretched by the extreme conditions in some catchments. In others, there was scope to support the work of other organisations and it is to the Agency's credit that this occurred. Either from their own control centres or at strategic and tactical commands, senior managers provided valuable information and interpretation during the progress of the flooding. Many Agency staff worked long hours in difficult conditions alongside colleagues from the emergency services.

On the other hand, a report to the Local Government Association from the County Emergency Planning Officers claims that quality of response from the Agency varied considerably. The report states:-

Warwickshire, for example, did not receive any assistance from the Agency other than receipt of warnings. In other areas the Agency supplied sandbags and boats. Buckinghamshire noticed clear differences between Thames and Anglia Regions, in that Thames Region 'seem to be more on the ball and attend liaison meetings, exchange and incorporate emergency contacts, updates, etc.'

There was not always a clear understanding on behalf of the Agency's control rooms of the command levels of other agencies, the role of Police Silver Command and the Local Authority Emergency Operation Centres. Neither was there consistency in attendance at Police Gold Commands by liaison officers from the Agency.

The Agency states, however, that it offered assistance to all the district councils in the Avon catchment.

After weighing evidence from those who managed events, those who assisted, and those who were rescued, the Review Team's overall assessment is that management of the initial response was successful. Despite five deaths, directly and indirectly due to the floods, many lives were saved where the potential for further loss was very high. There were few serious injuries and those requiring medical treatment were promptly removed to hospitals. The majority of individuals and families were evacuated to rest centres or helped to find accommodation with relatives or friends.

6.7. Recovery phase

The Review is less concerned with issues that arose during the recovery phase. The Agency has its specific responsibilities, amongst others, for repairing defences and assessing the extent of flooding. Principally, local authorities lead the recovery phase and the Agency responds to requests for appropriate help from them. The most obvious deficiency according to victims during and after the floods was reliable information. Not unreasonably, they wanted to know, amongst many other basic questions, why they were flooded, whether it could happen again, who would assist them with cleaning and repairing their homes, what to do about de-contamination and drying out, what public health and hygiene measures they should adopt, and whether any financial assistance or compensation would be available.

The Agency should contribute pro-actively to improved public information. There is an impression amongst some victims and their representatives that the Agency has been less active than it might have been because it fears claims for liability. Whilst caution is required in the face of threatened litigation, there is a strong case for clear and confident statements of fact, together with a readiness to contribute to general public understanding about flood defence, domestic precautions, and risks.

6.8. Media

Similar considerations to those mentioned above may have contributed to the Agency's relatively low profile in local media during and since the floods. Before the events of Easter, not many people in the affected areas associated the Agency with flood defence and flood warnings. Since then, the acts or omissions of the Agency have been widely identified by victims and their representatives as principal causes of loss and disruption.

Such sweeping accusations following a severe natural event are likely to be one-sided, obscured by misunderstandings and unrealistic expectations. The Agency, at local and national levels, has a public duty to explain its actions, to respond to questions and complaints, and to offer sympathy and apologies where appropriate. Performance by Agency managers, under aggressive questioning, was patchy in quality, perceived as reactive and defensive, and was less effective than that by other organisations in portraying Agency's achievements and conveying sympathetic explanations about what happened. Again, the pressures of handling the crisis may have diverted senior managers from attention to public information tasks. Reflection on media performance and lost opportunities could prompt a re-appraisal of media training and presentation.

6.9. Interests of the public and other authorities

The interests of the public and other authorities are considered to have been adequately served by the emergency response of the Agency in respect of those matters for which it has key responsibility, because:

- defence systems functioned as intended;
- mitigating action was taken to remedy failures on elements of the defence systems;
- the impact of flooding was lessened by deploying emergency response resources jointly with local authorities, the police and fire and rescue service.

Typical activities of the Agency's emergency work force included:

- flood patrols;
- temporarily strengthening or marginally heightening defences;
- removing obstructions and trash affecting channels, culverts, bridges, sluices, gates and pumps;
- providing (in some regions) sandbags to local authorities and the public.

Critical comment about the response actions of the Agency during the flood events may, at least in part, be based on public misunderstanding about the priorities for the emergency work force. The limited resources available and the exceptional demands imposed by the widespread events, may also not be well understood.

Due to misconception about the Agency's response role, criticism concerning lack of direct assistance to individuals has arisen but is ill founded. This misplaced critical comment may have stemmed from ignorance about the different primary purpose of response work by the Agency from that of the other organisations.

It appears that there were some serious failures, in all organisations, in relation to interfacing and co-operation, although correct and effective joint working seems to have been achieved generally. The failures related to issues including:

- out-of-date or incorrect information in procedures;
- local authority contacts not being available over the holiday period;
- local authority resources being insufficient for participating as pre-planned;
- inadequate links established with gold or silver control;
- information failing to pass down to lower levels of the communication chain;
- insufficient understanding of flooding circumstance by local authorities inhibiting the best use of resources.

6.10. Attention to statutory guidance

There are no issues of consequence.

7. STANDARDS OF DEFENCE

7.1. Background

Land suitable for urban development and intensive agricultural use is a scarce resource in England and Wales. River and coastal flood plains are potentially appropriate providing flooding frequency and high water table levels are reduced sufficiently to permit viable alternative use. Away from the coast, the urban and rural reaches of rivers and streams must be treated as an entity in order to cater for the land uses - urban, agricultural, recreational and nature conservation - over the whole extents of flood plains in a rational manner.

It is explained in Appendix A that the present arrangements for flood defence in England and Wales are founded on those which emerged from the Royal Commission on land drainage in 1927. A priority for the nation at that time was the need for increased home production of food. The Commission addressed the key issue of improving land drainage to achieve more productive agriculture on fertile flood plains.

The Commission recognised that downstream urban flood risks might arise from better defending agricultural land. Hence, the legislation which followed in 1930 incorporated provisions for remedying such problems.

Today, food production is a matter for consideration in the context of the Common Agricultural Policy (CAP), and no longer raises the concern it did in earlier decades. Urban land use is now the priority, and flood defence may be regarded as an infrastructure issue relevant to revitalising developed areas.

The public's tolerance of urban flooding has declined over the years as standards of living and expectations about effective public services, have increased. Protection against events of up to four per cent probability annually (25 years return period) may have seemed reasonable in the first part of this century. Today, urban communities expect much better protection and it can be argued that this is necessary to sustain or revitalise local economies. For fluvial flood defence, protecting to the one per cent annual probability (100 years return period) is now the normal design standard for new or improved defences, providing schemes affording such protection are economically justifiable and environmentally acceptable.

MAFF and Welsh Office have responsibility for flood defence policy at the national level. It is expressed in the statement *policy is aimed at reducing the risks to people and the developed and natural environment from flooding and coastal erosion by encouraging the provision of technically, environmentally and economically sound and sustainable defence measures.* The document "*Strategy for Flood and Coastal Defence in England and Wales*" presents and explains this policy. In the MAFF publication "*Project Appraisal Guidance Notes*" (PAGN), a methodology for identifying the optimum solution to a flood defence problem is required to be applied by the Agency and other authorities empowered to undertake flood defence works in support of grant aid applications.

The Agency, as the lead organisation providing, operating and maintaining flood defence, responds to the MAFF and Welsh Office policy by inter alia:

- making surveys to establish the need for capital and maintenance work programmes;
- applying economic and environmental criteria as well as urgency considerations in the selection and prioritisation of schemes for inclusion in the capital and maintenance work programmes.

Current flood defence expenditure by the Agency is in the order of £250m annually.

Severe weather is not uncommon in England and Wales but serious flooding is rare. Accordingly, the performance of the Agency and its predecessors in providing, operating and maintaining flood defences over many years must be judged as basically successful. However, the Agency has expressed the view that for the appropriate development and proper maintenance of its £7.5 billion of flood defence assets, an additional £30-£40m expenditure is required annually.

7.2. Performance of flood defences at Easter

In the Preliminary Report, the following basis for categorising flooding events is described.

- (1) *Failure of the flood defence system due to flood characteristics more severe than those assumed in the design of the system. Flooding in these circumstances should be considered inevitable and the only question arising is whether the original design standard is sufficiently high.*
- (2) *Failure, other than structural, of the defence system with flood characteristics less severe than those assumed in its design. Flooding should not occur in these circumstances and it would suggest flawed hydrologic/hydraulic analysis in the design process or a change in climatic or catchment characteristics since the defence was constructed.*
- (3) *Structural failure at discharges less than those assumed in the design of the defence system. This would suggest: deficient structural design; inadequate maintenance of defence works; or third party interference with the works.*
- (4) *Inappropriate operation of mechanical equipment with flood characteristics less severe than those assumed in the design of the defence system. This would imply: incorrect operating rules; failure to comply with operating rules; or failure of equipment to function correctly.*

- (5) *Reduced waterway capacity resulting from debris or gravel accumulations or other factors detrimentally affecting hydraulic performance during the period of the flood. Such issues may or may not have been foreseeable at the design stage and critical comment will turn on this consideration. The Agency's emergency response activity may also be relevant if impaired hydraulic performance contributed to flooding.*
- (6) *The inundated area being unprotected by flood defence works.*
- (7) *Flooding due to excess flows in watercourses behind defences, within the protected area.*

In situations where more than one of the foregoing six explanations apply, the Review will endeavour to identify the factors of greatest significance.

From the information and understanding afforded by the Agency's reports, explanations have been sought for the main river related events, based on the possible explanations set out above. In general terms, the situation revealed is that:-

- The majority of defence systems were in good order and flooding occurred because river flows exceeded the design criteria.
- Deficiencies in a few defence systems may have increased the extent and severity of flooding but some inundation would have occurred irrespective of these weaknesses.
- There were instances of inappropriate or non operation of mechanical equipment and the extent and severity of floods at the locations in question may have been increased.
- There are a few undefended village locations where watercourses through and downstream of the developed areas have been maintained to achieve environmental gains and these may have been at the expense of hydraulic efficiency. More extensive and severe flooding could have been the consequence.
- There is no evidence of flooding attributable to failures during the floods to cleanse screens or to provide any other form of emergency maintenance.
- Many of the undefended areas affected at Easter were known to be at risk and had been considered for protection but the opposition of residents or the lack of economic justification had prevented the implementation of capital schemes.
- Some of the affected areas were known to be at low or negligible risk - their vulnerability to river flood rates of rare severity was, however, exposed.
- Floods primarily associated with overspill from main river were in many places aggravated by flooding from ordinary watercourse. However, no flooding occurred to an area with main river defences wholly because of spillage from an ordinary watercourse.

7.3. Planning liaison process

Despite having a statutory involvement in the decision making process on development planning and control, the Agency's role is advisory.

The advice it gives concerns whether development of any form should take place on rivers or flood plains and if so on what conditions. It relates also to the development of land above the flood plain and is of particular importance when there is potential for an increase in the amount or intensity of runoff.

In theory, advice about the protection of flood plains from the direct or indirect effects of development can be disregarded by local planning authorities who are responsible for planning and control.

In practice, the formally stated commitment now given by Government, the Agency and many local authorities to flood plain protection as an aspect of sustainable development, makes it unlikely that the Agency's advice would be ignored. This is confirmed by the absence of evidence presented to the Review on Easter flood issues resulting from the neglect of advice provided in the context of the current policy.

The ineffectiveness of flood plain protection in previous periods was, however, well demonstrated at Easter. Situations where the advice of predecessors to the NRA (prior to 1989) had been ignored in relation to development taking place or the requirement for defence provisions, came readily to notice.

To summarise, the planning liaison arrangements established over the last 5 years or so appear to be working effectively in support of the Agency's flood plain policy. However, the Agency should maintain this strong line and be prepared to defend vigorously the advice it gives.

7.4. Impounding reservoirs

Winter and spring rainfall had fully replenished most, if not all, water supply and canal impounding reservoirs prior to Easter 1998. As a consequence, substantial attenuation of downstream flood flows did not occur.

