Environment Agency
DEFRA

Development of a Modelling and Decision Support Framework (MDSF) for Catchment Flood Management Planning

Inception Report

HR Wallingford
Halcrow
CEH Wallingford
Flood Hazard Research Centre

July 2001

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Summary

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DEFRA and the Environment Agency (EA) are embarking on a major exercise to develop some 80 Catchment Flood Management Plans (CFMPs) for all river catchments in England and Wales. The need for modelling and decision support tools to support the implementation of CFMPs has been recognised, and this project is concerned with the development of an appropriate Modelling and Decision Support Framework (MDSF).

The MDSF consists of a customised GIS and a set of tools to support Consultants in the implementation of the CFMPs. Five Pilot Studies for CFMPs have commenced. It is hoped that the methods adopted for all five will be consistent with the MDSF but two Pilot Studies (Medway and the Irwell catchments) have been specifically selected for Pilot implementation of the MDSF.

The Pilot Studies and the development of the MDSF are being run in parallel. Interim guidance on the methods proposed for the MDSF are contained in this report to assist the Consultants until the system becomes available.

This report is the Inception Report for the project and covers:
- Background to the project
- Approach to the design of the MDSF
- Interim guidance on the use of the MDSF
- Functional specification for the MDSF
- Future programme and tasks

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1. INTRODUCTION

1.1 Background

DEFRA and the Environment Agency (EA) are embarking on a major exercise to develop Catchment Flood Management Plans (CFMPs) for all river catchments in England and Wales. The need for modelling and decision support tools to support the implementation of CFMPs has been recognised, and this project is concerned with the development of an appropriate Modelling and Decision Support Framework (MDSF).

A proposal for the development of the MDSF was submitted to DEFRA/EA in April 2001 by a team consisting of HR Wallingford (Project leader), Halcrow, CEH Wallingford and Flood Hazard Research Centre at Middlesex University. The proposal was accepted and the project to develop the MDSF commenced in the middle of May 2001.

This report is the Inception Report for the project.

1.2 Catchment Flood Management Plans (CFMPs)

CFMPs are intended to provide catchment scale strategic planning frameworks for integrated management of flood risks to people and the developed and natural environment in a sustainable manner. The CFMPs must be based on a sound understanding of the hydrological and hydraulic processes at work in the catchment that influence the generation and dissipation of all types and frequencies of river flooding.

The following four actions are being taken to launch the CFMP programme:

- CFMP Guidelines have been drafted to assist Consultants who will undertake the CFMPs. These will be finalised over the coming months.
- The process and preparation of CFMPs is being piloted in five catchments.
- Data for undertaking CFMPs is being assembled by the Environment Agency.
- The MDSF is being developed.

Following completion of the pilot CFMPs, the main programme to cover some 80 catchments in total will begin.

1.3 CFMP Pilot Catchments

The pilot catchments and associated Environment Agency Regions are as follows:

The Irwell (North-West Region)
The Derwent (North-East Region)
The Severn (Midlands Region)
The Parrett (South-West Region)
The Medway (Southern Region)

The CFMPs will be carried out by consultants. Babtie are currently undertaking pilot CFMPs on the Irwell, Derwent, Severn and Medway. The Parrett Pilot CFMP is being undertaken by Lewin Fryer and Partners.

The Irwell and Medway have been selected for trialing of the MDSF and are referred to herein as the "MDSF Trial Catchments" and the corresponding CFMP studies as the "CFMP Pilot Studies".

The Irwell CFMP Pilot Study is being undertaken by the Preston office of Babtie. The client is the North-West Region of the Environment Agency, based at Warrington.

The Medway CFMP Pilot Study is being undertaken by the Croydon office of Babtie. The client is the Southern Region of the Environment Agency, based at Worthing.

In addition, the upper River Nene has been selected by the MDSF development team for internal tests on the system.

1.4 Project purpose and objectives

The overall purpose of the project is the development and demonstration of a GIS-based modelling system to support the DEFRA/EA programme of CFMPs. The purpose will be achieved via four key objectives related to the inception, development, demonstration and handover phases of the project:

- To define the functionality of the proposed Modelling and Decision Support Framework (MDSF) (Phase 1)
- To develop the MDSF (Phase 2)
- To demonstrate the MDSF on two pilot catchments in collaboration with the Consultants preparing the CFMP Pilot Studies (Phase 3)
- To complete the development of the MDSF system to a state in which it can be used by consultants to assist them in preparing the first generation CFMPs (Phase 4)

The objectives are inter-related and all are essential for achieving the overall purpose.

The project will run in parallel with the consultation period for the preparation of the CFMP Guidelines and the implementation of the five pilot CFMPs. The project is also intended to link and be compatible with other DEFRA and Agency initiatives including the National Appraisal of Assets at Risk, the National Flood & Coastal Defence Database, other national data management systems, and the Section 105 Flood Mapping programme. The issue of compatibility is discussed in Section 2.7.

1.5 Modelling and Decision Support Framework (MDSF)

The proposed MDSF will provide an environment for the systematic assessment of flood management options in order to derive preferred policies for flood management in a catchment. The assessment will take account of both present and future conditions.

A major benefit of bringing such systems to the CFMP process is that they will provide common approaches and tools to the analyses as well as providing a greater degree of consistency, transparency and replicability.

The MDSF is intended to support the consultants undertaking CFMPs but is not intended to be prescriptive. Application of the MDSF should take the following into account:

- A **flexible approach** is needed in the application of the MDSF to each individual CFMP. This is because each catchment is different and a range of approaches will be needed. In addition, data availability will vary from catchment to catchment.
- Responsibility for planning, pricing and undertaking the CFMPs lies with the Agency Project Managers and Consultants. The MDSF will provide a range of tools to undertake a CFMP, but the Agency and the Consultants must decide which approach to adopt in each case and they may select tools which are not supported by the MDSF.
- The MDSF is based on best available practice and research results, and does not include new research in the initial implementation.

The MDSF will consist of:

- A customised GIS which will permit users to import, manipulate and export relevant catchment data which they would obtain from the Environment Agency and other sources. Some development of data on land use and social impacts will be undertaken within the project.
- The external application of models for the prediction of catchment flood flows and levels.
- A toolkit containing tools for flood map generation, flood damage assessment, assessment of social impacts of flooding, and uncertainty estimation.
- A Procedures manual, which will guide users in the application of the MDSF to CFMPs, including guidance on how to use the external models and other tools.
- Training and support in the application of the MDSF will also be provided under this project.
- It is assumed that users will provide their own licences for proprietary software, which includes ArcView, the FEH and iSIS Routing.

The fundamental objective of the MDSF is to provide a system to facilitate the implementation of the CFMPs with an appropriate level of detail and within the specified overall budget.

An overview of the MDSF is given in Section 2.

1.6 Project tasks

The project tasks are set out in the proposal document submitted by HR Wallingford in April 2001. They are summarised below.

PHASE I – INCEPTION

I. Establish contact with the CFMP management team and other stakeholders

II. Review the suitability and feasibility of modifying the EUROTAS system as the basis of the modelling framework. Make recommendations for the approach to be adopted.

III. Consult with users and Agency stakeholders and produce a functional design specification. Propose a Quality System for the development of the software. Prepare an Inception Report

PHASE II - DEVELOPMENT

IV. Set up the Quality System.

V. Develop the MDSF

VI. Select and make provision within the system for the most appropriate tools to achieve the project objectives

PHASE III – PILOT APPLICATION

VII. Apply the MDSF to two nominated pilot catchments in co-operation with the consultants undertaking the CFMPs for these catchments

VIII. Carry out beta testing of the MDSF on these catchments and correct bugs.

PHASE IV - HANDOVER

IX. Produce MDSF Procedures and training material.

X. Provide training

XI. Set up licensing mechanisms, and provide support and updates to users

Note that Task VII (Develop the FEH national method) was not included in the project.

1.7 Progress to date

Phase I of the project has been completed, and includes the following work.

Establish contact with CFMP management and other stakeholders

Contacts have been established with the CFMP management team and the CFMP consultants with the assistance of the Project Officer. In particular, the Project Leader attended the CFMP team meeting in Birmingham on 25 May and met the DEFRA/Agency management team and the Pilot Study Consultants.

Contacts have also been established with other stakeholders, and meetings have been held both to inform and to obtain feedback on the proposals.

Suitability of the EUROTAS system, and basis of the MDSF system.

The EUROTAS system has been studied in detail, both during proposal preparation and during the Inception Phase. It has been decided to adopt a similar Framework specifically tailored to DEFRA/Agency standards and the requirements of the CFMP programme, consisting of:

- ArcView data presentation and data management system, with associated databases as required.
- External hydrological and hydraulic modelling, based on UK "standard" software.
- Data transfer protocols between the MDSF and the external models.

The review of EUROTAS is contained in Appendix F.

Consultations and development of the Functional Specification.

Consultations have taken place with a range of consultees including the Framework Consultants who will use the software, a range of Environment Agency departments and functions, and other organisations including DEFRA and the S105 consultants.

The functional specification for the MDSF has been developed as described in Section 4.

Datasets have been reviewed with the intention of identifying the status of all required data and work needed for inclusion in the MDSF. Datasets are covered in Section 4.3.

At a meeting of the project team and Pilot Study consultants on 31 May 2001it was agreed to provide interim guidance to the CFMP pilot consultants and this is provided in Section 3.

1.8 Feedback on the proposed MDSF

The following meetings were held in the last week of June 2001 to discuss the MDSF:

- Workshop on the proposed Functional Specification, held with Agency staff and Consultants who will be responsible for carrying out CFMPs, on 25 June.
- Presentation of the proposed MDSF to a wider audience including other Agency functions, DEFRA and project leaders for related projects, on 29 June.

The outcome of these meetings is summarised in Appendix E.

1.9 Structure of the report

The structure of the report is as follows:

Section	*Contents*
2	Overview of the MDSF
3	Interim guidance, as requested at the meeting of 31 May 2001
4	Functional specification
5	Future programme

2. OVERVIEW OF THE MDSF

2.1 MDSF principles

It is envisaged that the MDSF will be used by the CFMP consultants to support the development of CFMPs. In particular, the MDSF will be used to:

- Input pre-assembled data from Agency databases.
- Inspect and manipulate catchment data to support Scoping Studies.
- Predict flood flows on a catchment-wide basis for present and future conditions.
- Provide estimated flood water levels on a catchment-wide basis for present and future conditions.
- Predict flood extents at selected locations for present and future conditions.
- Appraise catchment flood management options using socio-economic criteria.
- Assess the uncertainty associated with the predictions.

The MDSF provides support for the assessment of flood management policies and options at catchment scale and is intended to be sufficiently accurate to choose between strategic options. It is not however intended to provide the level of detail associated with strategy studies and scheme appraisal.

The project is guided by a number of core principles which will continue to be applicable throughout the development, application and any future enhancements of the MDSF:

- **User driven** - The concepts set out in the project proposal have been used as a basis for consulting with the key stakeholders during the Inception Phase. However as far as possible the system will take account of user requirements.
- **Deliverable** – The MDSF will be handed over for use by others, and therefore ease of use and robustness are important considerations in the design.
- **Scope and functionality** –The CFMP process and approaches will develop over time. It is expected that the MDSF will continue to develop after completion of this project to provide additional functionality as required by the CFMP process.
- **Modular approach** – An over-arching framework will be developed to accommodate the initial functionality but this framework is also intended to be applicable to identified future enhancements and additions.
- **Integrated** – The MDSF cannot be seen in isolation but is set within a broader context including both CFMP-specific projects (eg CFMP Guidelines) and systems (eg EA data protocols and systems)
- **Sustainable** – Consideration has been given to the longer-term future of the proposed system as well as the immediate needs of users to achieve a balanced and supportable framework.
- **IPR** – No new private IPR will be created and the code of the new modules will be open.

2.2 Development of the MDSF

Catchment Flood Management Plans (CFMPs) are high level plans which identify overall flood management strategies which take account of likely future changes in the climate and catchment. CFMPs will inform Strategy Plans, where the more detailed development of schemes to alleviate particular flood problems will be carried out.

The proposed MDSF must therefore provide sufficient functionality to support the CFMP development process and a level of detail adequate to identify the need for flood risk management options at a broad catchment level. It recognises that more detailed work may need to be done in developing the Strategy Plans (that may follow on from the CFMPs) and much more detailed work will be required for the appraisal for individual schemes. The MDSF is intended to provide support at an appropriate level of detail that is consistent throughout the catchment rather than at the best possible level of detail.

The MDSF concept has been developed to support the CFMP process as described in the CFMP Guidelines. The Guidelines describe the process in relation to a flow chart, which is reproduced as Figure 2.1. The flow chart shows eleven distinct steps for undertaking a CFMP up to the development of a preferred plan, and a description is given for each step.

Figure 2.2 shows the general process for using the proposed MDSF. Each stage of the process is linked to specific steps in the CFMP Guidelines flow chart.

2.3 Environment Agency databases

The MDSF will facilitate the use of existing Agency national and local datasets. The system will enable Consultants to import core electronic data for inspection and manipulation. The main sources of Agency data will be the Agency's Environmental Data Management System (EDMS) and data held by Regional offices.

The EDMS contains several national datasets which include background OS maps, topography, the drainage network, the hydrometric network, environmentally important sites, indicative flood plain maps and Section 105 flood plain maps. In addition, the Agency Regions hold data which are specific to each Region. These include electronic spatial datasets suitable for importing into GIS systems, and other data including reports.

It is intended that outputs from the MDSF will be returned to the Agency databases in the form of electronic CFMPs. The proposed transfer of data between Agency databases and the MDSF is indicated on Figure 2.2.

2.4 MDSF Components

The MDSF as shown on Figure 2.2 consists of:

- MDSF Procedures
- MDSF System
    - Customised GIS
    - Modelling tools

MDSF Procedures
The MDSF Procedures will describe how the MDSF is to be used. This document will be a key element of the whole process as it will specify:

- The procedures for using the MDSF
- Standard procedures and practices
- Quality Control procedures to ensure that the analyses are transparent and auditable
- Procedures for ensuring compatibility with existing Agency systems

The MDSF Procedures will be fully cross-referenced with the CFMP Guidelines.

MDSF System
The MDSF System will support the analytical process outlined in the Procedures. It will combine a Customised GIS with a set of Modelling Tools and allow interfacing between the two. Through these components the MDSF System will support:

- Input of data from Agency databases in standard Agency formats
- Data visualisation and analysis
- Flow prediction and future land use and climate change scenario generation, using a hydrology tool based on application of the FEH.

- Prediction of water level and flood duration, and flood defence scenario modelling, using a hydraulic tool.
- Prediction of flood extent and depth using river water levels and a flood map generation tool.
- Estimation of flood damages using flood damage functions and flood depth and duration data.
- Estimation of social impacts of flooding.
- Uncertainty analysis procedure.

2.5 Application of the MDSF

Application of the MDSF will broadly follow the flow chart in Figure 2.2.

The MDSF will facilitate the use of national datasets and will also provide the facility to import local datasets. The Consultants will be responsible for data assembly for each CFMP using data supplied by the Agency National Centre for Environmental Data and Surveillance and from other sources. The MDSF will facilitate inspection and manipulation of data for preparing the Scoping Study, and developing an understanding of the catchment.

The MDSF will generally comply with Agency data standards. In particular, it is proposed to adopt the same standards for meta data, which provide specified information about each dataset.

The hydrology and hydraulics tools will provide flood flows and levels throughout the catchment. Not only is this important in the process of understanding how the catchment behaves, but the level information will feed directly into the flood map generation tool.

In order to minimise the need for a large number of model tests, it is recommended that sensitivity tests are carried out to determine the sensitivity of the catchment to key variables including land use change, climate change and flood storage (see Section 2.6.3). This might be carried out for at least one high return period event and one low return period event, as relative impacts are often greater at low return periods. This will involve the use of the land use and climate change scenarios.

The flood map generation tool will be used to produce flood extents and depths for existing and future scenarios. The output will be used in combination with the flood damage and social impact tools to estimate impacts for each case. The intention is to provide a system which permits rapid evaluation of impacts.

Management policies may then be evaluated using a range of techniques. For example:

- Flood storage options could be represented by changes to the flow routing model.
- Flood defence options could be represented by removal of defended areas from the impact calculation for return periods below the standard of defence.
- Flood proofing and flood warning options could be evaluated by changing damage functions.