The Agency does not own or control the operation of impounding reservoirs in the affected areas. Hence, it is not in a position to introduce drawdown arrangements if, in some cases, they could be shown to contribute to flood control without jeopardising water resource management. Although technically, environmentally and administratively complex, the investigation of dual use would seem worthy of consideration. It would involve reservoir operating procedures permitting either drawdown in anticipation of storm rainfall or throughout defined flood risk periods.

7.5. Interests of the public and other authorities

The three aspects of the Agency's responsibilities which relate to the standard of defence interests of the public and other authorities are:-

- (1) The duty to generally supervise all matters relating to flood defence.
- (2) The power to provide, operate and maintain flood defence systems on main river.
- (3) The power to enforce, or undertake in default, work associated with the flood defence responsibilities of others.

There is no evidence to suggest that, in general, inadequate attention is given to these issues. Indeed, the rarity of river flooding is testimony to sustained success over many decades.

Also, these matters must be examined in the context of the constraints imposed on the Agency's operations by policy set at Government level, the legal framework, and the organisation's limited financial and other resources.

It is evident that in most situations the Easter floods were attributable to factors beyond the Agency's control. These included:

- flood conditions which exceeded the defence design criteria properly adopted and applied when the systems were constructed;
- lack of defences due to proposals emerging from past feasibility studies which failed economic justification or other tests set by government departments;
- rejection by at risk communities of schemes proposed previously, due, in some instances, to their impacts on gardens and public areas;
- lack of awareness of vulnerability due to non-existent or vague records of past flooding;
- locations being covered by future stages of flood plain mapping programmes;
- flood plain developments having taken place against the advice of the Agency's predecessors;
- flooding from watercourses not classed as main river.

As indicated above at Section 7.2, there are no specific situations where it appears justifiable to claim that flooding would not have occurred if the Agency had better attended to its responsibilities for the provision, operation and maintenance of flood defence.

However, there are a few examples of deficiencies which seem likely to have caused an earlier on-set of and also more extensive and severe flooding than would have been the case if the systems had been in better order or equipment operated more appropriately.

The situation at Northampton is described in detail in the Agency's incident report in Volume II, and the Review Team's assessment is provided at Section 1.8. Factors of particular consequence relate to: missing sections of defence; variability in the condition of intact lengths of defence (some not in the ownership of the Agency); the poor state of ordinary watercourse and surface water drainage systems; and, maintenance activity on flood relief sluices in the winter half of the year when flood risk is greatest.

Therefore, when considering the interests of the Northampton public in relation to the Agency's activities, the adequacy of attention given to the three responsibility areas - general supervision / provision, operation and maintenance / enforcement etc. - is questionable. It is clear that greater attention would not have saved the town at Easter, but the flooding may have been less serious in its impact.

An example concerning the operation of equipment is at Worcester. The Agency's incident report describes a penstock at the inlet to a culvert upstream of the Blanquettes estate. Prior to the maining of the Barbourne Brook several years ago, Worcester City Council had used the penstock to finely control the flow through the downstream system. Easter was the first occasion when the Agency operated the penstock and the manner of its use does not appear to have taken maximum advantage of the capacity of the downstream system. It seems possible that because of the extreme weather some flooding of the estate would have occurred but less extensive and severe than that experienced. The doubtful adequacy of the condition and size of the culverts on this system is a general supervision issue but one dating from the 1960s and earlier, when the structures were built.

At other places, there is evidence of marginally subsided short lengths of defence. Again, flooding at Easter would not have been prevented by the absence of such deficiencies because the systems were overwhelmed over long reaches.

Application of the PAGN methodology to justify capital investment is commented on in Section 8.7. The view expressed is that the approach should be modified to account appropriately for unquantifiable social, environmental and political considerations and a line of investigation to establish a broader basis is suggested. Such modification would assist in ensuring that the interests of the public and other authorities are properly addressed in relation to proposals for new or improved flood defences.

7.6. Attention to statutory guidance

Requirement to operate on the basis of sound science:

The one area of particular concern is the application of computational hydraulic modelling in the design process to situations where the complexities of flow behaviour are beyond the limitations of the theoretical and empirical concepts on which the models are based.

The erroneous estimation of flood levels resulting from such misapplication of computer modelling has the potential to:

- mislead in relation to the defence standard of existing works;
- provide a flawed basis for the design and economic justification of new defences (and warning systems) or the improvement of existing systems.

Factors determining whether or not computational hydraulic modelling is appropriate include:

- the sufficiency of recorded flood data for calibration and verification;
- the confidence with which theory and empirical relationships in the model program can be applied to structures in the study reach;
- sequences of structures which could result in control sections changing with discharge in ways which may not be revealed by model proving against lesser flood events;
- the need for unrealistic roughness and discharge coefficients;
- the poor simulation of recorded flood levels on critical reaches.

In the design of sea and estuary defence, account is taken of the predicted sea level rise consequences of climate change. The lack of understanding of the fluvial flood hydrology effects have, however, so far precluded a similar approach in the design of river flood defences. However, there is a growing body of evidence supportive of the view that floods will increase in frequency and severity. This would appear to justify the introduction of a factor of safety in recognition of the uncertain validity of design flood characteristics derived from past events.

Requirement for value for money:

All aspects of the Agency's provision, operation and maintenance of flood defence appear to afford good value for money, and plans are in place aimed at further progressive improvement.

Requirement for holistic environmental management:

Works for the hydraulic improvement and maintenance of river and watercourse channels are undertaken with proper regard to the enhancement of nature conservation. In most situations, a good balance is struck between this interest and flood defence. In a few, however, it would seem that restrictions on dredging and controlling bankside, trees and bushes have the potential, particularly during the summer half of the year, to increase flood risks to upstream urban communities. It appears also that any such change in risk is not quantified or acknowledged by the relevant flood defence committee, with or without a decision about compensating measures.

Achieving national consistency:

The roles of MAFF and the Welsh Office in relation to the provision of flood defence have over many years encouraged national consistency, and they continue to do so.

National consistency in respect of maintenance has progressively increased since the formation in 1989 of a single agency for England and Wales. The initial work of the NRA since 1996 has been carried forward by the Agency.

8. MANAGEMENT OF FLOOD DEFENCE

8.1. Introduction

Although flood warning and defence issues are the primary concern of this review, the Agency's management and organisational arrangements have a bearing on some of the revealed problems and their possible solutions. cursory appraisal is made, therefore, of these arrangements, and observations offered on aspects of consequence.

8.2. Flood defence and holistic environmental management

The Agency's extensive portfolio of functions was designed by Parliament to enable integrated, holistic management and protection of the physical environment in England and Wales. The vision, aims and responsibilities of this ambitious programme are presented in the Environment Agency's publication *An Environmental Strategy for the Millennium and Beyond* (1997).

The Agency's principal aim is taken from Section 4 of the Environment Act 1995:

In discharging its functions so to protect or enhance the environment, taken as a whole, as to make the contribution towards attaining the objective of achieving sustainable development that Ministers consider appropriate.

Amongst the secondary aims covering a wide range of environmental objectives is one focused on flood defence. There the aim is:

to provide effective flood defence and warning systems to protect people and property against flooding from rivers and the sea.

Flood defence and warning stand out from the Agency's mainly regulatory portfolio. Although there is a regulatory aspect, the core activities are targeted at the first hand protection of people and property. They involve managing the works and developing the systems that enable the Agency to provide, operate and maintain flood defence and warning systems. These assets are valued at £7.5 billion, and the expenditure on their improvement, renewal, maintenance and operation is in the order of £250m annually. A rough calculation indicates that this expenditure consumes around 40 per cent of the Environment Agency's annual budget.

No other Agency function has substantial works to manage, or comparable levels of past, present and future investment. No other function brings Agency staff into such close relationship with the general public and their elected representatives. No other function carries a direct Agency responsibility for the lives and livelihoods of so many people.

The flood defence function is distinctive also because it is financed from government grants and regionally from levies on local authorities and internal drainage boards, with regional statutory flood defence committees directing investment and delivery programmes.

In the interests of assuming better integration between environmental and flood defence objectives, the Review Team strongly supports the Local Government Association and the Environment Agency in their intention to publish technical protocols on development planning and Local Environment Agency Plans that will cover flood defence issues.

8.3. Management of the flood defence function

The Environment Agency describes its flood defence staff and structures in the publication *An Action Plan for Flood Defence* (1998, pp.18-20). National direction is provided by the Water Management Directorate at Head Office, responsible for policy, standards, co-ordination and external liaison. At Head Office, the flood defence function includes a Head of Flood Defence - who does not have line management responsibilities for the function - with a small policy team. There are five Flood Defence National Boards that bring together flood defence managers and other experts from inside and outside the Agency to address key themes. These are strategic, regulation, operations, flood warning and improvements. The Flood Defence Managers Group comprising managers from the eight regions meets every three months. There is a flood defence research and development programme.

The Agency has provided the following explanation of its flood defence management arrangements.

In the Agency, Flood defence is delivered through two directions. Operational delivery is through the formal reporting lines of Director of Operations to Regional General Managers and on to Area Managers. Under the Area Manager, the majority of regions have Flood Defence and Water Resources Managers (2 regions have stand alone Flood Defence Managers) who act in the client role, and Contractor Managers who control the In-House Work Force. Flood Defence policy and strategy is delivered through the Director of Water Management and his Flood Defence Head of Function who link through Regional General Managers and Regional Water Managers to Regional Flood Defence Managers. In addition, certain specialist services may be delivered at regional level by the Flood Defence Manager's team.

Regional Flood Defence Committees and Local Flood Defence Committees bring together democratically elected people with MAFF, Welsh Office and Agency appointed members. These committees, which have executive powers, bring local knowledge to bear on problems, solutions, and funding priorities.

At an area level, in most regions the Agency integrates flood defence and water resources.

The dominant characteristics of the Agency's management structure might be described as essentially matrix and regional on which secondary functional lines are superimposed. The structure 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.

Questions of internal priority for flood defence investment are matters of Agency policy. The Review Team was interested to note that managers with the direct responsibility for this function, important in terms of proportion of total Agency budget and public accountability, were not members of regional management teams. It may, or may not, be the case that the senior managers responsible for water management adequately represent the flood defence function, bringing the necessary specialist knowledge and technical expertise to the top table.

The Review Team gathered impressions from internal discussions that the flood defence function may have lost focus, resources and expertise within the integrated management structure. These views were understandably strongest amongst staff with flood defence responsibilities and experience of other management arrangements for this much re-organised function. For example, it is alleged that the number of people employed on flood defence has reduced substantially in the twenty-five years since water authorities assumed responsibility for the function from river authorities. Informants cite reductions in employee numbers in the Welland and Nene catchments as typical for England and Wales.

The Welland and Nene River Authority in its final year, 1973-74, employed 60 engineering staff with 13 clerical support and 194 manual workers. In 1997-98, the numbers of Agency staff on the flood defence function in these catchments are now respectively 13, 2 and 44. In short, staffing has reduced by about 80 per cent in this period. Have responsibilities, after allowing for transfers to the private sector and support from regional head office, decreased, or efficiencies increased proportionately?

Some internal observers saw the problem of reducing numbers as less critical than loss of flood defence expertise, mature professional competence, and developed local knowledge of river systems. Questions were raised about the apparent scarcity of advanced expertise in hydrology, open channel hydraulics, and computational modelling, especially in safeguarding the Agency's client role when dealing with consultants providing specialist services.

Impressions of the function from outside the Agency were potentially more serious. It may seem trite to remark that there is no obvious reference to floods or protection of the public in the title of the Environment Agency. Even so, the Review Team encountered wide spread views, amongst flood victims and public service partners, that flood defence as a public protection service did not have a distinct identity. The Environment Agency title was not easily associated with flood defence, and it was difficult for members of the general public and for some public service partners to understand how the function was managed and delivered. Surveys by BRMB International for the Agency of people in flood risk areas between January and April 1998 found that only 22 per cent spontaneously named the Agency as the organisation responsible for either flood information, warnings, or as having flood defence powers. This was, however, twice the figure of the previous year and nearly four times the level of awareness found in the national adult population sample.

There are two elements to the flood defence management task. The first concerns planning, organising, directing and controlling resources and work programmes so that government and Agency policies and aims are progressed. The second relates to flood emergencies that are infrequent and arise with little time for preparation. The first aspect is the routine form of management necessary in all organisations and as such appropriate provisions are not too difficult to make, irrespective of whether the structure is functional, regional or matrix based. The emergency public protection aspect is, however, more problematic. That responsibility demands a clear command management structure that can snap into action with maximum pre-planning and practice for infrequent major incidents demanding close co-operation with emergency services and other partners.

The Review Team questions whether the emergency response element in the management task has received adequate attention. It is not an occasional extra responsibility but a core activity for which the Agency has a major responsibility critical for the achievement of its own flood defence measures of success as set out in *An Action Plan for Flood Defence*. In this respect, the critical measures are "*no human fatalities as a direct result of flooding*" and "*effective emergency response in partnership with local authorities and emergency services.*"

8.4. Effect of reorganisations

Flood defence has experienced three major organisational changes in under twenty five years as a result of responsibility passing from river authorities to water authorities in 1974, to the NRA in 1989 and, in 1996, to the Agency. Reorganisation of the function occurred also in the interim periods and between 1974 and 1989 and there was little or no similarity between the frequently changing approaches of the ten water authorities.

Although difficult to evaluate, these reorganisations must be judged damaging to the performance of the function, particularly as they were accompanied by loss of knowledge and expertise due to the early retirement of staff and departures in other ways. It is evident also that records were destroyed or misplaced in the 1970s and 80s. In addition to these consequences of reorganisation, morale inevitably declines in a climate of uncertainty and change, and does not quickly recover.

The legacy from organisational instability challenges flood defence management and will inevitably be unhelpful to performance for some time to come.

8.5. Asset management

Since the early 1990s, the NRA, and subsequently the Agency have sought to manage flood defence assets in a rational and consistent manner. The conceptual framework for asset management is understood to be similar in principle to that adopted for hydraulic systems in the water industry generally. It comprises:

- establishing present extents, conditions, missing elements, ownerships and protection standards;
- setting protection standard and structural soundness objectives for systems defending different types of risk areas;
- identifying capital and maintenance work requirements for achieving the declared objectives in the most economic manner;
- scheduling the required expenditures in capital and revenue programmes;
- implementing capital and maintenance projects.

The merit of this management approach may well be evident from the Easter floods in that most problems at defended locations were wholly attributable to flood severity exceeding defence standard and there were no structural failures.

However, in the case of some incidents, more frequent but less rigorous inspections than the full asset surveys would seem likely to have revealed deficiencies which, if corrected, would have delayed the onset of flooding and reduced extent and severity.

Unlike water industry systems, such as sewerage, potentially serious deterioration of elements of defences or their removal by others can occur without it being evident, perhaps for decades, until rare flood flows are experienced. More frequent but less detailed flood defence asset surveys would respond to this difficulty.

Individual accountability for the condition of flood warning and defence systems does not appear to rest unambiguously with senior technical staff, experienced in the function. It would seem desirable for such arrangements to be introduced within the framework of the overall asset management approach.

8.6. Flood defence research and development programme

The Agency's Flood Defence activities are supported by a business focused R&D programme to support development of policy, enable improvements in efficiency and effectiveness and provide a sound scientific and technical base.

The MAFF/Environment Agency Committee on Flood and Coastal Defence Research and Development which will be reporting later this year is an important source of external review and guidance. The committee is developing strategy, rather than a shopping list of projects, that will remain valid for the next 5 to 20 years.

The Agency's R&D objectives are:-

To undertake research into flood forecasting and dissemination to enable the Agency to provide an effective flood warning service.

To investigate environmental impacts.

To improve understanding of natural processes.

To undertake research into climate change, including assessment of potential impacts and risks.

To undertake research into all aspects of operational management, identify and introduce best practice.

Current or recently completed projects cover (inter-alia):

Producing a handbook on rainfall frequency studies to complement the Flood Estimation Handbook.

Evaluating the benefits of flood forecasting and warning services to support decision making on enhancing and developing an effective service.

Comparison of different real-time rainfall runoff flow forecasting models.

Risk management techniques for reservoir safety.

Practical and simple domestic property flood proofing measures.

Psychology and sociology of flood warning.

Techniques for real-time out-of-bank models to forecast flood inundation extent.

Developing a standard practice for freeboard.

Determining the effect of previous rainfall on flood events to improve flood warning capabilities.

Continuous monitoring of soil moisture.

Review of optimum accuracy of flow and rainfall forecasting.

Techniques for identification of flood plains.

Evaluation of radar data and rainfall forecasts in flood forecasting models.

Thunderstorm Warning Project (GANDOLF).

A number of projects collaborate with and contribute to, European Union funded research and development work. The river basin modelling, management and flood mitigation study (RIBAMOD) will assist in the mitigation and control of the impact of floods through better planning, management of rivers and catchments, and by improving the effectiveness of public warnings. The European river flood occurrence and total risk assessment system (EUROTAS) project is directed at the development and demonstration of integrated catchment models for the assessment and mitigation of flood risk.

The Agency's R&D programme also includes a project to assess the implications of climate change for all its functions. This project will take into account the IPCC's second assessment report and, for flood defence, update earlier work carried out for the NRA following publication of the IPCC's first report. The research is designed to support the development of a climate change strategy for the Agency and to support core functions.

The **interest of the public and other authorities** is well served by the content of the R&D programme in which many projects target improving the flood warning service. However, these improvements will not materialise unless the R&D outputs are applied across all regions of the Agency. There are indications that the take up of R&D in the past has been slow and patchy.

With regard to attention to statutory guidance, the position evident may be briefly stated as follows.

Requirement to operate on the basis of sound science:

This is fully satisfied and the R&D programme provides an important mechanism for linking with the external scientific community within both the UK and Europe.

Requirements for value for money and holistic environmental management:

These are well taken into account in the procedures for establishing the content of the R&D programme.

Achieving national consistency:

The outputs from the R&D programme need to be applied more widely and with a greater sense of urgency to achieve national consistency in flood forecasting and warning.

8.7. Justification of capital investment proposals

MAFF and the WO require the Agency to justify flood warning and defence capital investments on which grant aid is sought using their Project Appraisal Guidance Notes (PAGN) methodology. This in essence involves a rational and analytical economic based justification. However, it can be argued that the approach is too narrow because of the disregard of the social, environmental and political issues, which reflect the interests of the public in the proposed investments, from standpoints other than the economic one.

Investment decisions making conceptual frameworks embracing unquantifiable, as well as quantifiable, issues have been developed in the project management realm. This would appear worthy of consideration for modifying the PAGN methodology.

8.8. Agriculture Select Committee Enquiry

In their submission to the ASC flood and coastal defence enquiry, the Review Team expressed the view that, so far as fluvial flood defence is concerned, the complicated, confusing and regionally varying arrangements for flood warning and defence are not conducive to the provision and operation of these activities in ways maximising efficiency and effectiveness. They also prevent the allocation of funds to clear national priorities such as flood warning and flood plain mapping.

The submission concluded as follows.

As we see it, improvement can be brought about by either completely redesigning the arrangements from government level down or progressively further modifying the existing arrangements. The former is well beyond the scope of the Review and, therefore, the following suggestions affecting the Agency relate to changes more or less within the existing framework, which could initiate ongoing progressive change.

- (1) *Rationalisation of the Agency's flood defence committee structure - one RFDC per region without local or advisory committees would appear appropriate.*
- (2) *Removal of regional ring fencing of revenue to permit resources to be used flexibly in the context of national priorities.*
- (3) *Creation of a national flood defence committee with authority to direct the regional committees and allocate resources.*
- (4) *Replacement of scheme specific grant aid from MAFF and WO with block grants.*
- (5) *Redefinition of the Agency's policy on enforcement in respect of ordinary watercourses to bring about more effective action by riparian owners or local authorities.*
- (6) *Strengthening of the Agency's position in relation to preventing new development in flood plains and to securing substantial funding from developers for compensatory works for the hydrological consequences in extreme flood conditions of green field developments. These measures might in addition encourage brown site redevelopment as opposed to green field new developments, with resulting environmental benefits.*
- (7) *Giving the Agency powers to require information from owners of existing flood defence structures and a system of statutory improvement notices to ensure the proper maintenance of such structures.*

During the review, we have become aware of much good progress by the Agency, for example;

- *placing the management of its assets on a sound basis;*
- *ensuring costed plans are in place for the improvement of flood warnings;*
- *increasing the effectiveness of capital procurement;*
- *prioritising expenditure needs on a national basis.*

The current fragmented structure for the funding and delivery of flood defence could prevent the full benefits of this progress being realised for all of England and Wales.

In short, a radical overhaul, commencing as outlined above, seems necessary for a system designed for protecting and improving agricultural production but now focused on protecting a much larger urban population.

In addition to the foregoing, we have no reason to doubt the Agency's expressed view that to properly develop and maintain its flood defence assets in the short and medium terms, extra funding is required in the order of £40m per annum.

Legislative change would appear necessary for implementation of some of these proposals.

The ASC report dated 5 August 1998 proposes radical restructuring of the arrangements for flood and coastal defence and introduces new notions about strategies. It is beyond the scope of the Review to examine the implications of the Committee's proposals, but they do not appear contradictory to the views expressed above.

APPENDIX A

FLOOD DEFENCE IN ENGLAND AND WALES

A 1 Historic background

Although the 1531 Statute of Sewers initiated legislation relating to the drainage of land, it is the Land Drainage Act of 1861, enabling the establishment of drainage boards, which is the earliest legislation evident in the arrangements in place today. In certain low lying areas - such as the Somerset Levels, parts of Yorkshire and the Fens - internal drainage boards (IDBs) have been formed over the last century and more to take responsibility for improving and maintaining drainage

Prior to 1930, there were no other organisations charged with specific land drainage and flood defence responsibilities. However, in the late 1920s, in response to increasing concern about the UK's heavy dependence on imported food and the nation's consequent strategic vulnerability, it was recognised that improving the drainage of potentially fertile flood plain soils was a key requirement for increasing home food production. A Royal Commission was established and a framework for land drainage and flood defence emerged from its 1927 report. Although giving priority to agricultural interests, the Commission recognised that increased downstream urban flood risks might arise from better draining and defending agricultural land. Hence, the legislation which followed in 1930 incorporated provisions for remedying such urban problems. Grant aid from the Ministry of Agriculture, revenue provisions and the concept of main river also emerged from the work of the Royal Commission.

In the decade before and immediately after the second world war, the Ministry of Agriculture was at the top of the hierarchy of organisations concerned with land drainage and flood defence. The others were: catchment boards; internal drainage boards; county councils and district councils.

Whilst the names of some of the organisations have changed over subsequent decades, and major restructuring has occurred on several occasions, there has been no fundamental reframing of the arrangements for land drainage and flood defence in a period now approaching seventy years.

With UK membership of the Common Market, home food production became an issue for consideration in the context of CAP surpluses. Priority attention has, as a result, shifted from land drainage to urban flood defence. MAFF and Welsh Office policies and procedures as well as those of the drainage authorities have reflected this change of emphasis. However, the legal, financial and organisational arrangements designed originally for agricultural improvement are now, without fundamental modification, applied to urban interests (including the contribution of flood defence to the important matter of urban regeneration).

The term *land drainage* was deemed for many years to include flood defence, and this terminology accorded with the priority given to agricultural land drainage, as opposed to urban flood defence, following the Royal Commission. However, in the legislation described below, which was enacted in 1991, *flood defence* is the generic term replacing *land drainage* and is defined as ...*the drainage of land and the provision of flood warning systems, and the meaning of drainage is defence against water, including sea water.*

A 2 Relevant organisations and their inter-related roles

The policy framework for flood defence and coast protection is set by MAFF and the Welsh Office. In addition, they administer grant aid for capital projects concerned with flood defence and coast protection.

The publication "*Strategy for Flood and Coastal Defence in England and Wales*" explains government level policy and the background against which it is established.