It should be noted that the MDSF outputs will be compatible with a catchment scale analysis but will not provide the detail of strategy and scheme studies. Policy evaluation will be based on comparative results obtained from running different options.

2.6 Key issues

2.6.1 Tools and methods

Figure 2.3 shows some of the methods available for predicting flood flows, levels, flood extent, damages and social impacts. Selection of an appropriate method for each stage depends on the following factors:

- Availability of method
- Ease of use
- Ability to simulate all relevant processes
- Appropriate accuracy for CFMP level
- Completion of task within appropriate budget.

A range of methods are shown on the Figure, and those which are considered to be most appropriate at CFMP level are indicated. Selection of the methods to be supported by the MDSF was based on the following criteria:

- Appropriate for catchment scale analysis.
- Provides time dependent outputs of level and flow, to permit the evaluation of flood storage options, and to provide duration data for flood impact estimation.

However part of the Pilot process will be to provide feedback on the suitability of these approaches and recommendations for refinement.

2.6.2 Detail and accuracy

A particular concern in the use of tools for CFMPs is **appropriate level of detail** and **accuracy of results**. It must be remembered that the modelling exercise is comparative, in order to estimate relative impacts for each management option. Thus absolute accuracy is not required. However the results must be good enough to provide confidence in the overall outcome, and "reality checks" in the process are recommended. These might include, for example:

- Comparison of flood maps with Section 105 maps.
- Comparison of damage estimates with any relevant project appraisals already carried out.

2.6.3 Sensitivity of catchment

The CFMP process includes assessing the impacts of future scenarios including climate and land use change, and considering flood management options including storage. It is advisable at an early stage in the modelling process to identify the sensitivity of the catchment to such changes. This is needed in order to target effort most effectively in the development of the CFMP.

For example, earlier work suggests that land use change does not have a significant impact at catchment scale but does have significant local effects. This will need careful investigation.

Similarly, experience suggests that flood storage is not a practical option for managing large floods in some large catchments, because of the huge volume of water involved. However, flood storage can have a large impact on smaller floods in such catchments. In addition, flood plain restoration and wetland creation are likely to be important aspects of future catchment management, and the methodology should be able to assess the impacts these might have on flooding.

2.6.4 Number of model tests

There is a danger that a very large number of tests will be needed to adequately assess existing and future conditions, and options for flood management. These could include:

- Five return periods (see Section 3.2.2)
- Perhaps three different events for each return period, to provide design floods in different parts of the catchment.
- Land use and climate change scenarios, for all return periods to assess damages.
- Catchment management options for all return periods, to assess damages.

The Consultant should endeavour to reduce this number of tests by sensitivity testing, etc. However, this could be a major barrier to the application of some methods.

2.6.5 Defended areas

It will be important to identify defended areas as these have a very large impact on the flood damage calculation. Datasets on defended areas are generally incomplete, particularly with regard to defences which are not owned by the Environment Agency.

A pragmatic approach will be needed to try to ensure that major defences and their approximate standard of defence are identified. Use will be made of the dataset on flood defences compiled for the National Appraisal of Assets at Risk study and other Agency sources to provide a starting point for this work.

It will also be necessary to consider the impacts of defence failures, particularly flood storage areas which can be overwhelmed and be relatively ineffective during a "larger than design" flood.

2.6.6 Flooding in areas not covered by the indicative flood maps

There is a growing awareness that a significant proportion of flood damage occurs outside the limits of the indicative flood maps. Causes include flooding from Ordinary Watercourses, urban drainage systems, groundwater, overland flow, etc. Many of these incidents are local and not relevant for CFMPs. However it is suggested that the major areas of flood risk are identified and included in the CFMP problem identification phase.

2.7 Compatibility of MDSF with existing systems

One of the requirements of the MDSF is to be compatible with other Environment Agency Systems.

The Agency's Environmental Data Management System (EDMS) provides a central system for the management of environmental data within the Environment Agency. The system imports data from both the Regions and external sources. The system provides a common ArcView interface for inspection of data.

It is proposed to ensure that the MDSF is as compatible as possible with the EDMS. This will facilitate the extraction of data from the EDMS, and return of new data layers to the EDMS from the MDSF. It is further suggested that data from the MDSF needed for any other Agency function or database is obtained via the EDMS to ensure central co-ordination within the Agency.

The Agency is currently developing a National Flood and Coastal Defence Database (NFCDD). Dialogue will be opened with the team developing this to try to ensure compatibility. In addition, it is desirable that the system is compatible with the Agency's Corporate Information Strategy (CIS). Further investigation is needed to determine whether this can be achieved.

2.8 Quality assurance

The development of the MDSF will be undertaken using a Quality System based on ISO 9001 (BS 5750: Part 1: 1987). The proposed system will be that which is currently used by Halcrow, the team member responsible for development of the MDSF. Further information on the system is given in Appendix H.

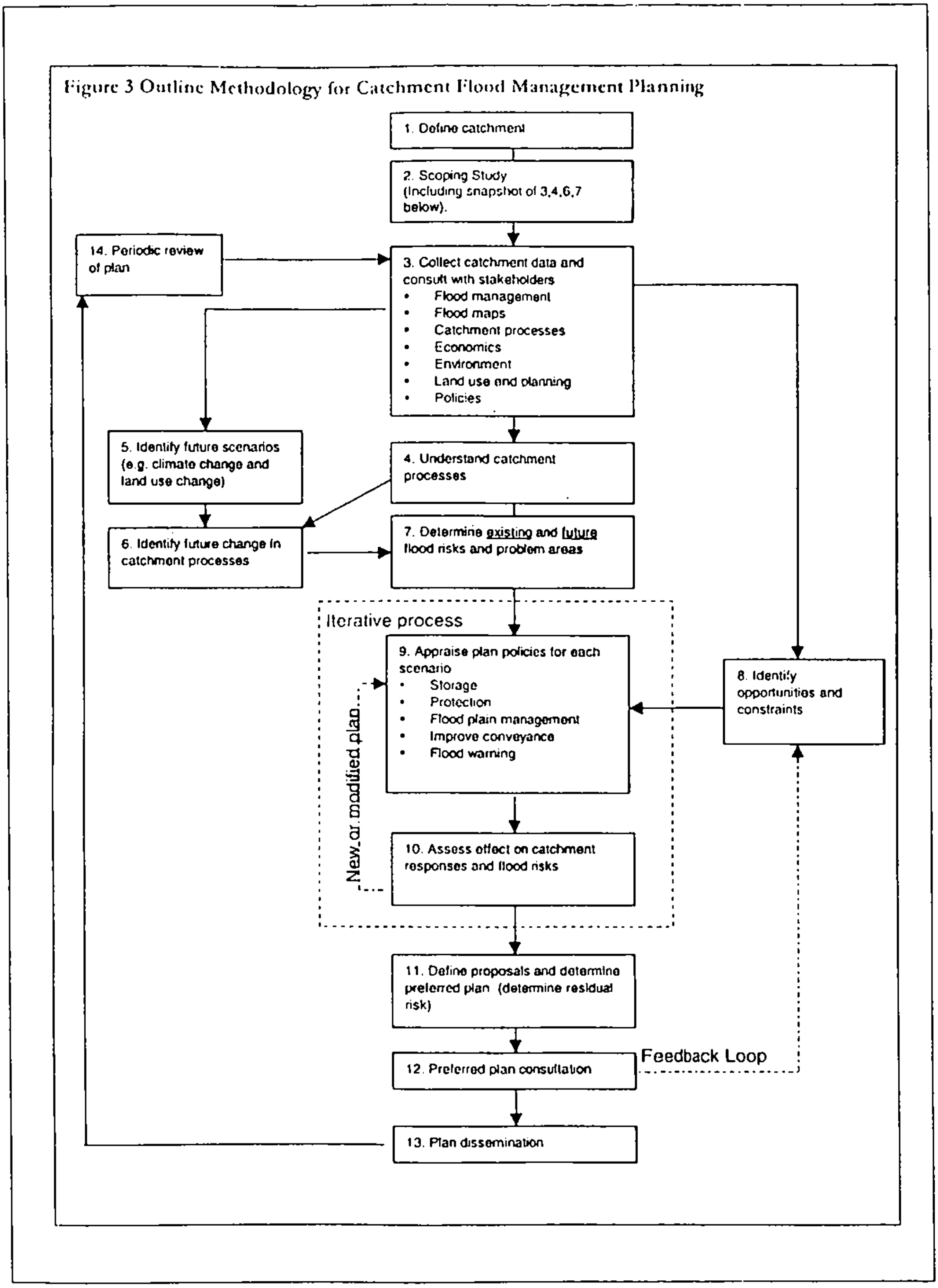


Figure 2.1 CFMP Process

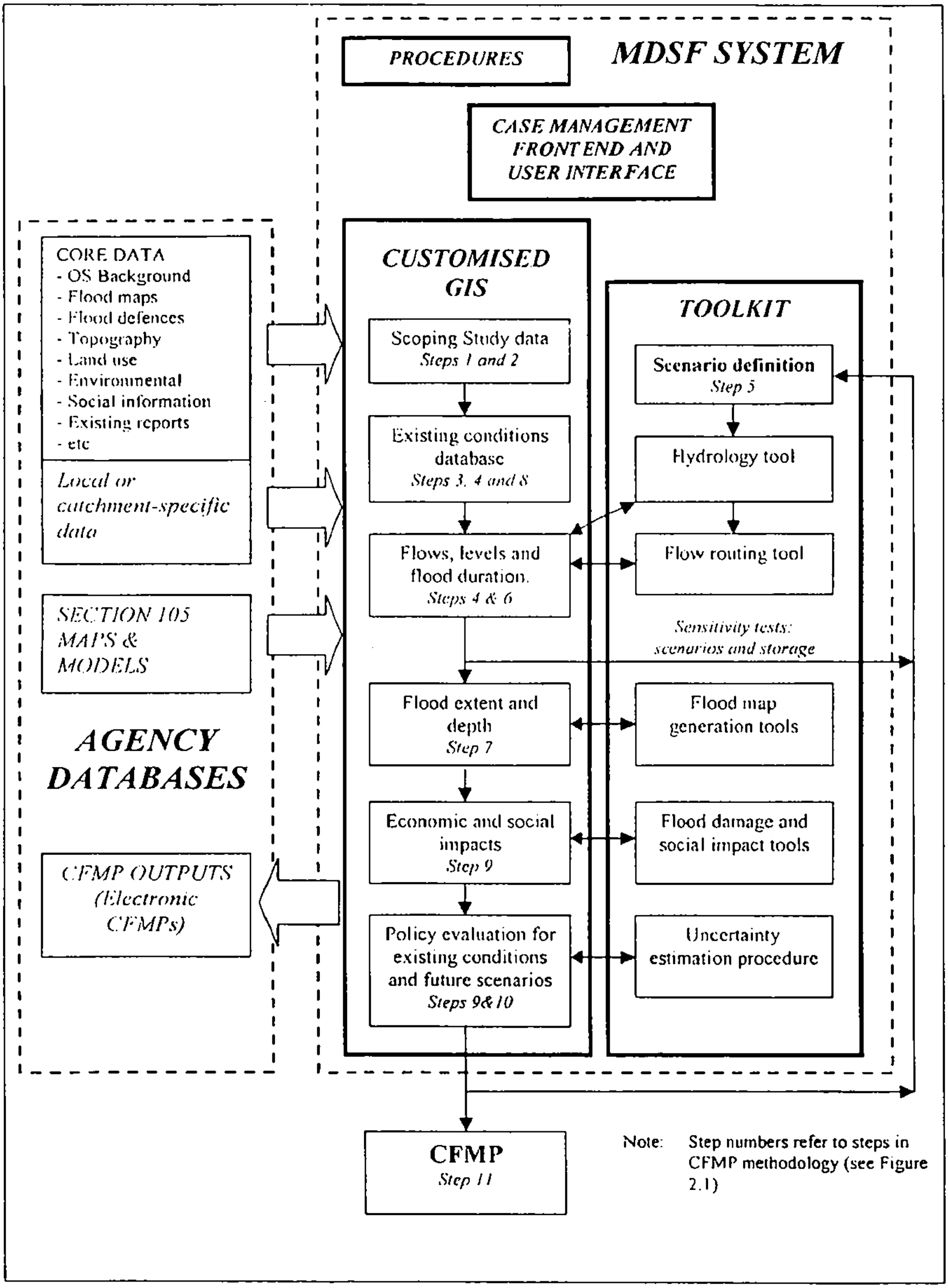


Figure 2.2 MDSF System

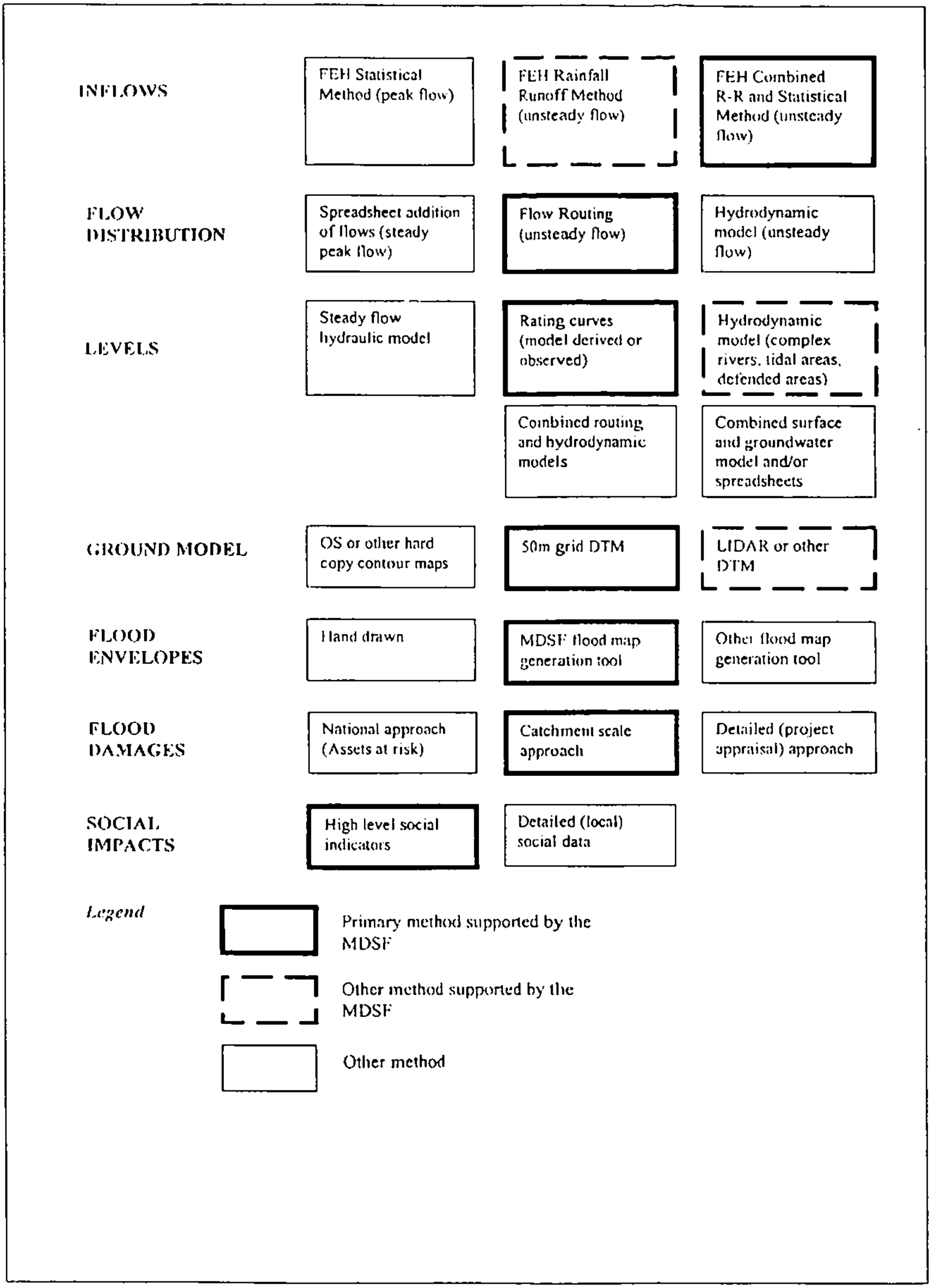


Figure 2.3 MDSF: Possible modelling methods

3. INTERIM GUIDANCE

3.1 Introduction

The Pilot CFMPs have commenced and the Scoping Studies for each pilot catchment are complete. The next task for the Pilot Study Consultants is to plan the implementation of the remaining activities in the CFMPs and agree a methodology and budget with their Clients (respective Regions of the Environment Agency).