The Agency and three other types of authority are involved with the provision of flood defence in the following ways:-

1. The Agency is responsible for river, sea and tidal defences which are of strategic importance.
2. Internal drainage boards are responsible for watercourses in certain low lying areas.
3. District councils may carry out flood defence works on minor watercourses and on sea defences.
4. Local authorities (or the Agency) other than district councils may promote schemes for the drainage of small areas of agricultural land.

The above organisations are eligible to apply for Exchequer grant, through MAFF or the Welsh Office, towards the cost of approved capital works.

Although generally supervising all matters, the Agency's own powers to carry out improvement or maintenance work are confined to watercourses designated as *main river* and to sea defences. Other watercourses, except those managed by IDBs, are the responsibility of riparian owners. However, district councils have power to carry out work on these *ordinary watercourses* for the purpose of flood defence.

The areas drained by ordinary watercourses managed by IDBs are known as internal drainage districts. They are often areas of high grade agricultural land requiring good standards of drainage in order to be used productively. The boundaries of drainage districts are related to known flood levels and do not accord with catchment or local authority boundaries.

The Agency has a general supervisory role in relation to internal drainage boards and the drainage activities of local authorities. Also, it may exercise a drainage board's powers if, in the opinion of the Agency, they are not being used to the necessary extent.

The Agency can require riparian owners to maintain any watercourse and may exercise control over the construction of culverts, bridges and other works. IDBs can act similarly within internal drainage districts.

A 3 Legal background

The 1991 Water Resources and Land Drainage Acts afford the legal basis for the administration and financing of flood defence in England and Wales. The Environment Act 1995 transferred to the Environment Agency the provisions relating to the NRA under the 1991 Acts.

The powers and duties of the Agency are covered specifically by the 1991 Water Resources Act and those of the internal drainage boards and local authorities by the 1991 Land Drainage Act.

The 1991 Acts include provisions for Ministers to make grants through MAFF and the Welsh Office to the Agency, internal drainage boards and local authorities. Grant applications may be made for flood defence capital schemes. In addition, Ministers may make grants towards expenditure by the Agency on flood warning systems.

The specific powers of the Environment Agency in terms of flood defence in major incidents derive from the Water Resources Act 1991, Section 165, and the Environment Act 1995, Section 37. In general, the Environment Agency should ensure its own flood defence systems function as intended, take mitigating action to remedy failures of elements of the defence systems, and lessen the impact of flooding by deploying emergency response resources jointly with local authorities, police, fire and rescue services.

On 5 March 1996 in a Ministerial Direction under Section 5 of the Water Resources Act 1991, the National Rivers Authority (and thus its successor body the Environment Agency) was instructed to *"take such steps as appear to it to be reasonable and practicable to provide warning of any danger of flooding"*.

Section 4 of the 1995 Environment Act requires the Government to give guidance on statutory objectives to which the Agency must have regard when discharging its functions. The guidance requires that the Agency should:

- i) adopt, across its functions, an integrated approach to environmental protection and enhancement which considers impacts of substances and activities on all environmental media and on natural resources;

- ii) work with all relevant sectors of society, including regulated organisations, to develop approaches which deliver environmental requirements and goals without imposing excessive costs (in relation to benefits gained) on regulated organisations or society as a whole;
- iii) adopt clear and effective procedures for serving its customers, including the development of single points of contact through which regulated organisations can deal with the Agency;
- iv) operate to high professional standards, based on sound science, information and analysis of the environment and of processes which affect it;
- v) organise its activities in ways which reflect good environmental and management practice and provide value for money for those who pay its charges and taxpayers as a whole;
- vi) provide clear and readily available advice and information on its work;
- vii) develop a close and responsive relationship with the public, local authorities and other representatives of local communities, regulated organisations and public bodies with environmental responsibilities.

The Environment Act 1995 places an obligation on the Agency, so far as is consistent with performing its flood defence and other activities, to further nature conservation and to have regard to:

- English and Welsh heritage;
- the well-being of rural communities;
- access to the countryside and heritage sites;
- the recreational use of land and water.

A 4 Environment Agency responsibilities

The Environment Agency is the lead organisation on flood defence. The watercourses (designated as main river) and the coastal systems for which it is responsible provide the flood defences of strategic importance. This work, together with the Agency's overall direction and supervision of all aspects of flood defence, is vital for sustaining the existing urban, agricultural and natural types of land use found on the river and coastal flood plains of England and Wales.

The Agency's flood defence related duties and powers may be summarised as:-

- An obligation to exercise general supervision over all matters relating to flood defence.
- Power to undertake fluvial flood defence on main rivers.
- Power to undertake sea and tidal defence anywhere.

- Power to make bye-laws for purposes connected with fluvial, sea and tidal flood defence.
- Power to provide and operate flood warning systems anywhere.
- Power to require the repair, maintenance or restoration of watercourses, bridges or other works on main rivers and ordinary watercourses, excepting those within internal drainage districts.
- Power to require works to maintain proper flow in main rivers and ordinary watercourses, excepting those within internal drainage districts.
- An obligation to determine applications for the construction of any works (including flood defence works by local authorities) affecting the flow of main rivers and ordinary watercourses, excepting those within internal drainage districts.
- Power to raise funds to cover expenditure on the foregoing through levies on local authorities, contributions from internal drainage boards and by applying for government grants.
- Power to act in default of internal drainage boards.

The Agency's work on the emergency response to flooding is based on its powers to maintain flood defences.

The powers described above are permissive with the exception of the obligations referred to for general supervision and consents to works.

In practice, the activities arising from the Agency's flood defence duties and powers are predominantly concerned with:-

- Identifying main river flood plains and, as a statutory consultee, advising planning authorities of the flood risk implications of developments in and beyond the flood plains.
- Assessing existing flood defence systems in order to identify deficiencies in relation to standard of defence objectives and thereby establish work programmes for improvement.
- Building new and improving and maintaining existing fluvial flood defence and land drainage systems.
- Building new and maintaining existing sea and estuary flood defences.
- Providing and operating flood warning systems in relation to main rivers, estuaries and the sea (although permitted to warn in relation to ordinary watercourses the Agency does not exercise its power to do so).
- Responding to flood emergencies.
- Enforcing action by riparian owners or others with responsibility for repairs to works (such as watercourse banks, bridges, culverts and weirs) on main rivers and ordinary watercourses, excepting within internal drainage districts where IDBs are responsible for this activity.
- Enforcing action by riparian owners to restore the condition of main rivers and ordinary watercourses, excepting within internal drainage districts where IDBs are responsible, in order to maintain proper flow.

- Consenting any temporary or permanent works (such as, in relation to the construction of bridges, culverts, walls and embankments) including flood defence works by local authorities causing potential or actual interference with flows in main rivers or ordinary watercourses, excepting those within internal drainage districts where IDBs are responsible for this activity.
- Protecting its flood defence and related works from river or coastal erosion.

The Agency exercises its powers through statutory regional and/or local flood defence committees assisted in one region by advisory committees. The statutory committees have executive powers to undertake capital and maintenance works and the other activities referred to above, and to raise the necessary funding. As such, they are not subject to formal direction by the Agency's board.

The present regional and local committee arrangements reflect the land drainage committee structures of the catchment based river boards which ceased in 1965. Some Agency regions cover more former river board areas than others. This, in part, explains the differing committee structures currently in place. Another factor explaining the differences is that, in some regions, committees have merged, accepted abolition or changed from statutory to advisory status. Due to the foregoing, the regional dissimilarities in flood defence committee arrangements are considerable, as illustrated below.

Flood Defence Committee arrangements

Region	Regional Flood Defence Committee	Local Flood Defence Committee	Advisory FDC
Anglian	1	5	0
Midlands	1	0	0
North East	2	0	0
North West	1	0	3
Southern	1	3	0
South West	2	3	0
Thames	1	0	0
Welsh	1	6	0

A 5 Internal drainage boards and local authority responsibilities

There are over 240 IDBs in England and Wales managing watercourses in drainage districts covering about 1¼ million hectares where land is largely, but not exclusively, in agricultural use.

With the exception of the Agency's Thames and North West regions, where IDBs no longer exist, the boards may be regarded as the second tier organisations on fluvial flood defence. The Agency operates at the top level with drainage boards mirroring its main river activity with their attention to ordinary watercourses within drainage districts.

In the North West region, all IDBs opted for abolition about 20 years ago at the time of North West Water Authority's responsibility for flood defence. The drainage systems of the boards were designated as main river, and the Authority took over the related pumping stations and other works. As NWWA's successor, the Agency now provides flood defence and land drainage services without direct charge to farmers, growers and others who formerly paid drainage rates to the IDBs.

IDBs continue to thrive in other areas, where high standards of land drainage and flood protection are essential for sustaining agricultural and urban land use within the drainage districts. Over the last two decades or so, IDBs have given increasing importance to protecting the urban areas within drainage districts, but the drainage of agricultural land continues to account for the majority of the resources deployed by drainage boards.

The drainage boards deliver capital and maintenance work programmes with funding raised from benefiting land and property owners and tenants either directly or via district councils through the general rates.

The duties and powers of IDBs may be summarised as:-

- An obligation to exercise general supervision of all flood defence matters within their districts.
- Power to maintain and improve existing and construct new flood defence and watercourse works within their districts.
- Power to make bye-laws for purposes connected with the above.
- Power to require the repair, maintenance or restoration of watercourses, bridges or other works on ordinary watercourses within drainage districts.
- Power to require works to maintain proper flow in ordinary watercourses within drainage districts.
- An obligation to determine applications for the construction of any works affecting the flow of watercourses within drainage districts.
- Power to raise funds to cover expenditure on the foregoing from those benefiting from the drainage services provided.

The work of district councils is founded on:-

- Power to undertake works on ordinary watercourses, which are not within the districts of IDBs, in the absence of action by riparian owners.
- Power to undertake sea and tidal defence where the Environment Agency does not assume responsibility.
- Power to require works to improve the condition of an ordinary watercourse in order to maintain proper flow.

Local authorities, other than district councils - that is, county councils and unitary authorities - have powers (as does the Agency) to carry out works to improve the drainage of small areas served by ordinary watercourses, but these powers are seldom used.

The powers of the IDBs and local authorities referred to above are permissive.

A 6 Flood risk management

It is the urbanisation of coastal and river flood plains which creates the potential for flood disasters. Left unoccupied to perform their functions in nature, the inundation of these areas would, at most, be disadvantageous to agriculture. Accordingly, the avoidance of further coastal and river flood plain development is a self evident lesson in relation to reducing the impact of future events. The Agency issued its publication *Policy and Practice for the Protection of the Flood Plains* in March 1997.

With most, if not all, natural hazards it is prudent to seek to manage risk, acknowledging that no matter how extreme an event, there is the possibility of it being exceeded. The validity of this notion to flooding is well established and it follows that flood risk cannot be eliminated on river and coastal flood plains.

It is not possible, therefore, to guarantee complete protection to communities in flood prone areas, and flood defences should be seen as works to reduce the risk of flooding but not to prevent it.

Probability concepts are used to indicate the rarity or likelihood of a flood, and this can be done in a number of different ways. The simplest would be to describe it by one of the following: "the highest in the last n-years", "the largest in living memory" or "the largest known". These have different degrees of precision depending upon how "living memory" or "largest known" are defined. Nevertheless, for exceptional floods they have the attribute of placing the flood into a time frame that is easily understood by the public.

For engineering and technical use, it is usual to express the severity in terms of a statistical probability. This is done, inter-alia, to facilitate the assessment of costs and benefits for flood alleviation works, which are subject to strict guidelines for public investment. The usual practice is to use return period or recurrence interval, which is the average interval in years between a flood of a given magnitude and an equal or larger flood.

When a flood is described as having a 50 year return period, the belief of many people is that another flood of this magnitude should not occur for another 50 years. The chance or probability of an equal or greater event in any and every year is, however, 1 in 50, alternatively expressed as 0.02 or 2 per cent. Therefore, a 50-year flood might occur more frequently than once every 50 years. Risk analysis can be used to calculate the chance that a flood of a given severity will occur over a fixed number of years.

The statement that a flood of a stated magnitude has a specified probability or chance of being equalled or exceeded in a given year appears to convey a better appreciation of risk to the general public than any other statistic. Hence, it is preferable when describing an extreme flood or a flood defence standard to refer only to percentage probability in any one year rather than to return period or some other statistic.

The components of flood risk management are:-

Flood warning:

Because people living and working in coastal and river flood plains cannot be assured of protection, there is the need to warn of impending inundation so that action is possible to mitigate damage and risk to life. Exercising powers referred to previously, the Environment Agency is the lead organisation on flood warning.

The flood warning process involves:

- having suitable remote data gathering facilities;
- forecasting flood characteristics including the time of onset of flooding and peak level;
- estimating the extents and locations of inundation and the consequential effects;
- preparing and passing messages to the people at risk about what to expect and the action to take;
- advising the organisations which are relevant to aiding the communities deal with the impending flooding.

Flood emergency response:

The Easter flood was a major incident as defined by the Home Office publication *Dealing with Disaster*. The key responsibilities of the Environment Agency include direct remedial action to prevent and mitigate the effects of the incident, to provide specialist advice, to give warnings to those likely to be affected, to monitor the effects of an incident, and to investigate its causes. In essence, the Agency, local authorities and the emergency services are required to work together to protect people and property.

Lead responsibility for emergency planning, derived mainly from civil defence powers, rests with principal local authorities, usually county councils. Emergency services - police, fire service, ambulance, and coastguard - collaborate with the county councils and each other to produce emergency response plans and to exercise those plans to ensure prompt and effective responses to major civil emergencies. Environment Agency statutory responsibilities are set out in the Water Resources Act 1991 and the Environment Act 1995. For fluvial and coastal flooding the Agency should ensure that it contributes its specific expertise to planning and response activities.

The Environment Agency describes one of its key success measures as: "*effective emergency response in partnership with Local Authorities and emergency services.*"

Flood defence:

Flood defence concerns measures which reduce the risk of flood plain inundation, when run-off from rainfall and /or melting snow exceeds the capacity of the receiving stream or river. The commonly adopted methods, singly or in combination, involve:

- the creation of reservoirs to temporarily store run-off;
- the construction of relief or replacement waterways to by-pass the hydraulically inadequate reaches of the existing system;
- the hydraulic improvement of the inadequate reaches by deepening, widening, reducing roughness and/or increasing gradients;
- the confinement of flood flows within walls or embankments, either adjacent to the waterway or set back on the flood plain.

As explained previously, the Environment Agency is responsible for flood defences of strategic importance with IDBs and local authorities performing supportive roles.

A 7 Climate change and rainfall variability

The impact of greenhouse gases on the climate is the subject of much scientific debate. Their capability to warm the earth's atmosphere is not in doubt. The concentration of greenhouse gases is rising. This is predicted to continue and to lead to a warmer climate. If correct, sea levels will rise and the risks of tidal flooding will increase. The design of sea defences already allows for higher sea levels.

However there is considerable debate about the detail of how the climate might alter and whether any change can yet be detected. Sir John Houghton in his book "*Global Warning: The Complete Briefing*" says that the changes which are likely to give most impact are those connected with the hydrological cycle and that all models agree that in a warmer world with increased greenhouse gases the hydrological cycle will on average become more intense.

The United States National Oceanic and Atmospheric Administration reported in August that in the past few decades global temperatures have persistently broken previous record highs every few years (1997 was the warmest year this century), but never to the extent now observed in 1998. Temperatures in every month from January to July have set a new all time high global record temperature and NOAA has stated that *...this is unprecedented and is not likely to occur in a stationary climate*. The Meteorological Office in a Memorandum to the House of Commons Agriculture Committee says that observed temperature in recent decades has gone beyond that expected from natural variability and that they believe human activities have played a part at least in the warming experienced in recent decades and may well be the main cause.

The Met Office's Hadley Centre for Climate Prediction and Research has made forecasts for the middle of the next century which indicate that precipitation will increase over most of the UK in wintertime, but decrease over the southern part of England in summertime. The nature of the rainfall is also expected to alter. Compared to pre-industrial times, very wet days (when rainfall exceeds 25 mm) are predicted to become by the 2050s some 4 to 5 times more frequent in the winter, and about 3 to 4 times more frequent in summertime. This in turn will increase the risk and frequency of flooding and also the need to operate flood forecasting and warning systems regularly and more frequently than at present.

The Met Office has advised the Review that there is good evidence of an increase in the proportion of rainfall from extreme events over the USA, although a similar analysis failed to find any convincing trend over Eurasia. No detailed statistical analysis has yet been carried out on UK rainfall.

The amounts rainfall vary from year-to-year and decade-to-decade entirely naturally. Until recently, natural variability was thought to be random, but recent work indicates that predictability of rainfall variability in broad terms over a few years ahead may be possible. Research at the Hadley Centre and elsewhere is seeking to demonstrate and realise this potential. This variability has been responsible for periods of severe flooding and drought in the past, and will continue to do so in the future. Although any tendency for increasing frequency of heavy rainfall days would be in line with climate model predictions, the Met Office advice is that it is not possible to attribute any given period of heavy rain, such as that during Easter 1998, specifically to man-made climate change.

Some research studies have identified changing patterns. An investigation in NW England by Orr shows increases since 1980 on the River Lune in the frequency of floods less than the 20 per cent probability flood and in the number of rain-days in the winter with 15mm or more. Studies by Chandler and Wheeler of rainfall in western Ireland have concluded that a long-term trend in rainfall amounts and a change in the pattern of wet and dry days is present in the rainfall record.

A non stationary climate means that a flood assessed in the past to be of a given severity can no longer be assumed to reoccur with the same frequency in the future and the indications are that severe floods may occur more often in the future than in the past. NRA R&D Report 12 *"Implications of Climate Change for the National Rivers Authority"* stated that *the extent of the impact that climate change might have on the frequency of flood plain inundation is currently (1994) unknown but its potential magnitude means that there is a need to investigate the issue.* In correspondence, the report's lead author (Dr N W Arnell) has advised that the information is becoming more convincing that flood risk is likely to increase with climate change. If so, there would be implications for flood warnings, defences and emergency response. In 1997, the International Commission for the Hydrology of the Rhine Basin published a major study of the impact of climate change and identified potential impacts for the year 2050. For the Rhine basin as a whole, it was concluded that peak floods are likely to occur more frequently and become higher, increasing the flood risk.

It is, therefore, apparent that the possible consequences of climate change on the frequency and severity of flooding in the UK need to be investigated further and relevant research elsewhere kept under review.

A 8 Environment Agency strategies, procedures and public information

The Agency has developed a strategic management approach which integrates strategies on the organisation's individual functions. All of the Agency's work is designed to be directed and managed in ways which protect or enhance the environment and achieve sustainable development.

The Agency's published strategy, procedural and public information documents have been examined in order to progress the Review on an understanding of the organisations objectives, plans and current approaches. Relevant aspects are as follows.

(a) For flood defence, the document *An Action Plan for Flood Defence*, broadly defines the purpose, direction and resources associated with this function in the short and medium terms. With regard to flood warning, the Action Plan states that in the five year period 1997-2001 the aim is to provide a reliable flood warning service by:

- *developing and implementing an effective flood forecasting system and issuing timely warnings to those at risk where possible;*
- *educating the public and organisations on the risk of flooding and their responsibilities;*
- *identifying the need for extending the flood warning service;*
- *testing emergency procedures annually.*

The Action Plan under the heading '*Initiatives and Targets*' declares, in addition, that an immediate corporate target is to improve the effectiveness of the Flood Warning System and achieve success rates for the receipt of warnings of 65 % in 1998 and 80% in 2001.

Under the heading '*Measuring and Reporting Outcomes*', the Action Plan states that key measures of success for the flood defence function will include :

- *an informed public;*
- *timely receipt of flood warnings;*
- *flood damage avoided;*
- *no human fatalities as a direct result of flooding;*
- *effective emergency response in partnership with local authorities and emergency services.*

(b) The Agency's document "*The Flood Warning Strategy for England and Wales 1997/98 to 2001/02*" is a document currently at final draft stage intended for release in due course to the public and organisations relevant to the flood warning service. The following are quotations or summarised statements from the Flood Warning Strategy document.

- (1) *The value of the warning service is dependent on whether :*
 - *warnings get to the right people and by what means;*
 - *warnings are accurate;*
 - *warning time is sufficient for effective action to be taken;*
 - *the people at risk and the emergency services are prepared.*
- (2) *The Agency will seek to raise the average effectiveness of response after receipt of a warning by undertaking a comprehensive campaign to raise the level of awareness in flood risk areas, so that people understand the warning service and know what action should be taken when flooding occurs. Local Authorities and emergency services are to be kept informed in order that they may fulfil their responsibilities in responding to major incidents.*
- (3) *Agency flood warning procedures are described in Dissemination Plans and these are available for inspection at Agency offices and have been distributed to other authorities who helped to formulate them.*
- (4) *A key standard is the warning lead time provided to people at risk before the onset of flooding, since this determines how much damage can be avoided. The Agency sets this as a level of service against which performance can be measured.' Prior warning will be provided (two hours in general) to people living in designated flood risk areas where flood forecasting facilities exist and where lead times enable us to do so' (quoted from the Environment Agency Customer Charter).*
- (5) *The Agency will set nationally consistent and achievable standards for flood warning.*
- (6) *The Agency will advise Local Authorities about significant urban flood risks and encourage the preparation of Major Incident Plans.*
- (7) *The Agency will undertake regular independent surveys of public awareness to measure ability to respond effectively to warnings (see Appendix A for summary of surveys made to date).*
- (8) *The Agency will identify, efficiently manage and seek to provide adequate financial and manpower resources.*
- (9) *The Agency will develop and adopt best national practice to appraise need using the Flood Warning Levels of Service Studies approach and draw up programmes for improvement in each region.*
- (10) *The Flood Warning Strategic Board will influence and be advised by the Agency's National Telemetry Group (i.e. in connection with telemetry and instrumentation).*

- (11) *The Agency will review its ability to issue warnings for its own reservoirs (operated mainly for flood retention) and other sites where Inundation Plans are in place.*
- (12) *The Agency will monitor the effects of climate change and review flood warning needs.*
- (13) *The Agency will regularly seek the experience of a sample of people who have been flooded within designated warning areas, and will regularly publish information on performance.*
- (14) *The highest priority for the Agency is to maintain and provide the existing flood warning service as described in the Flood Warning Dissemination plans.*
- (15) *The priority for Major Incident Plans is where the likelihood of flooding is low (less than 2% chance of flooding each year) but concern for human safety is high. Areas protected by defences which could fail or be overtopped should receive higher attention than (otherwise similar) unprotected areas. The Agency will encourage and work with Local Authorities according to this ranking.*
- (16) *All regions rely on weather services from the Met Office and elsewhere. A national project has been started to review the range of services provided, identify best practice and recommend options for improvement. Completion of this project is a priority.*

The Agency's Flood Warning Information pack is designed to advise people about flood warnings and what they should do if at risk from flooding.