In order to assist the Consultants with this task, interim guidance is needed to advise the Consultants on the methods and approaches which are likely to be included in the MDSF.

It is expected that the MDSF Pilot Studies will apply methods which are recommended in this Interim Guidance. The MDSF Development Consultant will endeavour to support the MDSF Pilot Study Consultants in the application of the chosen methods. The MDSF Development Consultant will also endeavour to supply deliverables as soon as they are available for use on the MDSF Pilot Studies.

It is also expected that the Consultants for the other Pilot Studies will follow the Interim Guidance in order to ensure that the Pilot CFMPs are consistent with the approach to be adopted for future CFMPs.

The Consultants are ultimately responsible for the approaches they adopt. The MDSF and the Interim Guidance are intended to assist the Consultants to undertake the CFMPs in a consistent way and with an appropriate level of detail.

It is hoped that feedback from the Consultants in the application of the MDSF will lead to improvements which will ensure that the MDSF achieves the objective of supporting the implementation of the CFMP programme.

With reference to Figure 2.2, interim guidance is given under the following headings:

- Data collection and management
- Return periods
- Prediction of flood levels and durations (existing conditions)
- Land use and climate change scenarios
- Flood mapping
- Economic damages
- Social impacts
- Uncertainty assessment
- Reality checks

3.2 Interim guidance

3.2.1 Data collection and management

No detailed guidance is proposed for data collection and management. The datasets which are likely to be required by the MDSF are listed in Appendix D together with information on sources. The following general principles are suggested with regard to data collection and management:

- National Datasets should generally be used. Many of these are already available from the Environment Agency.
- As far as possible, datasets should be in an appropriate electronic format (suitable for import into the ArcView Customised GIS).

- Where local electronic datasets are available which are better than the national datasets, these should be used.
- There will be many items of data and information available locally in a range of different formats. It is suggested that separate ArcView layer(s) are used to add specific items of information relevant to CFMPs from these sources.
- It is strongly recommended that CFMPs are undertaken using existing data, and no new data (eg surveys, etc) are collected.

3.2.2 Return periods

It is proposed to run the modelling tools for the following return periods:
5, 10, 25 and 100 years plus a higher return period (either 200, 500 or 1000 years).

These are required for the socio-economic appraisal. However in terms of the target return period for development of the preferred flood management option, this is a matter for the CFMP Guidelines and the particular catchment. If, for example, the majority of flood risk areas are urban, it might be appropriate to develop the preferred option to manage the estimated 100-year event and then test the robustness of the option for other events.

However, on rivers such as the Severn, low return periods are important. For example, the town of Bewdley (which received a high profile visit from the Prime Minister during the recent floods) floods frequently.

3.2.3 Prediction of flood flows

The method for estimation of flood flows used by the MDSF is based on the Flood Estimation Handbook (FEH), and interim guidance on application of the FEH is given in Appendix A, Sections A.1 to A.6.

3.2.4 Prediction of flood levels and durations (existing conditions)

Prediction of flood levels and durations requires the following:

- Prediction of flood flows at locations where flood levels are required.
- Prediction of corresponding flood levels.

A range of methods is available to predict distributed flood flows and corresponding flood levels, as indicated on the table below.

Level	Method	Comments
Zero	Direct use of the FEH statistical method to determine present flood flows at key points, plus rating curves to determine levels.	Does not readily permit prediction of attenuation and storage effects under future climate change and land use scenarios, or effects of storage and other flood management options.
1	Flow routing and rating curves	Water level prediction is subject to large uncertainty which may conflict with levels from Section 105 and other detailed models.
2	Flow routing plus use of results from Section 105 models, particularly rating curves.	Reduces "credibility" gap but may still not fully reflect river processes.
3	Use of existing full hydrodynamic models, particularly Section 105 models.	Most accurate but time-consuming. Possible use as a "reality check" on simpler approaches for existing conditions and the most important scenarios.

It should be noted that all the above methods require calibration except where an existing calibrated model is used.

The Interim Guidance for the prediction of flood levels and durations is to use a catchment flow routing model, as this is able to simulate the effects of future scenarios, flood storage and other flood management options. In this case flood flows are used as input data to a catchment flood routing model in order to generate flood hydrographs at locations of interest in the catchment.

Features of a flow routing model based on iSIS Routing

- The model is built up of nodes located throughout river system which include inflow points (from sub-catchments) and locations where flood flows / levels are required.
- The model routes hydrographs using wave speed and attenuation parameters. These may either be derived directly from model calibration, or derived from geometrical properties of the river valley.
- In the latter case, a simplified cross section is entered representing the reach downstream of each node. A slope is also required. Absolute levels are not needed but are desirable for generating water levels.
- Reservoirs can be included. These are represented by surface area against water level data. An outflow structure is required and the software includes a range of structures including weirs and sluices. Absolute levels are needed to relate the structure to the water level and other reservoirs/rating curves in the model.
- Routing does not allow for backwater effects. Thus, if an on-line reservoir was included in a river system, the backwater effects could not be represented.
- Off-line reservoirs can be included. These have an inlet and outlet structure. The reservoirs are storage nodes and have no friction, so should not be used to "by-pass" the river system. For example, an area of embanked floodplain might be represented by an off-line storage area with inflow and outflow at the same location.
- Where multiple channels exist the main channel should be selected. An alternative would be to aggregate the conveyances of several channels into one channel.

It is important that flood routing models should be kept as simple as possible in order to avoid an excessive amount of work and because the number of model tests could be large, as discussed in Section 2.6.4. It is suggested that the number of nodes might be of the order of 20 to 50 depending on the size and complexity of the catchment. These should include:

- Inflow points.
- Key gauging stations, for calibration (not more than two per catchment?)
- Locations where flood levels are needed (flood risk areas)
- Locations where flood management options might be located (flood storage areas, diversion channels, etc).

Once flood flows have been established at locations of interest, flood levels should be estimated using rating curves. These may be derived from:

- Routing models, although they may not be very accurate.
- Hydraulic models where available, for example Section 105 models.
- Known rating curves, for example gauging stations.
- Hydraulic calculation using river and flood plain cross-sections.

An alternative to flood routing models would be to use existing hydraulic models. Such approaches might be more suitable where embanked flood plains or tidal rivers must be considered.

3.2.5 Land use and climate change scenarios

The recommended interim guidance on land-use change is contained in Appendix A, Section A.7. Further discussion of soil and land use data is given in Appendix G.

The recommended interim guidance on climate change is contained in Appendix A, Section A.8.

The outputs from these scenarios are changes to inflows to the river system.

3.2.6 Flood mapping

It is not proposed to provide interim guidance on flood mapping. However, to undertake any economic damage assessment, flood outlines will be needed. It is hoped that an alpha version of the MDSF will be available when required by the MDSF Pilot Study Consultants, but this will depend on the Consultants' programmes.

3.2.7 Economic damages and social impacts

An outline methodology for assessing economic damages and social impacts is given below. A more detailed description of the proposed methodology is given in Appendix B.

1. Identify land use in all the areas affected by flooding
2. Determine and select the appropriate potential flood damage data sets for the catchment in question
3. Apply flood damage data to land use at risk for the return periods in question
4. Assess potential indirect losses for areas at risk and related areas
5. Sum potential direct and indirect losses and relate them to the probability of the events in question
6. Determine population at risk from flooding and its characteristics related to flood vulnerability
7. Access social vulnerability indicators for the catchment in question and apply them to the population at risk for the return periods in question
8. Assess the reduction in (a) potential flood damage, (b) indirect losses and (c) social vulnerability with the preferred flood mitigation options.

The way in which this assessment is achieved will depend on timing. As with the flood mapping, it is hoped that an alpha version of the MDSF will be available when required by the MDSF Pilot Study Consultants. If it is not available, it is suggested that the Consultants follow the above general procedure at an appropriate level (eg for whole residential/industrial areas rather than by individual properties).

3.2.8 Uncertainty assessment

No interim guidance for assessing uncertainty is proposed at this stage. Interim guidance will be issued at a later date depending on the requirements of the Consultants.

3.2.9 Reality checks

As discussed in Section 2.6.2, it is recommended that reality checks are carried out at key stages to ensure that predictions are reasonably consistent with previous more detailed work. These checks might include comparisons of flood flows, flood levels, flood extent maps and damage estimates, depending on the previous studies which have been carried out.

3.3 Deliverables

In order to assist the Pilot Study Consultants, expected dates for deliverables to Consultants are given below.

Deliverable	***Expected date (see Section 5.2)***
Customised GIS	7 September 2001 (alpha version)
Hydrological procedure	17 August 2001
Hydraulics procedure	17 August 2001
Flood mapping tool	7 September 2001
Flood damage estimation procedure	17 August 2001
Social impact estimation procedure	7 September 2001
Uncertainty estimation procedure	7 September 2001

4. FUNCTIONAL SPECIFICATION

4.1 Introduction

The functional design specification of the MDSF forms a key component of the project Inception Report. The conceptual organisation of the functional design specification is based upon the 'MDSF System' diagram (Figure 2.2) and the 'Modelling and Decision Support Framework (MDSF) Initial Top Level Data / Software Structure' diagram, as presented in the project proposal.

A number of key features of the proposed system are included in the design:

- Process component specifications, identifying objectives, data inputs, method and data outputs.
- Summary of data and metadata requirements to support the process component specifications.
- A MDSF 'method tree' illustrating the recommended and support methods available within the system.
- A brief guide to the MDSF user interface / decision support framework, including example prototype screen design.
- A tabular summary identifying system functionality prioritised into 'must have' (1), 'should have' (2) and 'could have' (3) features.

4.2 Process component specification

Process component specification summaries are provided in Appendix C for the following parts of the MDSF system:

- Scoping Study
- External Hydrology Tool
- External Water Levels Tool
- Flood Extent and Depth Tool
- Economic Damages and Social Impacts Calculation
- Uncertainty

It should be noted that the specifications outlined in the summary may be subject to revision if the development and pilot deployment of the MDSF system introduce new considerations.

4.3 Data and MetaData requirements

The data available for developing the CFMP's consists mostly of national data sets that are held at the NCEDS (National Centre for Environmental Data and Surveillance). The essential data as specified for the various steps of the MDSF are outlined in the Appendix D, which gives brief descriptions and details of the data. Where no national data set is available a regional alternative is mentioned. These regional data sets are not standardised and may vary according to region. Therefore details of the data are very brief. The second part of the list consists of available data that was not deemed essential, but may be of use as supporting data.

With regard to essential data for using the MDSF to undertake CFMPs, the following issues have arisen:

- It has not been possible to identify an existing land use dataset which is suitable for the economic analysis. It is proposed to develop the system used in the National Appraisal of Assets at Risk (NAAR) project, where land use was based on Addresspoint and Valuation Office data. The NAAR data was prepared for areas covered by the Indicative Flood Plain Maps, and it will be necessary to disaggregate and extend this coverage for areas which might flood in the future under change scenarios.
- The suitability of some datasets for application in the MDSF has not been fully assessed in some cases. If it is found that datasets are not suitable for the proposed application, it may be necessary to change the approach to match the data available.

4.4 MDSF Method Tree

Figure 2.3 provides an overview of the methods recommended and supported by the MDSF.

4.5 System User Interface / Decision Support Framework

Catchment Flood Management Planning using the MDSF will be centred on the use of ESRI GIS (Arc View 3.x with the Spatial Analyst and possibly 3D Analyst extensions) software. Extensions to the core Arc View functionality will facilitate the core objective of policy evaluation by assisting the user at each step of the process. Such development will take the form of a customised interface to the GIS, incorporating the ability to manage both datasets and metadata (or data-about-data) used and created at various stages of the evaluation process.

Policy evaluation for a particular catchment will be enabled by the comparison of results from various *cases*. Such inter-case comparison may take the form of a tabular summary of quantitative indicators, the visual comparison of affected areas and / or the comparison of policy questions.

A case comprises a combination of specific *climate, land-use and river engineering scenarios*. These scenarios will variously impact upon the hydrology calculation in the catchment (i.e., climate change and land use change) the calculation of water levels on the flood plain (river engineering changes) and the evaluation of economic damages (land use change).

Each case will have to consider flood extents at various return period frequencies – 5, 10, 25, 100 and 200 years – in order to identify the annualised economic damages. Initial assessment of a particular case with the baseline (defined using indicative flood plain maps for example) may not require such a suite of return periods.

The proposed user interface therefore operates at a number of different procedural levels:

- It provides a framework within which the user is guided to develop the case on a procedure-by-procedure basis, importing and managing datasets - both existing and those created from the external modelling tools - and their contextual information (metadata).
- It provides an interface to facilitate the user in operation of key GIS functionality, both the core functionality provided by the ESRI software and the added-functionality provided by bespoke development (e.g., flood extent calculation and economic damage assessment).
- The user interface acts as a decision support framework readily enabling effective policy evaluation of numerous modelled cases.

Figures 4.1, 4.2 and 4.3 illustrate example prototype screenshots for the MDSF case management, importing of base data, and visualisation of base data. It is important to note that these figures are not intended to prescribe the exact user interface / decision support framework that will be delivered in the MDSF, but rather that they give an indication of the structure and overall feel that will be implemented in the MDSF.

4.6 MDSF System Functionality

The following table identifies those features that will form the MDSF system functionality, prioritised into 'must have' (1), 'should have' (2) and 'could have' (3) features.

Table 4.1 MDSF System Functionality

Item	Component	Priority	Description
0	Decision Support Framework	1	Implement GIS layer metadata database consistent with Environment Agency database and NGDF standards
1	A. Scoping Study	1	Import base data into the MDSF (e.g., OS background)
2	A. Scoping Study	1	Visualise base data in MDSF
3	A. Scoping Study	1	Import 'existing conditions' data into the MDSF
4	A. Scoping Study	1	Visualise 'existing conditions' data in MDSF
5	B. Flows / Levels	1	Define generic data format for specification of point data
6	B. Flows / Levels	1	Define generic data format for specification of time-series data
7	B. Flows / Levels	1	Visualise time-series data within MDSF from associated GIS layer
8	B. Flows / Levels	1	Incorporate external modelling tools 'input data' and 'methods' within the MDSF as GIS layer metadata
9	B. Flows / Levels	2	Define generic data format for specification of sub-catchment area data
10	B. Flows / Levels	2	Visualise time-series data within MDSF from associated GIS layer for multiple return periods
11	B. Flows / Levels	2	Import hydrological boundary points / calculated water level points into the MDSF as a GIS layer from ISIS routing format
12	B. Flows / Levels	2	Import ISIS routing model data into the MDSF as metadata
13	C. Flows	1	Import hydrological boundary points into the MDSF as a GIS layer from generic format
14	C. Flows	1	Visualise hydrological boundary points with base data
15	C. Flows	1	Development of hydrology tool – enhance ISIS routing to allow for global edit on selected FEH parameters
16	C. Flows	2	Import hydrological sub-catchment areas into the MDSF as a GIS layer
17	C. Flows	2	Visualise hydrological sub-catchment areas with base data
18	C. Flows	3	Enable automatic updating of FEH catchment descriptors within external hydrological tool to reflect climate change / land-use change scenarios
19	C. Flows	3	Generate FEH catchment descriptors from MDSF data – catchment area, DPLBAR, SPR . . . - to verify FEH CD-ROM data / source of land use change impacts
20	C. Flows	3	Import FEH CD-ROM catchment descriptors into the MDSF as metadata
21	D. Levels	1	Import calculated water level points into the MDSF as a GIS layer from generic format
22	D. Levels	1	Visualise calculated water level points with hydrological points and base data

Table 4.1 MDSF System Functionality (Continued)

Item	Component	Priority	Description
23	E. Flood Extent / Depth	1	Provide TIN (3D Analyst) based methodology for generation of Flood Extent and depth maps
24	E. Flood Extent / Depth	1	Provide functionality to exclude defined areas from flood extent maps based on specified levels of service information
25	E. Flood Extent / Depth	2	Provide direct raster (Spatial Analyst) based methodology for generation of Flood Extent and depth maps
26	E. Flood Extent / Depth	2	Enable interpolation of modelled water levels by water depth through comparison with topographic data (extension of water level as original data)
27	E. Flood Extent / Depth	2	Enable definition of potential flood extent through interaction with (buffering of) topographic data (extension of by buffering indicative flood plain / river centre-line)
28	F. Socio-Economic Analysis	1	Re-aggregate NAAR land use data to provide capital value index of land use parcels at appropriate geographical scale for catchment flood management planning
29	F. Socio-Economic Analysis	1	Define socio-economic indicators at appropriate geographical scale for catchment flood management planning and relate to land use data
30	F. Socio-Economic Analysis	1	Define economic damage functions - appropriate to land use data as identified in item 28 - and define method for the application to selected set of return periods to produce estimate of annual average economic damage
31	F. Socio-Economic Analysis	1	Define method to enable interrogation of annual average economic damage by socio-economic indicator
32	G. Policy Evaluation	1	Provide defined criteria such that hazards are readily identifiable – tabular comparison of cases
33	G. Policy Evaluation	1	Provide defined criteria such that hazard 'hot-spots' are readily identifiable – map based comparison of cases
34	G. Policy Evaluation	2	Provide defined criteria such that hazard 'hot-spots' are readily identifiable – user-defined rule comparison of cases

It should be noted that the system specification outlined above may be subject to revision if the development and pilot deployment of the MDSF system introduce new considerations.