APPENDIX B

SUMMARIES OF WEATHER FORECASTS

Table 1-Weather Department Ltd Forecasts issued to Midlands Region

(L), (M), & (H) refer to Low, Medium and High confidence for rainfall amounts

Date/Time	Sunday 5 April - 1600hrs	
24 hours Synoptic Summary Plus Outlook Some heavy showers developing through course of the day. Further showers for Monday. Turning colder through this week.		
Rainfall (16-16hrs) Severn Lowlands	<u>Sun/Mon</u> 4 - 12 (M)	<u>Mon/Tue</u> 2 - 5 (M)
Amplification and Outlook for 24 hours ending 16.00 on:		
Wed 8 April	Some more persistent cloud and rain pushing southwards for Wednesday.	
Thur 9 April	Spells of rain into region, turning to sleet and snow at higher levels.	
Fri 10 April	Some wintery showers through region.	
Date/Time	Monday 6 April - 1600hrs	
24 hours Synoptic Summary Plus Outlook Unsettled conditions, mixture of sunshine and showers, some developing into heavy showers. More showers for Tuesday before colder wintery conditions spread down from north by mid-week.		
Rainfall (16-16hrs) Severn Lowlands	<u>Mon/Tue</u> 2 - 7 (M)	<u>Tue/Wed</u> 2 - 5 (M)
Amplification and Outlook for 24 hours ending 16.00 on:		
Wed 8 April	Some further showers, more organized band pushing down from north. Some locally heavy.	
Thur 9 April	Some wintery showers in eastern part of region.	
Fri 10 April	Some wintery showers in eastern parts. Western parts will miss these and stay dry.	
Date/Time	Tuesday 7 April - 1600hrs	
24 hours Synoptic Summary Plus Outlook Developing low will move southwards...bringing some heavy rain. Some snow likely later in the week.		
Rainfall (16-16hrs) Severn Lowlands	<u>Tue/Wed</u> 2 - 9 (M/L)	<u>Wed/Thur</u> 5 - 10 (M)
Wed 8 April	Cloud and rain pushing south some heavy and prolonged bursts in places in afternoon.	
Thur 9 April	An occlusion will bring some further rain, over hills and mountains turning to sleet and snow and some could be quite heavy.	
Fri 10 April	Spells of snow in eastern and northern parts	

Date/Time	Wednesday 8 April - 1600hrs	
24 hours Synoptic Summary Plus Outlook		
Developing area of low pressure pushing down from north will bring some wet and quite windy conditions through region tomorrow. Some sleet and wet snow over hills.		
Rainfall (16-16hrs) Severn Lowlands	<u>Wed/Thur</u> 6 - 15 (M)	<u>Thur/Fri</u> < 2 (H)
Amplification and Outlook for 24 hours ending 16.00 on:		
Thurs 9 April	Occluded front will bring some heavy rain at times, particularly towards south of region. Turning to sleet and snow over Welsh mountains	
Fri 10 April	Some wintery showers, will be light and quite well scattered.	
Date/Time		
Thursday April 9th - 1600hrs		
24 hours Synoptic Summary Plus Outlook		
Low pressure (990) remains over southern Britain today and tomorrow.		
Rainfall (16-16hrs) Severn Lowlands	<u>Thur/Fri</u> 9 - 20 (M)	<u>Fri/Sat</u> < 2 (M)
Amplification and Outlook for 24 hours ending 16.00 on:		
Fri 10 April	Occluded front likely to cross the region. Outbreaks of rain - some of these heavy.	

Table 2-Met Office Forecasts and Warnings issued by Norwich Weather Centre

Date (Time)	Type	Summary of Contents
6 April	10 day forecast	Patchy drizzle Wed, showers (60%prob), longer spells (60%) rain Thurs, Fri risk sleet or hail. Sat showers, longer spells of rain Sun. Rain: Wed 4-5mm. Thurs. 8mm Fri 8-10mm
8 April 15.50	Heavy Rainfall Warning	Heavy rain locally >20mm, Heavy thunder storms, persistent rain later tonight >20mm, heavy rain expected to continue Fri & Sat am.
9 April	10 day forecast	Thunderstorms thro' Thurs pm, Fri 60%chance rain. Rain: Thurs 12-20mm (12hr). Fri 15-18mm. Sat 3-8mm
9 April 11.18	Flash Warning Heavy Rainfall	Band of thunderstorms across Suffolk and Essex, localised flooding
9 April 18.14	Heavy Rainfall Warning	Further 8-15mm of rain. Further warning may be issued tomorrow (none issued)

1. Times are Times of Origin from Met Office
2. Rainfall amounts to North and Central areas .

Table 3-Met Office Forecasts and Warnings issued by Birmingham Weather Centre

Date (Time)	Type	Summary of Contents
9 April 04.50	Motor Weather Warning	Showers will merge across Midlands - longer spells of heavy rain.
9 April 11.35	Flash Warning Severe Weather	Rain and thunderstorms, locally very heavy downpours and hail. S. Midlands in afternoon. Local flooding. (Endorsed: "Manually to Northants Police").
9 April 15.15 \$	Flash Warning Severe Weather	Rain and thunderstorms, locally very heavy downpours and hail in Leicestershire. Local flooding.
9 April 19.15	Motor Weather Warning	Persistent rain - Midlands overnight, heavy bursts at times

1. Motor weather Warnings were not issued to Agency Regions or Thames Barrier
2. \$ No record of receipt as NMC Severe Weather Warning by Thames Barrier or in Regions

Table 4-Met Office Forecasts and Warnings issued by London Weather Centre

Date (Time)	Type	Summary of Contents
6 April 10.28	Routine (2 per week)	Wed: Scattered showers becoming widespread and longer spells rain heavy and thundery Thurs: Showers or longer spells rain, heavy and thundery Rain: Wed 17mm. Thur 25mm
8 April 16.03	Routine -daily overnight guidance	50% probability rain > 10mm in North and South Thames Valley
9 April 03.45*	Heavy Rain Warning	Sustained heavy rain, especially on high ground. 20 - 30mm in next 24hrs.
9 April 10.38	Routine (2 per week)	Thurs. More persistent rain likely Thames north (30mm in 12 hrs) Fri. Most persistent rain in Thames north (45mm in 24 hrs).
9 April 11.21 and 13.01 \$	Flash Warnings Severe Weather	Rain, thunderstorms, very heavy downpours and hail. North London. Local flooding. (Both warnings identical).
9 April 15.51	Routine - daily overnight guidance	Thames North probability > 10mm (50%)
10 April 07.29*	Heavy Rain Warning	Heavy perhaps thundery showers. > 20- 40 mm (20%), 60mm (10%)
10 April 17.57	Heavy Rain Warning	Showers to continue into the evening, locally heavy rain Cotswolds and Chilterns
10 April 16.07	Routine - daily overnight guidance	Thames North probability > 10mm (60%)

1. Times are Times of Origin from Met Office.
2. \$ No record of receipt by Thames Barrier or in Regions
3. * Heavy rainfall Warnings also issued for S Thames
4. % figures in brackets refer to probability

Table 5-Met Office Forecasts and Warnings issued by Bristol Weather Centre

Date (Time)	Type	Summary of Contents
8 April 22.41	Flash Warning Severe Weather.	Heavy persistent rain - Cornwall, some torrential downpours. Localized flooding possible, 1-2" rain.
9 April 11.23	Flash Warning Severe Weather	Rain, thunderstorms, local very heavy downpours and hail, N.Devon, Somerset, Wiltshire, Glos. and Bristol. Local flooding.

1. Times are Times of Origin from Met Office.
2. These appear as up-dated warnings from NMC at Thames Barrier at 23.25 08/04 and 11.26 09/04

Table 6-Met Office Forecasts and Warnings issued by Cardiff Weather Centre

Date (Time)	Type	Summary of Contents
9 April 11.15	Flash Warning Severe Weather	Rain and thunderstorms, locally heavy downpours rain and hail. Localized flooding (Mid Wales)
9 April 17.46	Flash Warning Severe Weather	Rain and thunderstorms, locally heavy downpours rain and hail. Localized flooding (All parts of Wales)

1. Times are Time of Origin from Met Office.
2. No Heavy rainfall warnings issued by Cardiff Weather Centre.

Table 7-Warnings received by the Thames Barrier from the National Met Centre National Severe Weather Warning Service

Date (Time)	Type	Summary	Distribution
8 April 15.10	Early Warning Severe Weather	Snow in Scotland. Heavy rain will affect SW England turning to snow.	Some Regions
8 April 23 15	Flash Warning Severe Weather	Heavy, persistent rain in Cornwall overnight. Some torrential downpours expected to lead to localized flooding. >25mm rain possible on high ground	Some Regions
9 April 10.15	Early Warning Severe Weather	Snow in Scotland, Heavy rain over N & W England may turn to snow.	Some Regions
9 April 11.26	Flash Warning Severe Weather	Rain and thunderstorms, local very heavy downpours and hail, (Mid Wales to East Anglia, across S. England from N. Devon to Thames estuary.) Local flooding.	All Regions except N.E. & NW
9 April 17.50	Flash Warning Severe Weather	Rain and thunderstorms, local very heavy downpours and hail. (From S. Wales, through S. Midlands to East Anglia. Expected to move to N. Wales, N. Midlands to Lincolnshire) Local flooding.	All Regions except Thames, S.W. and Southern

1. These messages were sent to the Environment Agency at Thames Barrier for internal dissemination by them to the Agency Regions.
2. Times are receipt at Thames Barrier from their log book; no delays in onward transmission have been identified.
3. Unable to establish distribution of some warnings as original documents not retained at Thames Barrier.

APPENDIX C

FLOOD FORECASTING, WARNING AND RESPONSE SYSTEM

Submission by Professor D J Parker, Flood Hazard Research Centre, Middlesex University

The centre has undertaken a series of research projects on the subject of flood warning dissemination over the past 15 years. The principal characteristic was to focus on interviewing the recipients of flood warnings (including those who should have received flood warnings). The research shed light on the causes of under-performing flood warning dissemination processes.

The Easter floods revealed both strengths and weaknesses in the Agency's warning performance and its relationships to other agencies involved in flood emergency response. Specific observations include:-

(1) Need for continuity of staffing and expertise in flood forecasting and warning services

At Easter the Agency faced two distinct requirements. The first to detect, interpret and warn others in the Agency, the second was for other agencies and flood plain occupants to be warned in a timely manner. It seems clear that in some cases the flood events were beyond the experience of Agency staff, which made it difficult for appropriate interpretations and warnings to be disseminated internally and externally. The research discovered the importance of continuity and it was clear that staff gradually accumulated experience of 'their' rivers.

Re-structuring and organisational change appears to have been particularly frequent in recent years in the Agency and has and is affecting flood forecasting and warning services. The research and experience at Easter emphasise the importance of continuity of staffing and expertise in the flood detection, warning and dissemination departments and of linkages to other agencies for effective flood forecasting and warning services.

(2) Flood warning systems should be provided for defended as well as undefended flood plains

The focus of flood forecasting and warning dissemination is usually on undefended flood plains. It is clear, from the experience at Northampton, that similar services need to be provided and regularly rehearsed for defended flood plains. The overtopping or breaching of flood defences presents particular dangers caused by high flood water velocities and the suddenness of flooding. The public at risk must be regularly informed of the value and limitations of their flood defences, including that defences can be breached or overtopped.

(3) The importance of high quality, high resolution of flood plain mapping

At Easter areas which had never flooded before and which were thought not to be at risk were flooded. This is one indication that the Agency's flood maps are not good enough. The research clearly indicated that it is difficult for the Agency and others to effectively allocate their resources if flood plain mapping is of insufficient quality. As a result flood warnings are poorly targeted. The Agency must therefore continue to invest in high quality, high resolution flood plain mapping not only for flood warning but also for flood plain development control.

(4) The believability of flood warnings

It is clear that a number of flood plain users (including mobile home users) failed to respond appropriately to their own detection of rising flood waters and/or to believe flood warnings. This is a well know problem in risk communication and behavioural science. It is believed that the design, content, wording, presentation and sequencing of the Agency's flood warning messages require review and modification to elicit the desired response by those at risk.

The research and that of others points to the importance of (a) warning messages being transmitted along multiple rather than single channels and (b) providing opportunities and mechanisms for warning recipients to confirm the message and how to respond. Most recipients require confirmation before they will respond effectively. Personal warning messages are more believable than impersonal ones (AVM falls into the latter category).

(5) Inter-agency liaison and effective working

The Easter floods revealed significant weaknesses in the total FFWRS when considered as a multi-agency response problem. There were indications that responsibilities of the Agency were insufficiently understood by local authorities and people and the police. There is a continual requirement in the civil emergency response field for the multiplicity of agencies involved to work on developing ever more refined understandings of each other's roles and responsibilities.

(6) Flood warnings in multi-ethnic communities

Research has indicated that flood prone populations cannot be considered homogeneous in terms of their ability to receive, comprehend and act upon flood warnings. Many parts of flood prone urban areas are the home of multi-ethnic communities and this is an issue which the Agency needs to address for flood warning.