Figure 4.1 Prototype screenshot: MDSF case management

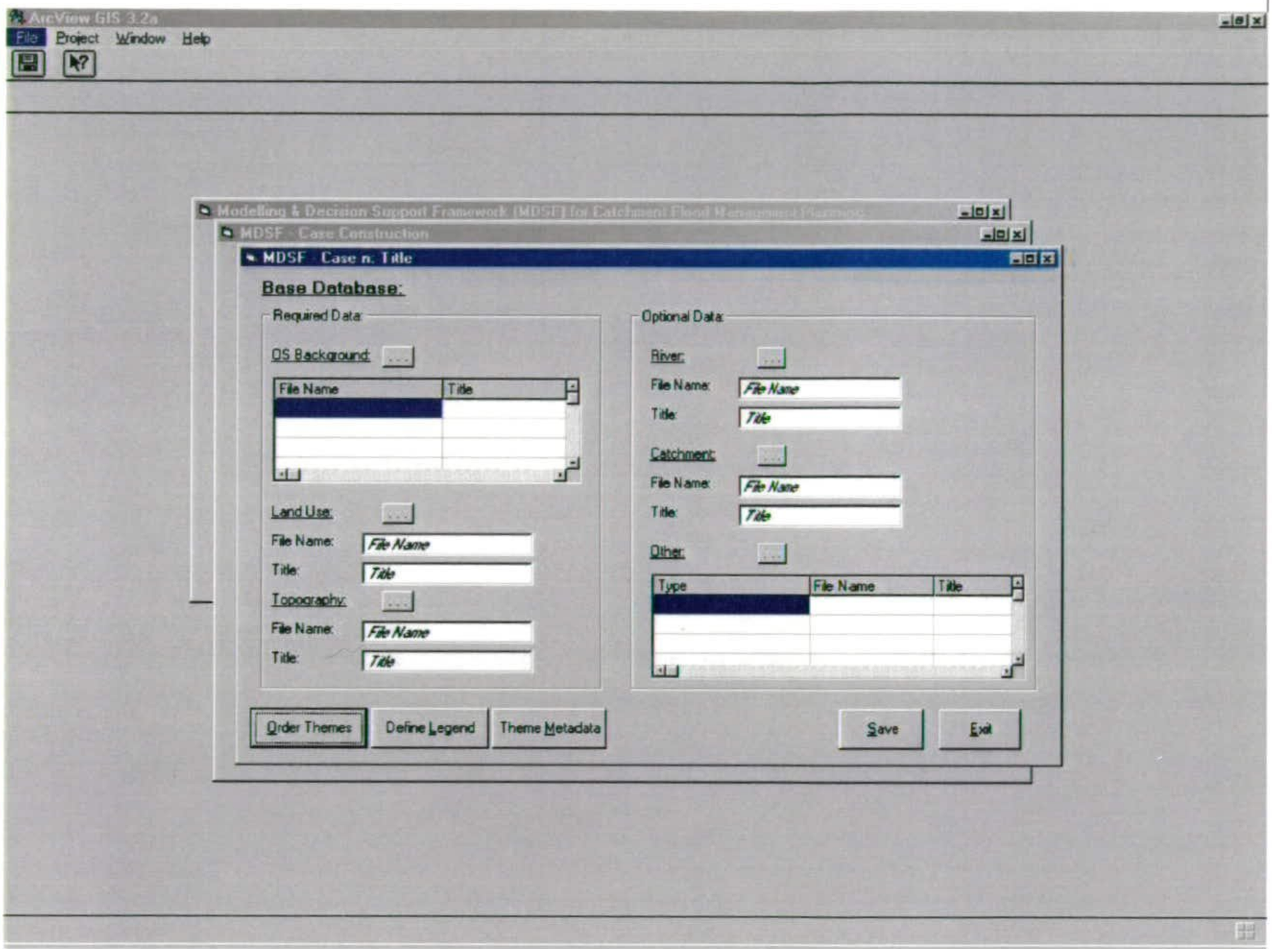


Figure 4.2 Prototype screenshot: MDSF base database

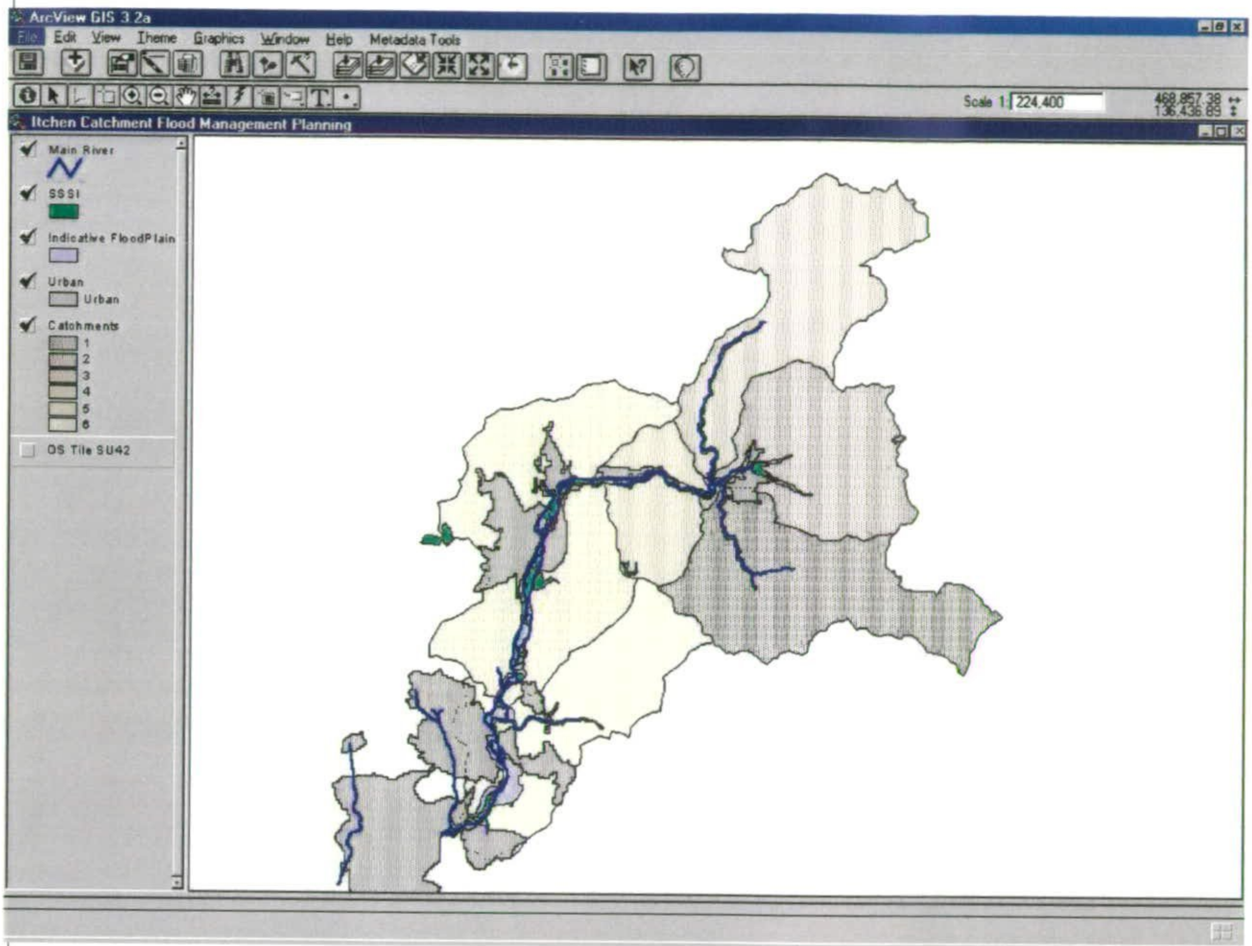


Figure 4.3 **Prototype screenshot: MDSF visualisation of base data**

5. FUTURE PROGRAMME AND TASKS

5.1 Work programme

The proposed work programme and its relationship to the timings of the pilot CFMPs and CFMP Guideline preparation is given in Figure 5.1.

There is considerable overlap between the *development* and *demonstration* phases of the project. It is intended to address this issue as follows:

- Provide interim guidance on the MDSF system at the beginning of July 2001.
- Support the Consultants in the application of the Interim Guidance during July and August 2001.
- Liaise with the MDSF Pilot Study Consultants and compare programmes for CFMP implementation and MDSF development. Try as far as possible to link the programmes in order to maximise the use of the MDSF in the Pilot studies.
- Release an alpha version of the MDSF in early September 2001.
- Support the Consultants in the application of the MDSF during September and October 2001. Alternatively, alpha testing may be carried out by the MDSF development team.
- Identify bugs and develop a beta version for release at the beginning of November 2001.
- Support the Consultants in the application of the MDSF during November and December 2001.
- Identify bugs and develop the final release version at the end December 2001.

The programme will depend on the MDSF Pilot Study programmes and the programme for the first group of CFMPs. It has assumed that the MDSF Pilot Studies will be complete at the end of October 2001, but it may be advisable to extend this to ensure that the MDSF is fully tested.

5.2 Key milestones and reporting

In association with the key phases of the project – inception, development, demonstration and handover – four key milestones can be identified as follows:

No.	Target date	Milestone
1	Jun 2001	Functional design specification agreed
2	Sep 2001	MDSF system (alpha version) available for pilots
3	Nov 2001	MDSF system demonstrated on two pilot catchments
4	Dec 2001	Transfer of MDSF to main CFMP consultants

Formal reporting will be focused toward these key milestones and deliverables and include:

Report	*Target date*	*Week No.*
Inception	Jun 2001	7
Progress	Aug 2001	17
Interim	Sep 2001	24
Final	Nov 2001	32

Disseminating and communicating progress and outcomes of the project to a wider audience will be important at all stages of the project and reasonable support will be provided to the Project Officer in achieving these aims.

Future programme and tasks are listed in Table 5.1.

Table 5.1 Future tasks and delivery dates

Proposal Task No	Task	Duration (weeks)	Completion (date, 2001)
IV	Set up quality system	2	13 July
V	System analysis	3	20 July
V	Set up modelling framework	10	7 September
VI	Hydrological procedure	6	17 August
VI	Hydraulic procedure	3	17 August
VI	Flood extent and depth	6	7 September
VI	Economic damages tool	8	7 September
VI	Social impact tool	8	7 September
VII	FEH National Method	2	24 August
VIII	Support MDSF Pilot Studies: Interim Guidance	10	7 September
VIII	Apply MDSF to Pilot Catchments using alpha version of software	8	2 November
IX	Support MDSF Studies: Beta testing of system	7	21 December
X	Liaise with CFMP Guidelines and produce Draft Procedures	4	7 September
X	Deliver alpha version of system	-	7 September
X	Deliver beta version of system	-	2 November
X	Deliver final version of system	-	21 December
XI	Provide training	-	2 November
XII	Set up licensing, etc	-	21 December

*Depends on pilot study programme

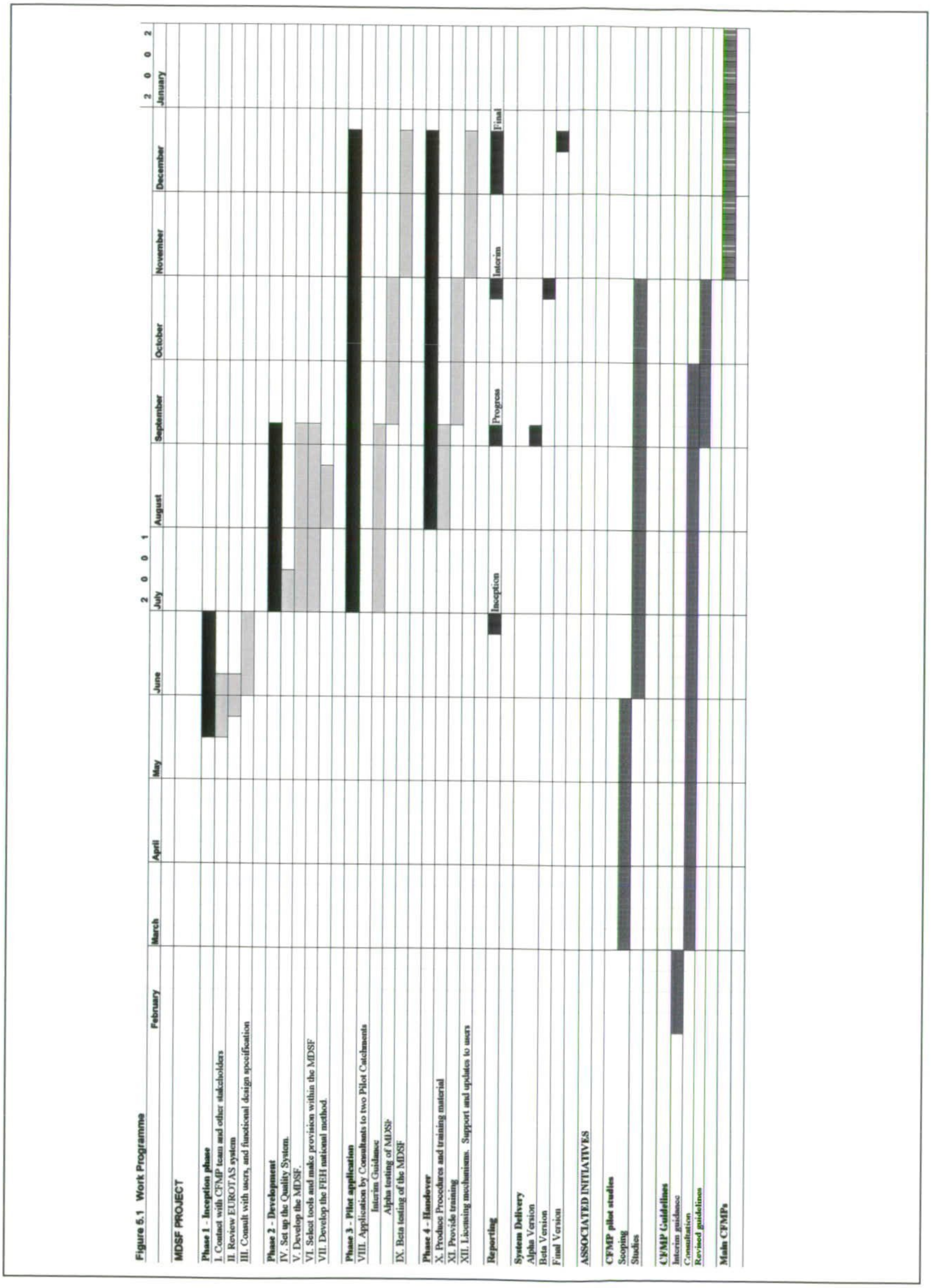


Figure 5.1 Work programme

Appendices

Appendix A

Interim Guidance – hydrology

Appendix A Interim Guidance – hydrology

Draft Guidelines on the use of FEH methods
for Catchment Flood Management Plans

A.1. Outline of main steps

- Using FEH CD-ROM, select/locate key points in Catchment (typically 10-20).
- Export catchment descriptors in CSV and WINFAP format. Also export DTM river & catchment boundary (new button to be added to FEH program – but in the interim must be defined and digitised from conventional maps). Descriptor values may need to be manually adjusted if the CD-ROM catchment boundaries do not match local knowledge.
- Apply FEH statistical method (WINFAP) to the selected key points to derive flood peaks for a standard set of return periods (5, 10, 25, 100 and 200 years). Compare with automated FEH estimates (to be released shortly by CEH in ARCVIEW compatible format).
- Apply FEH rainfall-runoff method (iSIS implementation), and use flow routing tools to combine flood response from sub-catchments to define flow hydrographs at selected key points.
- Incrementally reconcile FEH statistical and rainfall-runoff methods to obtain unit hydrograph Tp (and possibly UpTp), standard percentage runoff SPR, and possibly local rainfall/antecedent condition adjustments for each sub-catchment.
- Apply design events across the catchment for a range of storm durations and for the standard 5, 10, 25, 100 and 200 year return periods.
- Adjust design rainfall and model parameters to assess impacts of climate and land-use change.

A.2. Sub-catchments and corresponding catchment descriptors

Catchment Flood Management Plans are used to define flood risk and assess management options throughout a large catchment, and thus they require flood estimates at a range of key locations. These locations should be selected to define structural catchment features (such as major tributaries, reservoir sites, gauging stations), but also to yield sub-catchment and intervening areas of relatively uniform geomorphology, climate and land-use. Typically 10-20 such sub-catchment/intervening areas will be required, but more detail may be needed for specific purposes (such as defining urbanisation impacts on local catchment response). Small sub-catchments, likely to have short 'times to peak', should be avoided where possible as the timestep used for FEH rainfall-runoff calculations should not normally exceed 25% of the shortest sub-catchment time to peak.

Key locations in the catchment may be defined using the FEH CD-ROM, and their corresponding catchment boundaries and catchments descriptors exported to file for use in WINFAP and iSIS (export of boundaries is not currently available but is under development). Catchment boundaries should be confirmed against local information and the descriptor values adjusted if discrepancies are found (FEH Volume 5, Chapter 7, Section 7.2). Descriptors for 'intervening' areas between 'upstream' and 'downstream' key points are needed in the FEH rainfall-runoff model, and should be determined as:

$$CD_{inter} = (AREA_{down}CD_{down} - AREA_{up}CD_{up})/AREA_{inter}$$

Where CD represents any of the catchment descriptors DPSBAR, PROPWET, URBEXT, SPRHOST, SAAR, or (if appropriate) the rainfall descriptors C, D1, D2, D3, E and F. The use of separate rainfall descriptors for upstream and intervening sub-catchment areas (rather than applying downstream descriptors uniformly throughout) is recommended for areas of strong relief and significant rainfall variability (Chapter 9, Section 9.2.2). Note that DPLBAR is akin to a 'first moment of area' and should be found as:

$$DPLBAR_{inter} = (AREA_{down}DPLBAR_{down} - AREA_{up}\{DPLBAR_{up} + LDP_{down} - LDP_{up}\})/AREA_{inter}$$

A.3. Use of FEH statistical peaks

The FEH statistical method, being directly based on observed flood peak data, is generally preferred for estimating T-year flood peaks. This recommendation may be overridden if local circumstances provide clear reasons for preferring the rainfall-runoff method (FEH Volume 1, Chapter 5). Such circumstances include where reservoirs or sub-catchments of disparate character are involved (requiring full design hydrographs). The rainfall-runoff model is also, in general, better suited to assessing flooding under future land-use or climate conditions (by explicit adjustment of model parameters or of rainfall inputs).

Since a major purpose of Catchment Flood Management Plans is to assess flood response as it grows through the various sub-catchments and to assess the impacts of land-use and climate change, rainfall-runoff modelling is considered the most appropriate approach. However, it is recommended that the statistical method is also applied to improve confidence in the assessment of existing conditions, and that reasonable effort is made to resolve any differences in flood peak estimates between the two methods. In the last resort, and if appropriate, the hydrograph from the rainfall-runoff method may be scaled to match the peak from the statistical method. Expert judgement will be needed to ensure that the adjustments are sensible and justifiable. In some circumstances it may not be appropriate to make any adjustment (see below for further discussion on reconciliation).

Results from the FEH statistical method at the key locations should also be compared with the automated FEH statistical estimates. These form a national data set of 2, 5, 10, 25, 50, 100 and 200 year flood peaks on a 50 metre grid covering all catchments draining an area of at least 0.5 km^2. Derived by an automatic implementation of the FEH statistical method, with fixed rules for incorporating appropriate local data from the FEH data set, they provide a picture of how flood-peaks change across the catchment. Although mainly indicative, they do show the spatial stability of the statistical method and help to justify its use in scaling the rainfall-runoff hydrograph.

A.4. Peak flows by the FEH statistical method

A WINFAP based application of the FEH statistical method is recommended at each of the selected key sites. To this end it is expected that additional data (e.g. recent EA annual maxima data) should be obtained to extend the existing data (after checking for consistency and trend). Pooling groups should also be carefully reviewed. The primary steps to follow are listed below - they constitute a standard application of FEH statistical methods and are given here to indicate the general level of application that is required. More details of the methods are provided in Volume 3 of the FEH.

- **Estimate QMED at each site** using at-site flow data if available, otherwise using data transfer techniques in combination with the catchment descriptor equation (FEH Volume 3, Chapters 3 & 4).

- **Select the 100-year return period pooling group** (use for return periods between 20 and 200 years). If shorter return periods are critical it may also be beneficial to derive a 20-year return period pooling group (FEH Volume 3, Chapter 6). Review each pooling group checking for inappropriate catchments, or adding additional similar catchments

- If catchments are particularly permeable or urbanised then use of the urban adjustment (FEH Volume 3, Chapter 9) or permeable adjustment (FEH Volume 3, Chapter 19) may be necessary. Any permeable adjustment must be made outside the WINFAP program.

- **Combine QMED and the growth curve** to estimate 5, 10, 25, 100 and 200-year return periods plus any others of specific concern (FEH Volume 3, Chapter 7).

A.5. Overview of the FEH rainfall-runoff model

The FEH rainfall-runoff model is described as having three parameters: Standard Percentage Runoff (SPR); unit hydrograph time to peak (Tp) and baseflow (BF), for which values may be obtained from (in order of preference): observations at site, observations at suitable donor or analogue sites, or catchment descriptors. Peak flows predicted by the model also depend on the adopted design storm (its duration, depth and profile) and the antecedent condition (CWI). Moreover, the recommendation to use observed unit hydrograph shape (where known) in place of the standard triangle introduces additional parameters (e.g., at the simplest level, a local factor K in the equations for unit hydrograph peak, Up=(K/Tp)AREA and time base TB=(5.555/K)Tp).

In its standard 'three parameter' form, the model generally over-predicts T-year flood peaks (FEH Volume 4, Chapter 7), and new research to 'revitalise' the method, particularly by a more localised choice of design storm and antecedent condition, is currently at the scoping stage. In the interim, it has been suggested that the modelled hydrograph should be scaled to match the peak discharge derived by the statistical method. Such an adjustment could be considered equivalent to adjusting one or more of SPR, CWI, rainfall depth or return period, all of which would also affect runoff volume. But peak flow could also be adjusted by changing time to peak, the design storm profile or unit hydrograph shape, none of which would change runoff volume.

Any adjustments to the rainfall-runoff model should therefore be carefully considered as to their implications. Any adjustment to Tp, SPR, or BF should be justified against observed event data or using BFI values at the site or nearby (FEH Volume 4, Chapter 2, Sections 2.2 to 2.4). Any effective local adjustment to storm depth or antecedent condition should consider the regional error patterns shown in fig. 1 (taken from IH Report No 111, Boorman et al, 1990). This figure relates to 2-year return period hydrograph peaks as given by the FSSR16 rainfall-runoff model, but using observed values of Tp and SPR, the only differences from the FEH form are in baseflow estimate and the use of FSR design rainfall depths.

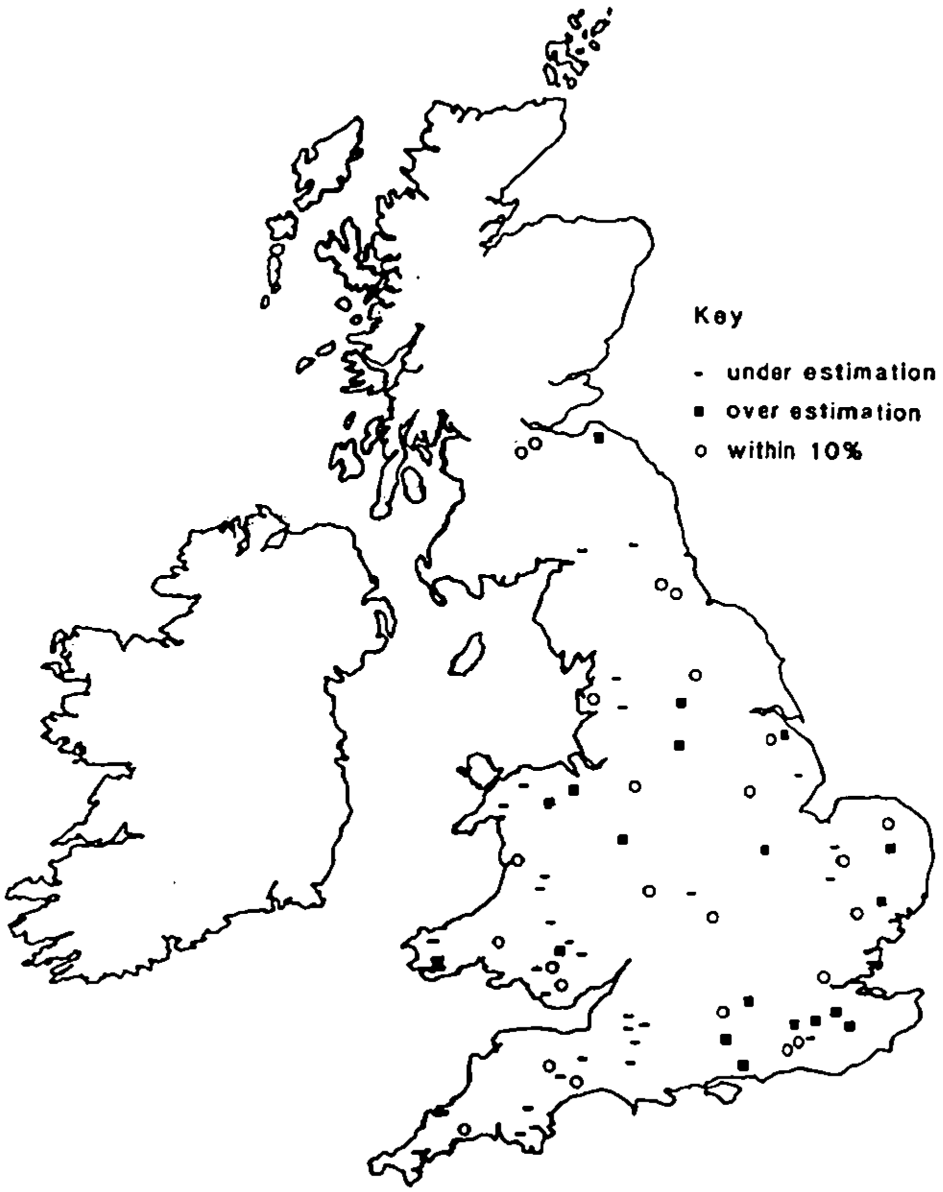


Figure A.1 2-year flood peak estimates using FSSR16 model with observed Tp and SPR

A.6. Flood hydrographs by the FEH rainfall-runoff model

The application of the rainfall-runoff model is essentially as given in Volume 4 of the FEH, with particular notice taken of the recommendations for reservoired catchments (Chapter 8) and disparate sub-catchments (Chapter 9). The basic steps described below are particularly concerned with modelling the catchment as a combination of sub-catchments, and to resolving differences with the statistical method. Section and Chapter references refer to FEH Volume 4, unless otherwise specified:

- **Estimate model parameters Tp, SPR, and BF** at key points using the iSIS FEH boundary unit or otherwise,. Adjust values using observed data at-site or at donor catchments (Chapter 2, Sections 2.2 to 2.4, with data in Appendix A, on the 'Miscellaneous Floppy' in Volume 4, or from analysis of new data by the methods described in Appendix A). It is anticipated that local adjustment factors should be relatively stable or vary consistently across the catchment with geomorphology, soil type, or land-use. BFI values for use in making adjustments may be obtained from the EA, or may be derived from several years of mean daily flow data as the average ratio of baseflow to total flow (with baseflow defined from the 'turning points' in the minima of successive 5-day flows).

- **Use iSIS FEH boundary unit to derive 5,10,25,100 and 200 year design hydrographs for upstream catchments**, using the standard design duration, (1+SAAR/1000)Tp, design profile, storm depth (for return period) and antecedent condition. Note that the sensitivity of peak flow to storm duration is generally low, and the design duration equation is meant to approximate the critical duration that causes the highest peak discharge. Note also that for the standard 'rural catchment' design inputs, the rainfall return periods needed to estimate flood peaks of a range of return periods are tabulated in Chapter 3, Table 3.1.

- **Compare derived hydrograph peaks with FEH statistical estimates**, and attempt to reconcile differences. Rescaling hydrograph values to match at each return period and for each sub-catchment is not recommended, but an average adjustment should be sought, based for example on the 25-year return period. Residual differences of 10-20% between the statistical and rainfall-runoff methods may be taken as a general reflection of the uncertainty in flood peak estimation. Rescaling the runoff hydrograph should be viewed as a last resort after incorporating local adjustments for Tp, SPR, and BF (and possibly the unit hydrograph peak flow factor K described in section 5 above). An attempt to justify any rescaling should be made by reference to Figure A.1. Rescaling should preferably be couched in terms of a local adjustment to CWI or the return period relationship between rainfall depth and flood peak (possibly reflecting seasonal features).

- **Use iSIS to derive hydrographs for successive downstream points**, based on locally adjusted values of Tp, SPR and BF for upstream and intervening sub-catchment areas, treating intervening sub-catchments as discrete inputs at the 'downstream node', and using flood routing units to model river processes.

  Design storms for downstream key sites will in general differ from those upstream, and the procedure defined in Chapter 9, Section 9.2.2 should be followed to define the critical duration at each point. Unlike estimating floods for the upstream sub-catchments individually, great care must be taken that the iSIS FEH unit input data applies the same storm duration, profile, return period, and areal reduction factor to all sub-catchments above the key site. This applies irrespective of urban condition. For significantly urbanised key sites critical conditions should be determined by considering the urban design conditions as an additional exercise. In catchments with significantly varied rainfall characteristics, T-year rainfall depths and initial CWI values may be varied between sub-catchments (using intervening rainfall descriptors as discussed in Section 2 above). Note that any flood outline derived from a single iSIS run should represent the flooding generated by a single storm, but the design hydrographs at successive key sites through the catchment will derive from different storms, and interpolation between them will give a worst case envelope outline.

- **Compare hydrograph peaks with FEH statistical estimates at downstream key sites** and reconcile differences. Hopefully the differences will generally be small. However it should be recognised that the rainfall-runoff method takes explicit account of deterministic effects through the catchment (such as the effect of reservoirs, flood plains, or catchment shape) even if the modelled effects may be only partially verified. Yet it assumes (normally) a uniform rainfall input over the catchment (rarely observed for a large catchment, but possibly acceptable for assessing design hydrographs). The statistical method is based on real observations, but cannot easily include deterministic effects (it does includes some effects by association - e.g. large catchments tend to have areas of flood plain). Some attempt to reconcile differences by adjusting CWI or return period relationships between storm depth and flood peak may be appropriate, but the validity of any adjustment can only be made on a 'one-off' basis, taking due account of relative uncertainties in each approach (including hydraulic uncertainties in the river routing).

A.7 Land use change

Dealing with land-use change presents many unknowns. It is not possible or realistic to provide simple percentage changes in flood peak based on land-use change because of the complexities involved. Observed data at the catchment scale seldom shows consistent effects (except for urbanisation) even though small scale plot studies can detect significant impact on the rainfall runoff method. Many land use changes (see Chapter 9) involve compensatory impacts in terms of flood response, perhaps generating faster runoff but a greater soil storage capacity to reduce runoff volume.

An assessment of model predictions is planned in the coming months and some quantitative recommendations will be developed by October 2001. The following guidance is provided as an interim measure – it has not been tested, is likely to change, and may not provide realistic answers.