APPENDIX D

MODEL METEOROLOGICAL SERVICE FOR FLOOD DETECTION, FORECAST, WARNING AND RESPONSE

Submission by The Meteorological Office

D 1 Radar Data and Nimrod Forecasts

Dissemination to all Agency Regions of quality controlled 2km/5 minute single site data, UK composite, Regional Radar Composite (5km/15 minute and 2km/5 minute if required), and rainfall forecasts from the Met Office Nimrod system through high-speed resilient telecommunications links.

Implementation of developments in radar - based products; the integration of Met Office GANDOLF thunderstorm forecasting methods into the Nimrod rainfall forecast system; real-time estimates of uncertainty in radar rainfall measurements; dissemination of radar rainfall accumulation fields over identified areas/catchments on various time scales; integration of forecast thunderstorm probability and peak rain rate from the Convective Diagnosis Project into Nimrod.

Pursue relevant longer-term development projects; the development of a storm-scale (1km resolution) Numerical Weather Prediction model and its application to flood forecasting; investigation of the use of probability-type rainfall and hydrological forecasts in flood risk management.

D 2 Met Office Rainfall and Evaporation System (MORECS) Service

40km x 40km areal estimates of soil moisture deficit to help assess catchment states and run-off.

D 3 National Severe Weather Warning Service

Warnings up to 5 days in advance of extreme events likely to cause widespread disruption to human activity provided as part of the Public Met Service.

D 4 Warnings of Heavy Rainfall, Snow/Snow Melt from local Weather Centre

Warnings to Agency Flood Warning Duty Officers by fax, telex or electronically with back-up telephone call to confirm receipt. Flexible warning criteria for different hydrological and catchment characteristics to include best estimates of rainfall quantities and intensities above the relevant warning criteria, along with the likely time of occurrence. Probability of rainfall intensities and amounts in different 'bands'.

Routine daily conference around 5 p.m., between Agency Flood Warning Duty Officers and Weather Centre Forecasters. Routine daily update of probability of rainfall accumulations by fax, telex or electronically exceeding relevant thresholds. Inclusion of Agency flood warnings in national and regional TV and radio broadcasts.

D 5 Routine Weather Centre Forecasts

Detailed daily forecasts for next 48 hours to each region by fax, telex or electronically, sub-divided to cover hydrological zones. Forecasts of maximum rainfall totals expected in each hydrological 'zone' within each region for 6 hour periods with confidence levels. An indication of the general synoptic, weather situation for the period, with a detailed summary for each day to include other meteorological elements.

Three times weekly (Mondays, Wednesdays & Fridays) 5 Day Ahead Forecasts as outlined above but for 12/24 hour rainfall forecast periods rainfall accumulations with an outlook for the weather trend for Days 6 to 10.

A 24 hour, 365 days per year back-up consultancy service to enable Agency's staff to clarify warnings, routine forecasts and discuss short term weather prospects.

Twice daily North Atlantic actual and forecast pressure and frontal fields charts for each day out to 5 days ahead.

D 6 Integrating the 'joint' team

The 'human factor' is a vital component in developing trust and rapport between Agency and Met Office staff at all levels and is particularly important during a flood event.

Annual meetings at national senior management level to discuss strategic issues and at middle management level to review regional services and present verification reports. Non-operational contact person within each Agency region to co-ordinate services across all functions and be the trouble shooter. Visits by Weather Centre forecasters and Flood Warning Duty Officers to each others Operations Centres.

Radar Data Quality Management Group meetings.

D 7 Training

Tailored training courses for Flood Warning Duty Officers on Weather Radar and 'Background to Meteorology'.

D 8 Access to Agency's Telemetry Raingauge Network

Met Office access to the Agency's telemetry raingauge network would improve radar adjustment, Nimrod Forecasts, post event analysis, Weather Centre Heavy Rainfall Warnings and give more accurate real values of rainfall and Soil Moisture Deficit.

APPENDIX E

FLOOD WARNING CHRONOLOGIES

Chronology 1 - Anglian Region - Northampton

Time	Source	Description
Monday 6 April		
11.57	10-day forecast (Met Office)	Longer spells (60%) rain Thurs Rain: Wed 4-5mm. Thurs. 8mm Fri 8-10mm
Wednesday 8 April		
15.50	Heavy Rainfall Warning	Heavy rain locally >20mm. Heavy thunder storms, persistent rain later tonight >20mm, heavy rain expected to continue Fri & Sat am.
Thursday 9 April		
05.00	Telemetry	Start of rainfall at Litchborough (64mm in 15 hrs)
10.00	Telemetry	Start of rainfall at Ravensthorpe (53.5mm in 12hrs)
11.18	Flash Warning Heavy Rainfall	Thunderstorms Suffolk and Essex, localised flooding
11.26	Flash Warning Severe Weather	Rain and thunderstorms, local very heavy downpours and hail. (Mid Wales to East Anglia, across S. England from N. Devon to Thames estuary.) Local flooding.
11.59	Telemetry	1st rain gauge (Litchborough) sends out alarm for 20mm in 24hrs, implies 20mm in 8 hrs.
13.43	10-day forecast (Met Office)	Rain: Thurs 12-20mm (12hr). Fri 15-18mm.
15.30	Area Office	Flood Control Room opened.
15.45	Flood Control Room	AMBER Warning, issued on River Nene (generalised broadcast warning for Kislingbury, Weedon and Bugsbroke Mill Northampton)
16.10	Flood Control Room	AMBER Warning, issued by AVM to properties as above, (except Northampton)
16.25	Flood Control Room	RED warning for Kislingbury, broadcast and AVM
17.00	Flood Control Room	Approx. hourly forecasting of flows commences
17.20		Filling of Northampton Washlands commenced.
18.14 revised	Heavy Rainfall Warning	Further 8-15mm of rain. Further warning may be issued tomorrow (none issued).
19.00	Post Event Study	Flooding commenced in Weedon (u/s Northampton)
21.28	Flood Control Room	RED warning issued for Weedon, broadcast and AVM
23.00	Flood Control Room	Prediction of 109 cumecs (cf Red alert of 125 cumecs)

Friday 10 April		
00.00	Property Owner	1st call to Fire Brigade reporting flooding in Northampton.
01.00	Post Event Study	Kislingbury flooding from river commences (earlier reports of flooding from surface water systems)
02.45	Telemetry	Peak at St. Andrews bypass (03.00 at St Andrews Mill)
03.00	Post Event Study	Northampton washlands full
03.30	Telemetry	Peak at Upton Mill (03.00 Upton bypass)
04.00	Telemetry	Peak flow at Northampton (St. Andrews)
07.00	Post Event Study	Northampton washlands 0.62m above spillway
07.00	Emergency Planning Officer	Agency advised by CEPO of flooding and evacuation in Northampton.

1. Flood Control Room (Lincoln) open overnight 9/10th April.

Chronology 2 - Midlands Region - Leamington

Time	Source	Description
Wednesday 8 April		
15.10	Early Warning Severe Weather (Met Office)	Snow in Scotland. Heavy rain will affect SW England turning to snow.
16.00	Routine Forecast (Weather Dept Ltd)	6 - 17mm in next 48 hours; Thur - Some heavy rain at times. Fri - Wintery showers, light and well scattered.
23.15	Flash Warning Severe Weather (Met Office)	Heavy, persistent rain in Cornwall overnight. Some torrential downpours expected to lead to localized flooding. >25mm rain possible on high ground
Thursday 9 April		
07.27	Flood Forecasting System (FFS) model	Duty Officer alerted by routine daily 07.00 model run forecasting Yellow threshold at Shipston on Stour at 16.00. 2 hourly forecast model runs from 09.00 initiated.
08.00	Area Office	Flood warning operations commenced in office with continuous manning until 17.00 hrs 12 April
08.30	Flood Forecasting	Regional Forecasting Duty Officer commenced duty in office.
09.20	Telemetry	27 mm reported at Shipston and 32.5mm at Chipping Campden over previous 24 hrs (routine)
09.38	Telemetry	1st Alarm - from Shipston on Stour rain gauge: 18mm in 9 hrs
09.52	Telemetry	Alarm for Chipping Campden: 18mm in 6 hrs
10.13	Area Office	1st YELLOW Warning issued: River Stour (A7) - Shipston
10.15	Early Warning Severe Weather (Met Office)	Snow in Scotland, Heavy rain over N & W England may turn to snow.
11.00	FFS model run	YELLOW threshold level predicted for Eathorpe at 23.30 RED threshold predicted for Easthorpe "overnight" and in subsequent runs up to 23.00
11.26	Flash Warning Severe Weather (Met Office)	Rain and thunderstorms, local very heavy downpours and hail, (Mid Wales to East Anglia, across S. England from N. Devon to Thames estuary.) Local flooding.

11.40	Area Office	1st AMBER Warning issued: River Stour (A7) - Shipston
14.00	FFS model run	YELLOW threshold level predicted for Eathorpe at 20.30 AMBER threshold level predicted for Eathorpe at 23.30
14.05	Area Office	1st RED Warning issued: River Stour (A7) - Shipston
15.00	FFS model run	YELLOW threshold level predicted for Eathorpe at 16.30 AMBER threshold level predicted for Eathorpe at 22.30
15.54	Area Office	YELLOW Warning issued for R Leam (A6) - Leamington
16.00	Routine Forecast (Weather Dept Ltd)	9 - 22mm in next 48 hours Fri - Outbreaks of rain - some heavy
16.00	Telemetry	YELLOW threshold exceeded (A6) - Eathorpe Gauge
17.00	FFS model run	AMBER threshold level crossed for Eathorpe
17.02	Area Office	AMBER Warning issued for R Leam (A6) - Leamington
17.15	Telemetry	Amber threshold exceeded (A6) - Eathorpe Gauge
17.50	Flash Warning Severe Weather (Met Office)	Rain and thunderstorms, locally very heavy downpours and hail from S. Wales, through South Midlands to East Anglia. Local flooding.
18.00	Flood Forecasting	Regional Forecasting Duty Officer operating from home
*21.00	FFS model run	RED threshold level predicted for Eathorpe at 06.00 10/04
21.05	Interrogation	Eathorpe levelling off
*23.00	FFS model run	RED threshold level predicted for Eathorpe at 06.30 10/04
23.18	Area Office	RED Warning issued for R Leam (A6) - Leamington
Friday 10 April		
00.00		Red threshold exceeded (A6) - Eathorpe Gauge
04.30	Property Owner	1st report of property flooding (from surface water / sewers)
05.30	Newspaper report	R Leam out of bank - property flooding by river commences
07.00	Newspaper report	Most properties flooded
08.15	Flood Forecasting	Regional Forecasting Duty Officer commenced duty in office.
09.00	Telemetry	44mm rainfall reported at Shipston in previous 24 hrs and 60mm at Milcote in previous 24hrs
10.00	Telemetry	Deduced time of peak in Leamington
20.20	Flood Forecasting	Regional Forecasting Duty Officer operating from home

Notes:

1. River Forecast produced on 9 April at 07.00(routine run daily), 09.00, 11.00, 13.00, 14.00, 15.00, 17.00, 19.00, 20.00, 21.00 & 23.00
2. Selected river forecasts only shown
3. model outputs available 15-20 minutes after the run on the hour

Chronology 3 - Thames Region - Kidlington

Time	Source	Description
Wednesday 8 April		
15.23	Early Warning Severe Weather	Snow in Scotland. Heavy rain will affect SW England turning to snow.
16.03	Routine Forecast (Met Office)	50% probability rain > 10mm
Thursday 9 April		
03.45	Heavy Rainfall Warning (Met Office)	Sustained heavy rain, especially on high ground 20 - 30mm in next 24hrs
08.30	Regional Office	River Control Room opened
10.00	Telemetry	37mm rainfall measured at Chipping Norton over previous 24 hrs #
10.30	River Control Room	YELLOW Warnings on River Cherwell, Reaches 1 & 2
10.15	Early Warning Severe Weather	Snow in Scotland, Heavy rain over N & W England may turn to snow.
10.38	Routine Forecast 5-day (Met Office)	More persistent rain (30mm in 12 hrs, 45 mm in 24 hrs).
11.26	Flash Warning Severe Weather	Rain and thunderstorms, local very heavy downpours and hail, (Mid Wales to East Anglia, across S. England from N. Devon to Thames estuary.) Local flooding.
15.10	Property Owner	1st report of property flooding in Cherwell catchment
15.51	Routine Forecast (Met Office)	Thames North 50% probability > 10mm
17.00	River Control Room	AMBER Warning Cherwell Reach 1 (Banbury) issued
18.30	Regional Office	River Control Room closed
22.10	Site Report	Level at Banbury 1.68, highest ever = 1.72. Verbal report of 60mm rain recorded.
22.30	Duty Officer from home	RED Warning Cherwell Reach 1 (Banbury) issued AMBER Warning Cherwell Reach 2 (Kidlington) issued