The suggested method is to approach land-use change via the Tp(0) and PR parameters of the rainfall-runoff method. Where possible alternative PR and Tp(0) values are found from similar catchments with the alternative land use. However, a more general assessment of sensitivity is also suggested - involving examining how much overall response is affected by varying the Tp(0) and SPR parameters e.g. if Tp(0) is reduced in the upper reaches does this have any impact on a downstream conurbation. If sensitivity is found to be low then the implication would be that land use changes are not critical. If sensitivity is high it will indicate that more detailed work will be needed.

Note that the effect of land-use change can be expected to have most effect on low-return period floods, and very little effect at high return period floods. For high return period floods it is the total volume of rainfall that is the critical factor.

Urbanisation effects:
Urbanisation effects are already build into the rainfall-runoff method and Tp(0) and PR values can thus be readily adjusted for urbanization. Note if the catchment Tp(0) is observed then the effect of additional urbanisation should be obtained by scaling Tp(0) by the ratio of the catchment descriptor Tp(0) values.

In the absence of local projections of changes in urbanization, a baseline 5% change in urbanization is suggested.

Other Land Use changes:
The fact that it is very difficult to draw any consensus of land use change effects detectable at downstream locations suggests that any effect is probably (1) very dependent on local conditions and the exact nature of the change (2) not very large at downstream locations.

It is probably only worth while considering major changes in land-use e.g. change of crop is not worth considering, but change from arable to forestry (or vice versa) may be. Even within a particular land-use type it must be borne in mind that recommended practices change - often to try and offset or minimize any known effects e.g. forestry guidelines today include use of buffer zones and contour ploughing to counteract rapid-runoff. Thus care must be taken since historical information on land-use effects may not always be appropriate.

As a interim measure, the effect of land-use change may be investigated by varying Tp and PR in the following manner:-

<u>Varying PR in the rainfall-runoff method:</u>

PR should be varied by adjusting the SPR parameter with reference to other catchments that currently have the alternative land-use. The preferred approach is to identify 1-3 catchments with the target land-use type and with similar geology/soils, climate and area (local if possible). Observed SPR values, or SPR values derived from BFI for these donor/analogue catchments should be obtained and an average value used to replace the current-day SPR value for the catchment of interest. It is not appropriate to use SPRHOST values from the donor/analogue catchments. NB If only part of the catchment is subject to land-use change then the adjustment to the SPR value should be areally weighted.

It may be helpful to ascertain how sensitive the flood response is to variations in SPR by looking at possible minimum and maximum SPR values. The following assumes that the maximum effect caused by land use change would be equivalent to either (1) making 15% of the affected area impermeable (SPR=70%) or (2) making 15% of the affected area totally permeable (SPR=0%). This is very crude and there is no science to back up these figures – they simply equate to treating land use change analogously to the urban case, but with a quarter the effect. If PLC is the proportion of the catchment affected by land-use change then the range of PR values to be considered are then:-

$PRadj = PR\,(1 - 0.15\,PLC)$ (catchment more permeable)
$PRadj = PR\,(1 - 0.15\,PLC) + 70 \times 0.15\,PLC$ (catchment less permeable)

Note that these figures may well not represent any feasible land use change effect and are suggested as a starting point for assessing general sensitivity.

Note also that an impermeable catchment corresponds to an SPR of 70% - values of SPR in excess of 70% should not be used.

Varying Tp(0) in the rainfall-runoff method

It is not known how Tp(0) will be affected by different land-use types and there is little scope for adjusting it via the catchment descriptor equation for Tp(0).

The preferred approach is to use similar catchments with the alternative land-use type to adjust Tp(0) (as for SPR these should have similar soils/geology, climate and area). The Tp(0) value will need to be transferred to the catchment using the usual data transfer approach (Section 2.2.5). Care will need to be taken with this approach and some form of areal weighting may also be needed.

Finally, it may be valuable to experiment to determine whether a catchment is sensitive to changes in Tp(0) values. For this values Tp(0) could be adjusted to 66% and 150% of the current value. These figures are broadly based on the variations that are typically found in observed Tp(0) values and have no further scientific justification beyond this.

A.8. Climate Change

In the case of climate change, it is now quite clear that global mean temperature is rising (by 0.6°C since 1900, and a predicted further 1.5-2°C by the 2050's). This would suggest a more active and variable climate with higher rainfall depths. However, analysis of historic data has failed to show any clear trend, and modelled results based on Global Circulation Models (GCMs) show considerable variability about a possible overall pattern of drier summers and wetter winters. GCM data relate to large space increments (~300km) and long timesteps (essentially monthly rainfall depths), and it remains uncertain how impacts should be applied at the catchment level (e.g. is any increase in rainfall due to more storms or more depth in each storm). A number of 'continuous simulation' studies have been performed on large catchments (e.g. Reynard et al; 1999, working on the Thames and the Severn) applying the GCM monthly average changes as uniform factors to historic daily rainfall (and similar adjustments to evaporation). Such 'unintelligent downscaling' has suggested that the 1 in 50-year flood peak may be increased by up to 20% by 2050. Although highly uncertain, this figure has become a simple benchmark for what allowance should reasonably be made for climate change impacts on floods of all return periods. There is no firm evidence at this time to suggest the use of any factor other than +20%.

More work is required on suitable safety factors to include for climate change, and it is not yet clear what form any updated recommendations may take. Possible approaches include:

- use of hotter analogue catchments in the FEH statistical method
- adjustments to the FEH rainfall descriptors (including antecedent conditions) to reflect hotter conditions
- global factors of safety, derived from detailed simulation studies but applied as final adjustments to model results

Finally, a number of more general points on climate change must be made:

- Any recommendations on climate change will relate to future conditions, and will not affect the present flood risk.
- The need to consider climate change in any flood management scheme depends on the design life of the scheme.
- Providing flood management for uncertain future conditions may not represent the best use of current resources; a better option may be to re-assess schemes as any changes occur (and can be predicted with more certainty).
- Adopting a 50-year design flood now is to adopt a 2% chance of getting a flood of that size this year, next year, or any subsequent year. It is not an assumption that a flood of that size will not occur for 50-years. If flood planning could be based on this latter assumption it might seem appropriate to allow for climate change now. However, this assumption can never be made – there is always a risk that a flood larger than the design flood will occur.
- The likely impact of climate change on current flood estimates is probably much less than the general uncertainty due to inadequate flood data.

Appendix B

Methodology – socio-economic components

Appendix B Methodology – socio-economic components

The socio-economic methodology within the catchment flood management plan is designed to highlight areas where flood damage potential is greatest, and to explore the strategic options for damage mitigation to be reviewed and evaluated against the costs of this mitigation and any environmental consequences.

The detailed methodology starts with the land use of the areas at risk from flooding. Different land uses have different damage susceptibilities, such that retail and commercial properties have high damage potential, residential properties have intermediate damage potential and most industrial uses have low damage potential (except where the industry concerned is related to highly damage susceptible items such as electronic equipment).

The land use of the areas at risk therefore needs to be determined from secondary sources or whatever data is otherwise available. The exact source of secondary data has not yet been established, but the National Assets At Risk project uses Addresspoint data to identify areas of residential property and national sources of rating information identifies commercial, retail and industrial properties. A method is needed at the catchment scale to determine land use, using these data sources and others as appropriate. It will not be desirable to rely on field surveys of land use data, or necessarily to rely on local sources (e.g. planning department data).

The next stage of the methodology is to determine the appropriate flood damage functions for these land uses, related to the depth of flooding and the duration of flooding at any one particular location (taken from the flood extent maps and the flood hydrographs). A set of look-up tables is likely to be produced for different regions for the country (probably the Environment Agency regions), with potential damage data for residential, retail, commercial and industrial property, and agricultural land (although the methodology for agricultural land has yet to be determined). The GIS system will relate damage potential to the flood extent and depth and duration, to develop a stage-damage curve for flood risk areas within the catchment. It will be necessary, in this respect, to differentiate between protected and unprotected floodplain areas, and also between areas with different standards of flood protection (assuming that some floods being modelled will overtop virtually all standards of protection provided within the catchment).

In addition, it will be important to capture some aspects of indirect flood losses, because these can be regionally significant. It is likely that the methodology adopted here will be to relate indirect losses (e.g. loss of trade; traffic disruption; etc) to different types of land use, or else some other form of nationally available data. The product will be indirect losses for events of different flood durations, for different parts of the catchment.

It is important to try to capture some aspects of social impacts of floods. These can include health impacts from floods, the disruption caused by flooding, and the stress and trauma felt by flood victims during flood events. The results from detailed case study research undertaken by Middlesex University in the past will be re-evaluated in order to determine some aggregate social impact indicators. Thus it is likely that social impact will be scaled on a scale of 1-10, or some other such scale, to indicate minor impacts through to major health and trauma effects.

In addition to mapping the damages, losses and social impacts, it will be necessary to determine the mitigating effects on these impacts of different flood alleviation options. These options will involve structural or non-structural measures, in the form of engineering works, source control, other forms of flood storage, channel enlargements and levee embankments. In general these are designed to mitigate the risk of flooding, by reducing its probability or likelihood of occurrence.

Other flood mitigation options are designed to reduce the losses caused by floods without affecting their probability. Thus warning systems reduce flooding damage by allowing the population at risk to reduce potential damage by taking damage-averting actions. Flood insurance will mitigate the damage caused to particular households by spreading damage costs across a wider population. Other non-structural solutions include land use zoning in the floodplain, to prevent the build up of high damage potential land uses, and the acquisition and demolition or removal of properties from flood risk areas.

The results of these socio-economic analyses will be some sort of ranking of preferred options within the catchment, possibly on a reach-by-reach basis but also for the catchment as a whole (e.g. source control; land use control; etc). What decision support system will be embedded within the methodology to aid this decision making is not clear at this stage, but the identification of "hotspots" in terms of damage potential should be complemented by strategic options for damage mitigation through modifying flood flows or modifying damage potential.

Appendix C

Functional Specification Sheets

Process components

Component: Scoping Study and existing conditions database **CFMP Step:** 1 and 2 (contributes to 3, 4 and 8)	**Option:** Base **Revision:** DMR/JW 30/05/2001 DMR 26/06/01
Objectives: • Display readily available data to facilitate identification of flood risks • Identify urgent flood risk management problems • Help to identify gaps in data • Identify opportunities and constraints	
Data inputs: Essential data • Background maps (1:50,000, 1:250,000) • Catchment boundaries • Drainage network • Land use • Flood extent maps • Location of flood defences (where available) • Level of service of flood defences (where available) • Land use designations (eg SSSIs, etc)	**Data inputs:** Optional data • Non-Main River flooding • Topography (eg LIDAR) • Proposed future development • Type and extent of existing models • Other, see Appendix D
Methods: • Dialogue showing essential and optional data • Default views • Combinations of layers to illustrate catchment information, for example main areas of flood risk.	
Data outputs: • Default layouts for Scoping Study Report	
Issues: • Not all problems covered by flood risk maps (eg Ordinary Watercourses) • The CFMP Guidelines indicate that much of the data collection takes place after the Scoping Study Report is complete. Some optional data will be essential for Step 3 of the Guidelines (existing conditions database), where all information for MDSF procedures will be collated.	
Uncertainties: • Accuracy of flood risk maps • Date of data	

Process components

Component: Hydrology tool	**Option**: Existing and future scenarios
CFMP Step: 4 and 6	**Revision**: JP on 13/6/2001 MGS on 26/06/2001

Objectives:
To enable users to:
- Understand sources of flood water on a catchment wide basis
- Select appropriate design rainfall for required sites within the catchment
- Estimate flood hydrographs from required sub-catchments – for a range of return periods, and for current land-use and climate conditions
- Estimate effect of changing land-use and climate

Data inputs
- FEH catchment boundaries and river networks (for areas greater than 0.5km^2)
- FEH catchment descriptors on CDROM
- FEH peak flow data CDROM
- FEH summary rainfall-runoff event data
- FEH automated statistical QMED and growth factor grids
- Additional local flow/rainfall data (e.g. from the EA) – quality controlled.

Methods
- Estimate peak flows by full FEH statistical method (WINFAP with local data)
- Compare full and automated FEH statistical estimates
- Determine 'at-site' flood hydrographs by full FEH rainfall-runoff model (parameters adjusted to reflect local data, model as applied by iSIS Hydrology)
- Reconcile rainfall-runoff and statistical methods
- Apply reconciled rainfall-runoff model to sub-catchments using appropriate rainfall inputs and initial conditions. Range of storm durations and return periods
- Assess future land-use and climate scenarios, based on best current guidance on adjustments to rainfall and model parameters

Outputs
- Sub-catchment flood hydrographs at input nodes to the hydraulic routing tool used to model the core river (and reservoir) system.
- The hydrographs will relate to: various storm durations and antecedent conditions ('critical' at different downstream locations); a range of return periods; and current and future land-use and climate scenarios

Issues
- Procedure for accessing FEH catchment boundaries and river networks
- Assessing catchment descriptors for downstream sub-catchments
- Passing local data to WINFAP package
- Passing locally adjusted model parameters to iSIS Hydrology module
- Method for reconciling statistical and rainfall-runoff methods
- Design storms and initial conditions for large/varied catchments
- User-friendly standardisation of event duration and return period across all sub-catchments for input to iSIS model
- Scenario specification (adjustments to model parameters or outputs)

Uncertainties
- Errors in peak/hydrograph estimation
- Unknowns in scenario specification and impacts

Process components

Component: Water levels **CFMP Step:** 4 and 6	**Option:** Existing and future scenarios **Revision:** DMR 30/05/2001 DMR 26/06/01

Objectives:

- Predict peak water levels at appropriate locations for flood mapping/flood damage estimation.
- Predict level hydrographs where required for flood mapping/flood damage estimation.

Data inputs:

- Inflows from hydrology tool.
- Flood hydrographs at gauging stations for model calibration. If these are not available, data on the geometric properties of the river would be needed (river and flood plain sections at c5km intervals).
- Rating curves at water level prediction sites (for use with routing model). These may be derived from gauging stations, hydraulic calculation or existing hydrodynamic models.

Methods:

- Flow routing model (iSIS Routing) to provide flow estimates at all required locations, using inflows from hydrology tool.
- Use of rating curves to convert flows to levels (including use of Section 105 and other models to derive rating curves).
- Possible use of hydrodynamic models instead of routing models for parts of the river system where:

  They exist already

  Detailed modelling of embanked flood plains is required

  There is significant tidal influence (for example, fenland rivers where the geometry is simple but tidal effects are important)

Data outputs:

- Peak flood levels at all required locations.
- Longitudinal sections of main watercourses, showing flood levels
- Level hydrographs at all required locations.
- Data layer in customised database showing flow and level hydrographs, to facilitate understanding of catchment processes.

Issues:

- Need to keep modelling simple (whether routing or hydrodynamic).
- Routing models have shortcomings, as indicated above.
- Survey work may be needed to develop accurate rating curves (existing models should be used wherever possible).
- Should groundwater be taken into account and, if so, how?

Uncertainties:

- Large uncertainties in inflows.
- Uncertainties in routing/modelling procedures.
- Accuracy of rating curves

Process components

Component: Flood extent and depth map **CFMP Step:** 7	**Option**: Base option **Revision:** JMW/TREC/DE on 30/5/2001 MGS/DJE on 20/6/2001

Objectives:
Calculate flood extent and flood depths

Data inputs:
- Water levels (probably maximum level) at a limited number of points on river system
- River centre line as polyline
- Digital elevation model (probably grid of ground levels – may need to be resampled to a finer resolution and the river imposed as an artificially low area)
- Indicative flood plain map (IFM) or other means to identify the approximate extent of the flood plain
- Defended areas (as polygon) and associated level of service

Method:
1. Interpolate water levels at intermediate locations along the river by linear interpolation on either water level or water depth (if river polyline has Z values). Needs spacing defined.
2. Generate a line perpendicular to the river centre line at all water level points. Extend line to the river centre-line + buffer / IFM + buffer / topographic intersection + buffer (buffer to be user defined, eg 1km). Allow the user to edit the perpendicular line to reflect flow paths.
3. Assign the water level to minimum of 3 points on the perpendicular line.
4. Create a TIN of the water surface (3D Analyst method)
5. Convert the water surface TIN to a grid - at the same locations as the ground surface grid (3D Analyst method)
6. Create a surface from the water levels using spatial interpolation –e.g., IDW (Spatial Analyst method)
7. Use matrix subtraction to generate a grid of water depth (-'ve values mean not flooded).
8. Create flood polygons and combine contiguous flood polygons
9. Allow the user the option of removing flooded areas that don't intersect with the river line
10. Allow the user the option of removing flooded areas that are defended, according to level of service criteria

Data outputs:
- Raster grid of water depths
- Vectors of depth contours

Issues:
- Problem: method assumes single water level across floodplain. Response if different water levels are available for the flood cells then the method could be extended to cope
- Problem: ignores embankment failure. Response acknowledged simplification

Sources of Uncertainties Introduced During Component:
- Errors in ground model/data
- Errors in water level data (especially in the interpolation process)

Process components

Component: Procedure for economic flood damage assessment, social impact assessment and flood risk analysis	Option: Base option
CFMP Step: Step 9	**Revision:** EP-R/PHvL on 26/6/2001

Objectives:

Overall aim: To enable the MDSF to provide an indication of levels of economic exposure to flooding by incorporating the socio-economic dimension of flooding into the assessment of flood risk. The socio-economic impact dimension of the risk analysis is made up of:

- the economic impact of floods at a catchment scale;
- the social impact of floods at this scale
- the damage and loss reductions that different broad policy options and flood defence strategies will yield.

Achieved within MDSF by:

- Providing damage functions for an agreed set of land use (economic) categories
- Providing indicators for the indirect effects of flooding on the sub-regional economy
- Providing high level social vulnerability indicators
- Providing a procedure for applying these in order to assess flood risk –including advice on:
- Data sources for land use, social indicators, economic indicators
- Interpretation of this data as required by the MDSF process

This will:

- Allow an assessment of the spatial distribution of different levels of flood risk within a catchment in a manner that could inform the identification and selection of flood risk management policy options
- Help identify flood risk 'hot spots' that could influence the selection of policy measures
- Provide information as a basis for setting indicative FD budget allocations to the different catchments on the basis of the levels of risk within them
- Help develop an approximate relationship between different policy options at different costs and the benefits that they bring

Data inputs:

- Present land use in the flood plain classified by each of the eight economic (or land use) sectors Flood damage indicators for each of these eight economic sectors based on flood depth
- Population for the floodplain, broken down as far as possible into vulnerability groups (by age; social class; ethnicity, etc). This can be done from secondary sources (e.g. the census; etc)
- Strategic infrastructure on the floodplain (mainly communication links but also strategic utilities; hospitals; etc)

Base Method:

1. Identify land use and strategic assets in all the areas affected by flooding and categorise by agreed categories
2. Obtain flood depths for each land use unit (which could be 50 m grid squares) via the GIS
3. Determine and select the appropriate potential flood damage data sets to apply to the catchment in question
4. Assess flood damage for land use at risk ideally for the following return periods (1 in 5; 1 in 10; 1 in 25; 1 in 100; 1 in 200)
5. Consider the use of information on defence reliability
6. For large land use areas calculate average damages
7. Assess potential indirect losses for areas at risk and related areas
8. Sum potential direct and indirect losses and relate them to the probability of the events in question
9. Aggregate over a set of return periods (area under probability/damage curve)
10. Determine population at risk from flooding and its characteristics related to flood vulnerability
11. Access social vulnerability indicators for the catchment in question and apply them to the population at risk for the return periods in question
12. Combine steps 6, 7 and 8 to give a measure of flood risk
13. Assess the approximate reduction in (a) potential flood damage, (b) indirect losses and (c) social vulnerability that result from different policy options for flood risk mitigation

Data outputs:

- Maps and tabulations of the level and spatial distribution of flood risk (including defence problems and specific hazards) in the catchment including:
  - Potential damages at different return periods
  - Potential indirect losses/benefits (industry; transport disruption) at different return periods
  - Hazard hot spots determined by a set of criteria
  - Vulnerable groups determined by a set of criteria
  - An indication of the relative approximate effectiveness of different flood risk mitigation measures

Issues:

- Definition of flood risk and criteria for risk 'hot spots' needs to be defined and agreed.
- The level of detail of data and analysis required is one that is practicable within the data and resources available for the pilot CFMP process
- Reliability of flood defences – we need to take account of the issue whilst recognising that such data will be imprecise.
- Projected land use on flood-plain needs to be included in future scenarios (i.e. up to 50 years hence)
- **An assessment of benefits (or relative effectiveness) of different policy options is required by the CFMP process – the precise extent to which the MDSF can contribute to this process needs to be determined by the MDSF and CFMP teams.**

Sources of Uncertainties Introduced During Component:

- Uncertainty in the economic and social data (e.g. social class/vulnerable groups data)
- Lack of precision in categorisation of land use (including failure to be able to capture the dynamics of land use change and vulnerability to flooding)
- Lack of precision inherent in averaging of damage functions over catchments/regions
- Unknowns inherent in forecasts of future flood plain development
- Lack of precision introduced by using insufficient or inappropriate return periods to make the analysis a serious one (and not misleading, which is what the Section 105 and the IFP maps are)
- Lack of precision in the assessment of benefits / effectiveness of different policy options – this (in addition to all the above) will introduce uncertainty into decision making

Process components

Component: Procedure for uncertainty estimation CFMP Step: 9 and 10	Option: Base option Revision: PHvL on 22/6/2001

Objectives:
- To identify and understand the sources of uncertainty affecting the analysis carried out within the MDSF, along with the relative contribution of each source of uncertainty to the overall uncertainty attached to the result
- To assess the aggregate level of uncertainty attached to the result
- To understand how this uncertainty is propagated through the analysis
- To express this uncertainty in a manner that is useful to decision makers in formulating CFMPs

Context:
Uncertainty affects all stages of the CFMP process:

- the data used in developing CFMPs will have varying degrees of uncertainty attached to them
- further uncertainty will be introduced into the process through the models and forms of analysis used;
- uncertainty is inherent in the use of long term scenarios, within which the degree and nature of uncertainty will change;
- the results from the MDSF will be used as an input to a decision-making process which will need to understand of the degree, nature, and implications on decision making of uncertainty
- the extent and implications of uncertainty needs to be expressed and communicated in a meaningful form.

Data inputs:
- information on sources and extent of uncertainty attached to all data used
- information on sources and extent of uncertainty introduced by all each analytic procedure used
- information on extent of uncertainty attached to future scenarios used

Method:
1. Identify and assess the sources of uncertainty affecting each stage of the process for producing flood risk maps encapsulated within the MDSF
2. Categorise the types of uncertainty present
3. Apply procedure for assessing the different types of uncertainty present in terms of their influence on the overall uncertainty of the outputs from the MDSF
4. Identify the dominant sources of uncertainty affecting each stage of the MDSF process, and apply a procedure for assessing their relative significance
5. Apply data structures that carry information on uncertainty, and GIS routines to assess and to propagate information on uncertainty
6. Apply GIS routines to assess and to propagate uncertainty information
7. Express the uncertainty in a meaningful form and attach to the outputs from the MDSF in the form of meta-data

Data outputs: • Overall level of (relative) uncertainty attached to each stage of the MDSF process • Key contributory factors to this level of uncertainty • Data structures that carry information on uncertainty
Issues: Problem: Uncertainty assessment in this context is a potentially complex area in which there are various techniques for assessing uncertainty and evaluating its impacts, many receiving research attention[1] (see table in footnote) – do simple pragmatic methods exists for use in the MDSF? Response: The MDSF team to determine this through consultation with individuals/groups involved in research in this area. Problem: to what extent is have estimates of the uncertainty inherent in existing data been made? Response: as for the above. Problem: to what extent have estimates been made of the uncertainty inherent in the analytic techniques that will be used within and in conjunction with the MDSF? Response: as for the above. Problem: to what extent have estimates been made of the uncertainty inherent in flood risk assessments of the type to be produced with the MDSF? Response: as for the above.
Uncertainties: • 'Recursive' uncertainty – that is, uncertainty about how best to deal with uncertainty in a simple pragmatic way!

[1] **Types of Uncertainty and techniques for their Assessment**

Defined uncertainty			**Undefined uncertainty**
Uncertainty affecting **identity** – eg what is an adequate description of flood risk for use in the CFMP process? *Assessed through debate and/or tests leading to agreed definitions*	**Analytical** uncertainty		Uncertainty concerning **our level of ignorance** – absence of evidence is not evidence of absence *Difficult to assess explicitly but can in some sense be taken into account by hypothesis testing using Bayesian probability theory and its extension, Dempster-Shafer theory*
	Model or parameter **error** *Assessed by comparative evaluation, sensitivity analysis, and informed by expert judgement*	Stochastic **variability** *Assessed by statistical analysis, and careful interrogation of the data*	

Appendix D

Data summaries

Necessary data sets to input

General data for background and planning

1. OS background and base data
2. Designated areas

Data sets are referenced in the EA Meta database by Meta No. This number should uniquely identify the required dataset. Further details of the relevant data sets are given in the tables below. These datasets are nationally available and have no restrictions on use within CFMP projects.

1. Base data

Category	Data Required	Description	Format	Currency	Source[1]	Licensing and Cost	Comments
BASE DATA	OS general mapping backdrop containing information on urban areas, towns villages, farms, water and woodland and infrastructure– to act as a general location plan	OS Raster images which mirror the OS LandRanger series. Information contained on urban areas, cities, towns, villages, farms, water and woodland	1:50,000 image Complete coverage for England and Wales.	Updated annually	EA	Available from EA as part of EA corporate license with OS, provided the correct acknowledgement together with the Consortium Member's references is shown on all graphic copies and screen images where possible, irrespective of use	Separate data images exist for urban areas, farms, water and woodland and as separate layers for roads, canals and railways. All layers are needed.
		OS polyline data layers showing canals, railways and roads (A/B/minor/motorway /primary routes and single carriageways)	Available as 1:250,000 scale polyline data. Complete coverage for England and Wales	Updated annually	EA		

EA Meta data details:

Category	Dataset Name (EA)	Scale	Short Description (EA)	File Name	Coverage	Data Type	Quality	Meta No
OS Base Data	Gazetteer (OS) at 1:50,000 - Farms	1:50,000	Name & Location for farms	gaz_farms_50k.shp	National	Point	Derived from OS 1:50,000 Gazetteer. The positional accuracyis given in BNG co-ordinates to a nominal 500m & represents the centre of 1km grid square in which the feature lies	271
	Gazetteer (OS) at 1:50,000 - Hills	1:50,000	Hill or mountain above 30m with a definitive name	gaz_hills_50k.shp	National	Point	as above	272
	Gazetteer (OS) at 1:50,000 - Roman	1:50,000	Roman antiquities	gaz_roman_50k.shp	National	Point	as above	273
	Gazetteer (OS) at 1:50,000 - NonRoman	1:50,000	Non-Roman antiquities	gaz_nonroman_50k.shp	National	Point	as above	274
	Gazetteer (OS) at 1:50,000 - Woodland	1:50,000	Any forest or wooded area	gaz_woodland_50k.shp	National	Point	as above	275
	Gazetteer (OS) at 1:50,000 - Water	1:50,000	any river, lake, loch, reservoir or water feature	gaz_water_50k.shp	National	Point	as above	276
	Gazetteer (OS) at 1:50,000 - Other	1:50,000	All other names which do not appear in the other 7 categories	gaz_other_50k.shp	National	Point	as above	277

Category	Dataset Name (EA)	Scale	Short Description (EA)	File Name	Coverage	Data Type	Quality	Meta No
Infrastructure	Railway - Network at 250,000	1:250,000	Rail Network of Great Britain at 250,000	railway_250k shp	National	Polyline		131
	Roads - B Class at 250,000	1:250,000	'B' class roads in Great Britain. Extracted from OS Strategy data	roads_B_250k shp	National	Polyline		221
	Roads - Minor at 250,000	1:250,000	Minor roads in Great Britain. Extracted from OS Strategy data	roads_minor_250k shp	National	Polyline		223
	Roads - Motorways at 250,000	1:250,000	Motorways in Great Britain. Extracted from OS Strategy data	roads_mway_250k shp	National	Polyline		224
	Roads - A Class at 250,000	1:250,000	'A' Class Roads in Great Britain. Extracted from OS Strategy data	roads_A_250k shp	National	Polyline		225
	Roads - Primary at 250,000	1:250,000	Primary Roads in Great Britain. Extracted from OS Strategy data	roads_primary_250k shp	National	Polyline		231
	Roads - Single Carriageways at 250,000	1:250,000	Primary Routes with Single Carriageways. Extracted from OS Strategy data	roads_single_250k.shp	National	Polyline		236
	Canals at 250,000	1:250,000	Canals at 250,000	canal_250k shp	National	Polyline		53
	Urban Areas at 250,000	1:250,000	Urban Areas in Great Britain. Extracted from OS Strategy data	urban_areas_250k shp	National	Polyline		237

2. Designated areas

Category	Data Required	Description	Format	Currency	Source	Licensing and Cost	Comments
Designations	Areas of Outstanding National Beauty (AONB) boundaries And other designations	Areas of Outstanding Natural Beauty digitised by FRCA from Countryside Commission maps	Polygons at 1 50,000 Complete coverage for England and Wales	Updated when changes occur. last updated in January 2000	EA	Available to EA from Countryside Commission provided use is restricted to named project.	

EA Meta data details:

Category	Dataset Name (EA)	Scale	Short Description (EA)	File Name	Coverage	Data Type	Quality	Meta No
Designations	Designations - Community Forests at 50,000	1 50,000	Boundaries of Community Forests digitised by FRCA from Countryside Commission Maps	cforest_50k shp	National	Polygon		58
	Designations - Green Belt at 10,000	1 10,000	Green Belt Data obtained form the DETR	greenblt_10k shp	National	Polygon		80
	EA - LEAPs at 250,000	1 250,000	Local Environment Agency Plan (LEAPs) boundaries	leaps_250k shp	National	Polygon	Cleaned in Arcinfo, Topology, disputes with boundaries	90
	Designations - RAMSAR Areas at 10,000	1 10,000	Sites identified by the Ramsar Convention on Wetlands of Internaional Importance	ramsar_10k shp	National	Polygon		132
	Designations - Ramsar Sites (Welsh) at 10,000	1 10,000	welsh sites identified by the Ramsar Convention on Wetlands of International Importance	ramsar_wa_10k shp	National	Polygon		133
	Designations - Scheduled Ancient Monuments at 250,000	1 250,000	Scheduled Ancient Monuments point data for the central GR at a Scheduled Ancient Monument	sam_250k shp	National	Point		143
	Designations - Sites of Special Scientific Interest at 10,000	1 10,000	Sites of Special Scientific Interest in England	sssi_10k shp	National	Polygon		145
	Designations - Special Areas of Conservation at 10,000	1 10,000	Special Areas of Conservation and Proposed Special Areas of Conservation in England	sac_10k shp	National	Polygon		147
	Designations - Special Protection Areas at 10,000	1 10,000	Special Protection Areas the land classified under Directive 79/409 on the Conservation of Wild Birds	spa_10k shp	National	Polygon		148

Step 4 Hydrology Tool

Data sets needed are the following:

FEH CD ROM

Catchment Outlines from EA (NB Not identical to FEH boundaries, these may become available at a later stage from CEH Wallingford)

1. River Network

All datasets are nationally available and have no restrictions on use within CFMP projects.

1. FEH CD ROM

Category	Data Required	Description	Format	Currency	Source[1]	Licensing and Cost	Comments
HYDROLOGY	Details of gauged locations, catchment characteristics and annual maxima	FEH/WINFAP database provides annual maxima data for UK gauging stations as well as derived data listed as indices reflecting baseflow, soil type, runoff, urban extents (incls suburbs) as well as drainage path lengths/slopes, mean catchment altitude. Catchment descriptor information also available for user defined areas, facilitating flood risk analysis at ungauged sites	Independent FEH CD Rom with interrogation facilities, linked to WINFAP database which stores Annual Maxima and Catchment Descriptor information for gauged sites throughout the UK	Software issued in 1999, indices set at 1990 values Manual updates possible.	CEH	Handbook: £250 +VAT FEH CD-ROM £750 +VAT FEH-WINFAP £1500 +VAT	On a case by case basis, the indices can be manually changed to reflect recent changes, for example increased urbanisation. Data are provided as a single index value per catchment area examined Critical indices to update, URBEXT, SPRHOST

EA Meta data detail: Currently the dataset is not available within the EA, but can be purchased as above.