Friday 10 April		
03.00	Post Event Survey	Estimated time of peak (2.75m) flood in Banbury
07.29	Heavy Rainfall Warning (Met Office)	Heavy perhaps thundery showers. > 20- 40 mm (20%), 40-60mm (10%)
07.55	Area Office	Incident Room at Wallingford opened
09.30	Regional Office	River Control Room opened
10.00	Telemetry	70mm rainfall measured at Byfield over previous 48hrs #
12.03	Telemetry	Rain since 10.00 09/04 33.6mm at Grimsbury raingauge
14.45	River Control Room	RED Warning Cherwell Reach 2 (Kidlington) issued
16.07	Routine Forecast (Met Office)	Thames North 60% probability > 10mm
17.57	Heavy Rainfall Warning (Met Office)	Showers to continue into the evening, locally heavy rain Cotswolds > 10mm (100%)
18.30	Site Controller	First flooding to property in Kidlington reported - water still rising (between 18.30 and 22.00 water level up by 3 - 8cm)
20.00	Regional Office	River Control Room closed
20.45	Post Event Study	Peak level (2.1m) at Enslow River Cherwell @
23.00	Area Office	Incident Room closed
Saturday 11 April		
18.00	Post Event Study	97m ³ /s measured peak on Cherwell (by current meter) at Marston Ferry Road Bridge

Notes

1. # requires pro-active interrogation of telemetry to obtain data.
2. @ obtained from data logger after the flood event.

Chronology 4 - Welsh Region - Skenfrith

Time	Source	Description
Wednesday 8 April		
MetFAX 5-day Forecast		(Forecast for Thursday) The day will start cloudy with outbreaks of rain, and snow over the hills, with further slight accumulations. During the afternoon, drier brighter weather is expected to spread into north and west Wales but south east Wales will stay cloudy with occasional rain and hill snow into the evening.
Thursday 9 April		
09.30	MetFAX 5-day Forecast	A cloudy day for Wales with outbreaks of rain heavy at times, in most areas. The odd rumble of thunder is possible in the heavier rain. Remaining cloudy overnight with further rain, some heavy at times.
10.00	Telemetry	Duty Officer begins active monitoring of rainfall and river levels
11.26	Flash Warning Severe Weather	Rain and thunderstorms, local very heavy downpours and hail, (Mid Wales to East Anglia, across S. England from N. Devon to Thames estuary.) Local flooding.
12.43	Flood Incident Room (Area)	YELLOW Warning issued to agricultural areas on R Wye, NFU at Hay
13.48	Flood Incident Room (Area)	YELLOW Warning issued to undefended locations on R. Usk, All sites.
14.05	Flood Incident Room (Area)	YELLOW Warning issued to undefended locations on R Monnow, Monmouth & Skenfrith
15.30	Post Event Survey	1st property flooding at Skenfrith (from surface water).
15.49	Flood Incident Room (Area)	YELLOW Warning issued to agricultural areas and undefended areas on R Wye, Hay to Hereford, Hereford to Ross
15.51	Flood Incident Room (Area)	YELLOW Warning issued to undefended locations on R. Wye, Hereford City
16.42	Flood Incident Room (Area)	AMBER Warning issued to defended locations on R. Wye Monmouth
17.24	Flood Incident Room (Area)	AMBER Warning issued to agricultural areas and undefended areas on R Wye, Hay to Hereford, Hereford to Ross
17.24	Flood Incident Room (Area)	AMBER Warning issued to undefended locations on R. Wye, Hereford City
17.50	Flash Warning Severe Weather	Rain and thunderstorms, local very heavy downpours and hail. (From S. Wales, through S. Midlands to East Anglia. Expected to move to N. Wales, N. Midlands to Lincolnshire) Local flooding.
18.28	Flood Incident Room (Area)	AMBER Warning issued to undefended locations on R. Monnow, Monmouth & Skenfrith
19.00	Telemetry	Peak level of 4.58m at Grosemont gauge on River Monnow
19.00	Post Event survey (property owner)	Further property flooding in the Skenfrith area (initially from local watercourses followed by main river)
19.11	Flood Incident Room (Area)	RED Warning issued to undefended locations on R. Monnow, Monmouth & Skenfrith
23.30	Post Event survey	River Monnow beginning to peak at Skenfrith

Friday 10 April		
00.37	Flood Incident Room (Area)	RED Warning, Hereford to Ross
02.39	Flood Incident Room (Area)	YELLOW Warning issued to undefended locations on R. Wye, Lydbrook
02.41	Flood Incident Room (Area)	RED Warning issued to defended locations on R. Wye, Monmouth
03.00	Telemetry	Peak level of 5.698 at Monnowgate gauge on River Monnow
06.33	Flood Incident Room (Area)	AMBER Warning issued to undefended locations on R. Wye, Lydbrook

Notes

1. No Heavy Rainfall Warnings were issued by Cardiff Weather Centre during these floods.
2. Area did not receive Severe Weather Warnings distributed from Thames Barrier.
3. Flood Incident Room manned overnight 9th/10th April.
4. Includes warnings for sites other than Skenfrith.

APPENDIX F

FLOOD WARNING - BASELINE SURVEY

This survey was carried out for the Agency to make strategic comparisons of consistencies of approach between regions in the four main components of a FFWRS. Its findings mirror those of the Review in many important aspects.

*Selected Issues from Summary and Recommendations of
Food Warning: Baseline Survey by J B Chatterton & Associates (February 1997)*

1.0 Detection systems and Data Acquisition

- 1.1.2 *Users should have early access to improved data from Nimrod as input to forecasting models.*
- 1.1.3 *There is no current initiative to utilise GANDOLF for short lead time predictions.*
- 1.1.7 *There is a need for national guidance on calibration before wide scale quantitative use of weather radar.*
- 1.2.4 *A key issue is the reduction of manual links in the FFWRS as the manual interface between telemetry-forecasting-warning is labour intensive.*

2.0 Forecasting

- 2.1.4 *There is a plethora of forecasting models used throughout regions. The development of compatible 'modular' systems with standard inputs and outputs should be explored.*
- 2.2.3 *A 'traffic light system' (ready-steady-go) could be introduced to give advance warnings for the mobilisation of operational staff. In some defended areas, the first warning is red, local authorities require some estimate of certainty.*
- 2.3.1 *There needs to be national consistency criteria on the definition of main river.*

3.0 Warning

- 3.1.2 *A national steer on consistency of approach to prioritising warning is required.*
- 3.3.3 *The development of a full time professional resource within each region to ensure the continued success of Flood Warning Dissemination Project is needed. Use of volunteer, cascade resource for Floodcall duties is wholly inappropriate.*
- 3.5.2 *The Flood Warning Dissemination Project may have raised public expectation about the warning service.*
- 3.6.1 *A review of Best Practice is required to optimise consultation/liaison issues. Some regions' plans do not show all flow risk areas, only those for which a warning service is currently provided.*
- 3.7.1 *Ensure the development and continuity of strong links to Local Authority disaster plans. There is a strong requirement to ensure compatibility between CEPO and ENVIRONMENT AGENCY plans.*
- 3.7.8 *Although police co-ordinate disasters and consequent evacuations their role in warning is still sometimes confused.*

4.0 Response

- 4.1.1 *Wales have developed a template for resource requirements and roles for escalating levels of event (yellow - wide scale red). This could be reviewed as a national standard.*
- 4.1.5 *The regional lead versus area or district lead for flood forecasting and warning is widely variable. A detailed review of the forecasting/warning chain of command may elicit a Best Practice nationally.*
- 4.2.1 *The development of national consistency of Best Practice for flood room manuals is opposed as area/regions follow their own working operational procedures based on local custom and practice.*
- 4.3.7 *Resource constraints restrict the development of dedicated flood warning teams. Rosters include staff from other functions with limited experience.*
- 4.5.2 *Effectiveness of future warnings cannot be evaluated until tools (e.g. use of quantitative radar) provide extra lead time.*
- 4.5.3 *Efficiencies can be improved by isolating causes of lag in the monitoring-forecasting-warning-dissemination chain.*

APPENDIX G

SOCIAL ISSUES IN WARNING SYSTEM RESPONSE

Submission by Dr Maureen Fordham , Department of Geography, Anglia Polytechnic University

I present just three points below which I believe are likely to be of importance in the Easter floods. They are not radically new issues (although the third is not widely recognised) but deserve highlighting in light of the Environment Agency's (relatively) newly acquired name and roles.

1. Clarifying the Agency's role

There is clearly some confusion evident regarding the role of the Agency in an extreme event, particularly regarding the issue and dissemination of flood warnings. Two issues arise initially: (i) is the Agency performing its role adequately? (ii) is the Agency perceived to be performing its role adequately? The latter is most problematic and difficult to remedy. The Agency may well be performing adequately (or better than adequately) but if it is perceived to be responsible for areas outside its remit, it will inevitably appear to be performing badly. This is something I believe you are addressing but it is worth awarding special attention. With this in mind, Agency staff must be careful in their descriptions of Agency roles. For example, Appendix A, signed by C A Robertson (pp. 26-28 of your Preliminary Report), describes the Agency's role regarding flood warning as: to take the lead role to disseminate flood warnings directly to the public on a best endeavours basis. This wording would seem to me to raise expectations beyond the ability of the Agency to deliver such a service. Especially as it is often said that it took over the lead role of disseminating warnings from the police since April 1996. This suggests a duplicate role that they do not actually perform.

2. Inter-agency communication and working

Effective inter-agency operations in times of extreme events are largely dependent on relationships of trust built up prior to the event. This suggests that regular exercise should take place to bring together all the interested agencies and groups prior to an event occurring. While the initiative for this may often lie elsewhere (e.g. with the Emergency Planners) it is in the Agency's interest to raise the issue and regularly pursue it.

3. Social issues in warning system response

The disaster management literature tells us that the probability of an adaptive response to a disaster warning message is greater for individuals who are:

- 1. younger (age)*
- 2. female (gender)*
- 3. white (minority status)*
- 4. new to the community (length of community residency)*

5. *more involved in community organisations (community integration)*
6. *higher in socio-economic status (socio-economic status)*
7. *parents (presence of children)*
8. *living near relatives (presence of kin networks)*
9. *highest in risk perception (emergent risk perception)*

Thus, those who do not conform to these 'ideal' characteristics may be more vulnerable and in need of specifically targeted information or communication methods. Others who may be vulnerable include: those for whom English is not their first language (see 3 above; the homeless; the deaf, blind, physically or mentally impaired (many of whom may be living alone in the community); those in solitary geographical locations. Furthermore the list above refers to the actions of those who have received a warning; a further problem exists in first identifying and locating individuals/groups. While women tend to respond more actively to a warning once received, they may not actually receive one because they are still viewed somewhat stereotypically as 'housewives at home'. However, they are more often likely nowadays to be out; either at work or performing a range of unofficial care roles outside of the home. They may have complicated family lives that involve them taking and collecting children from an extended family group and this may make it difficult for them to respond to a call to evacuate (e.g. they will not do so until they have gathered together their family or ensured their whereabouts). These (and other) complicating social issues can make an apparently adequate warning service ineffective. Some of these issues may well have been revealed to you in your further work when you have talked to a wider range of people (beyond Agency staff). I just mention them to you as possible complicating factors which can influence warning systems effectiveness.

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