2. Catchment outlines

Category	Data Required	Description	Format	Currency	Source[1]	Licensing and Cost	Comments
Hydrology	Catchment boundaries to act as defining limits for Catchment Plan information	Catchment boundaries for England and Wales as used in the CEH Hydrometric register, and used in FEH software	Polygon data at 1:50,000 scale Complete coverage for England and Wales	Updated 1998, 2000 version available from National Water Archive	EA	Provided by National Water Archive, CEH Wallingford to EA. Use restricted to named project	Some catchments will need to be subdivided for particular plans, any subdivisions must be stated in order to prepare data layers with appropriate boundaries.

EA Meta data details:

Dataset Name (EA)	Scale	Short Description (EA)	File Name	Coverage	Data Type	Quality	Meta No
River Catchments at 50,000	1 50,000	River Catchments at 50,000 from IoH	catchmnt_50k.shp	National	Polygon		140

3. River Network

Category	Data Required	Description	Format	Currency	Source[1]	Licensing and Cost	Comments
Hydrology	Digital drainage network	Institute of Hydrology River Network, derived from digitised river information taken from 1:50,000 OS maps.	Polylines at 1:50,000 scale. Complete coverage for England and Wales.	Produced in 1990	EA	Supplied to EA by the Institute of Hydrology use restricted to named project.	Different to the basis for the drainage network of FEH CD Rom which is based on digital terrain modelling and flow pathways as opposed to main rivers.

EA Meta data details:

Dataset Name (EA)	Scale	Short Description (EA)	File Name	Coverage	Data Type	Quality	Meta No
Water - IH River Network at 50,000	1:50,000	rivers at 50,000 from IH	rivers_50k.shp	National	Polyline		86

Water Levels Tool

Data sets needed are the following:

0 Input from Step 4 Hydrology Tool

None of the following datasets are available nationally and have to be obtained from the EA Regional / Area offices by the consultants. There are no issues with licensing.

1 Flood Hydrographs
2 Geometric properties
3 Rating curves

1 Flood Hydrographs

Flood hydrographs are not available nationally. Regional / Area offices of EA have flood hydrographs for gauging stations.

2 Geometric properties

Geometric properties of the river are derived from survey, for the flood plain the 50m topographic data (OS Panorama) could be used or LIDAR if available.

3 Rating curves

Rating curves are available from the EA regional / area offices or may be derived from other sources, e.g., previous modelling.

Step 7 Flood Extent and Depth map

Data sets needed are the following:

0 Input from water levels tool
1 River centre line
2 Digital Elevation Model
3 Indicative floodplain map

1 River Centre Line

Category	Data Required	Description	Format	Currency	Source[1]	Licensing and Cost	Comments
Hydrology	Digital drainage network	Institute of Hydrology River Network, derived from digitised river information taken from 1:50,000 OS maps.	Polylines at 1 50,000 scale Complete coverage for England and Wales.	Produced in 1990	EA	Supplied to EA by the Institute of Hydrology use restricted to named project.	Different to the basis for the drainage network of FEH CD Rom which is based on digital terrain modelling and flow pathways as opposed to main rivers.

EA Meta data details:

Category	Dataset Name (EA)	Scale	Short Description (EA)	File Name	Coverage	Data Type	Quality	Meta No
Hydrology	Water - IH River Network at 50,000	1:50,000	rivers at 50,000 from IH	rivers_50k shp	National	Polyline		86

2 Digital Elevation Model

Category	Data Required	Description	Format	Currency	Source[1]	Licensing and Cost	Comments
BASE DATA	Topography	Digital terrain information	Grid data available at 100m or 50m resolution Complete coverage for England and Wales	50m grids updated annually.	EA	Available from EA as part of EA corporate license with OS. provided the correct acknowledgement together with the Consortium Member's references is shown on all graphic copies and screen images where possible, irrespective of use.	Superfluous if LIDAR data are available for the whole catchment – this is unlikely.

EA Meta data details:

Category	Dataset Name (EA)	Scale	Short Description (EA)	File Name	Coverage	Data Type	Quality	Meta No
Base Data	Topography - 50m resolution	50m	Topography (50m) folder containing ARC/INFO coverage	topo_50m	National	Grid		269

Locally in the regions more detailed data may be available, e.g., LIDAR, photogrametry, land survey. LIDAR coverage is still very sporadic around the country and not available nationally. This data is held at the regional offices.

3 Indicative Floodplain Map

Category	Data Required	Description	Format	Currency	Source[1]	Licensing and Cost	Comments
FLOOD RISK	Fluvial and coastal flood outlines for a range of return periods for initial identification of areas at risk	Indicative Flood Plain Maps at the 1:100 year (fluvial) and 1:200 (coastal) year return period. Maps based on best available information at time of annual update. Sources of information from which maps derived include Section 105 maps, historical event information and the Flood Risk Map for England and Wales, IoH Report No. 130	Polygons at 1:10,000	Updated annually, most recent version is year 2000	EA	Produced by EA and freely available on EA website - no restrictions on use	Indicative floodplain maps provide an overview of land potentially at risk from flooding form the land or the sea. Whilst sources of information are given on a general basis, no indication is given on an individual basis. Thus some outlines may be very crude and based on historical events whilst others may be based on detailed modelling and Section 105 maps. Where possible, Section 105 maps should be sought with the relevant region.

EA Meta data setails:

Data Input	Dataset Name (EA)	Scale	Short Description (EA)	File Name	Coverage	Data Type	Quality	Meta No
Floodplain	Indicative Tidal Flood Maps (Year: 2000)	1:10,000	This is a coverage of the indicative floodplains around the country. This is the fluvial dataset and it was digitised for the Agency by Jeremy Benn Associates	indicative_tidal_flood_10k.shp	National	Polygon		411
	Indicative fluvial Flood Plains (Year: 2000)	1:10,000	This is a coverage of the indicative floodplains around the country. This is the fluvial dataset and it was digitised for the Agency by Jeremy Benn Associates	indicative_fluvial_flood_10k.shp	National	Polygon		412

Locally in the regions flood plain data is available for other return periods than 1:100. These are mostly results of S105 modelling. These floodplain indications are available from the regional offices, but only for small areas in the regions, there is no national coverage and return periods calculated vary by region. Results of the S105 modelling is incorporated in the indicative floodplain for the national dataset, as well as historic flooding events and other relevant data.

Step 9 Economic Damages

Data input required:
1 Land Use
2 Population
3 Infrastructure
4 Indicative Flood Plain Map / Flood Plain Map as previously calculated in analysis

Meta data details have been derived from the EA Meta database held at NCEDS Twerton. Meta No are unique and can be used to request data sets.

1. Land Use

Category	Data Required	Description	Format	Currency	Source'	Licensing and Cost	Comments
LAND USE	Land cover	Institute of Terrestrial Ecology land cover map is a digital dataset, providing classification of land cover types into 25 classes, at a 25m (or greater) resolution.	Data supplied as 25m grid. Complete coverage for England and Wales	Derived from LANDSAT imagery from 1990, updated version expected completion date of June 2001	EA	Supplied to the EA by the Institute of Terrestrial Ecology, use restricted to named project.	

EA Meta data details:

Data Input	Dataset Name (EA)	Scale	Short Description (EA)	File Name	Coverage	Data Type	Quality	Meta No
Land cover	Landcover (ITE) at 25m	25m	Landcover (1990 ITE) - folder containing ARC/INFO coverage	landcover_25m	National	Grid		89

Urban and agricultural land use data required for the economic analysis is likely to be derived from the MAFF funded 'National Appraisal of Assets at Risk from Flooding and Coastal Erosion' project.

2. Population

Category	Data Required	Description	Format	Currency	Source[1]	Licensing and Cost	Comments
Population	Data on population distribution, age distribution	Enumeration districts as used in Census	1:200000 Polygon data Complete coverage for England & Wales		Source data belongs to the ED-LINE consortium	Derived from large scale maps in which the Crown through OS holds the copyright from 1991 and from 1991 census boundaries drawn on those maps in which the Crown through ONS holds copyright.	
	Total Population	Population numbers per enumeration district	Point data, 1 for each ED Complete coverage for England and Wales	1991	Census	Available from EA, for use in named project.	

EA Meta data details:

Data Input	Dataset Name (EA)	Scale	Short Description (EA)	File Name	Coverage	Data Type	Quality	Meta No
Population base data	Admin - Electoral Wards at 10,000	1:10,000	Voting area used for district councils. Extracted from Ordnance Survey Boundary Line Data	ward_10k.shp	National	Polygon		64
	Admin - Enumeration Districts at 50,000	1:50,000	Boundaries used for Census data	enumeration_50k.shp	National	Polygon		67
	Urban Areas at 250,000	1:250,000	Urban Areas in Great Britain. Extracted from OS Strategy data	urban_areas_250k.shp	National	Polyline		237

Further population data can be extracted from the Office of National Statistics under a 5-year free license. The license as currently used by Middlesex University is sufficient to cover use of the data for this project (according to HMSO). Crown Copyright needs to be mentioned. Further data from the ONS of 1998 is at ward level and includes: age distribution, deprivation index, no of employed. Age distribution is given in percentage and could be extrapolated to the population numbers at the enumeration district level.

3. Infrastructure

Category	Data Required	Description	Format	Currency	Source[1]	Licensing and Cost	Comments
BASE DATA	OS general mapping backdrop containing information on urban areas, towns villages, farms, water and woodland and infrastructure– to act as a general location plan.	OS polyline data layers showing canals, railways and roads (A/B/minor/motorway/primary routes and single carriageways)	Available as 1:250,000 scale polyline data. Complete coverage for England and Wales	Updated annually	EA	Available from EA as part of EA corporate license with OS, provided the correct acknowledgement together with the Consortium Member's references is shown on all graphic copies and screen images where possible, irrespective of use.	Separate data images exist for urban areas, farms, water and woodland and as separate layers for roads, canals and railways. All layers are needed

EA Meta data details:

Data Input	Dataset Name (EA)	Scale	Short Description (EA)	File Name	Coverage	Data Type	Quality	Meta No
Infrastructure	Railway - Network at 250,000	1:250,000	Rail Network of Great Britain at 250,000	railway_250k.shp	National	Polyline		131
	Roads - B Class at 250,000	1:250,000	'B' class roads in Great Britain. Extracted from OS Strategy data	roads_B_250k.shp	National	Polyline		221
	Roads - Minor at 250,000	1:250,000	Minor roads in Great Britain. Extracted from OS Strategy data	roads_minor_250k.shp	National	Polyline		223
	Roads - Motorways at 250,000	1:250,000	Motorways in Great Britain. Extracted from OS Strategy data	roads_mway_250k.shp	National	Polyline		224
	Roads - A Class at 250,000	1:250,000	'A' Class Roads in Great Britain. Extracted from OS Strategy data	roads_A_250k.shp	National	Polyline		225
	Roads - Primary at 250,000	1:250,000	Primary Roads in Great Britain. Extracted from OS Strategy data	roads_primary_250k.shp	National	Polyline		231
	Roads - Single Carriageways at 250,000	1:250,000	Primary Routes with Single Carriageways. Extracted from OS Strategy data	roads_single_250k.shp	National	Polyline		236

4. Indicative Floodplain

Category	Data Required	Description	Format	Currency	Source[1]	Licensing and Cost	Comments
FLOOD RISK	Fluvial and coastal flood outlines for a range of return periods for initial identification of areas at risk.	Indicative Flood Plain Maps at the 1:100 year (fluvial) and 1:200 (coastal) year return period. Maps based on best available information at time of annual update. Sources of information from which maps derived include Section 105 maps, historical event information and the Flood Risk Map for England and Wales, IoH Report No. 130.	Polygons at 1:10,000	Updated annually, most recent version is year 2000.	EA	Produced by EA and freely available on EA website – no restrictions on use	Indicative floodplain maps provide an overview of land potentially at risk from flooding form the land or the sea. Whilst sources of information are given on a general basis, no indication is given on an individual basis. Thus some outlines may be very crude and based on historical events whilst others may be based on detailed modelling and Section 105 maps. Where possible, Section 105 maps should be sought with the relevant region.

EA Meta data details:

Data Input	Dataset Name (EA)	Scale	Short Description (EA)	File Name	Coverage	Data Type	Quality	Meta No
Floodplain	Indicative Tidal Flood Maps (Year: 2000)	1:10,000	This is a coverage of the indicative floodplains around the country. This is the fluvial dataset and it was digitised for the Agency by Jeremy Benn Associates.	indicative_tidal_flood_10k.shp	National	Polygon		411
	Indicative fluvial Flood Plains (Year: 2000)	1:10,000	This is a coverage of the indicative floodplains around the country. This is the fluvial dataset and it was digitised for the Agency by Jeremy Benn Associates.	indicative_fluvial_flood_10k.shp	National	Polygon		412

Locally in the regions flood plain data is available for other return periods than 1:100. These are mostly results of S105 modelling. These floodplain indications are available from the regional offices, but only for small areas in the regions, there is definitely no national coverage and return periods calculated vary by region. Results of the S105 modelling is incorporated in the indicative floodplain for the national dataset, as well as historic flooding events and other relevant data.

Other available data

National

1. Geology drift and solid
2. Groundwater vulnerability zones (aquifers)
3. River Habitat Surveys
4. Rainfall average data 1940-1970
5. OS Raster Backdrop 1:50000

Regional

6. Location of flood defenses (incomplete)
7. LIDAR
8. Agricultural Land Classification Maps (out of date)

Geology

Category	Data Required	Description	Format	Currency	Source[1]	Licensing and Cost	Comments
Geology	Geology maps	Baseline geological information, including solid, drift, superficial, made ground, sub surface features and geohazards and boundaries of all bedrock units and Quaternary deposits.	Tiles available at 1:50,000 (10k scale also available for 1% of England and Wales)	Updated 2000 – 2001 360 digital tiles (1 50000, 20-28km^2) cover England and Wales 171 exist 105 in preparation	BGS	British Geological Survey All 171 tiles (Bulk buy) 1st year - £33151.50 + VAT Thereafter - £8072.35 + VAT License for 1 tile (1 50000, 20 – 28km2). 1st year - £265+VAT Thereafter £65 + VAT	Useful to support information contained within groundwater vulnerability maps due to higher resolution, though dataset incomplete.

EA Meta data details:

Category	Dataset Name (EA)	Scale	Short Description (EA)	File Name	Coverage	Data Type	Quality	Meta No
Geology	Geology Drift	1:625,000	Drift geology - BGS	geoldrift_625k shp	National	Polygon		159
	Geology Solid	1:625,000	Solid geology - BGS	geolsolid_625k.shp	National	Polygon		160

Groundwater vulnerability zones (aquifers)

Category	Data Required	Description	Format	Currency	Source[1]	Licensing and Cost	Comments
HYDROGEOLOGY	Aquifer maps	Provided as Groundwater vulnerability maps. Resources are divided into vulnerability classes subdivided into major, minor, non-aquifers, soil classification at the surface and the presence, if any of low permeability drift deposits. Boundaries based on published geological and soil survey mapping and are therefore relatively fixed.	Polygon data at 1:100,000 scale Complete coverage for England and Wales	Updated in 1999.	EA	These were created jointly by the EA/ British Geological Survey and Soil Survey, the agency has free use of the data internally.	Information regarding the thickness and type of overlying cover and depth to groundwater will be required in order to refine interpretation of these maps to a catchment specific level.

EA Meta data details:

Category	Dataset Name (EA)	Scale	Short Description (EA)	File Name	Coverage	Data Type	Quality	Meta No
Hydrogeo logy	Designations - Groundwater Vulnerability at 100,000	1:100,000	An assessment of the vulnerability of groundwaters to diffuse sources of pollution Aquifer & soils classifications	gwv_100k shp	National	Polygon	Minor discrepancies between digital & paper based maps Paper are more accurate.	161
	Designations - Groundwater Vulnerability (drift) at 100,000	1:100,000	An assessment of the vulnerability of groundwaters to diffuse sources of pollution Low distribution of low permeability drift deposits - needs to be used with other dataset (Groundwater Vulnerability - gwv)	gwv_drift_100k shp	National	Polygon	Minor discrepancies between digital & paper based maps Paper are more accurate	162

River Habitat Survey

EA Meta data details:

Environment	River Habitat Monitoring Sites	Unknown	River Habitat Monitoring Sites	rhs_un.shp	National	Point		0141

River habitat surveys have been carried out by the EA since 1994 and are continuously updated, generally on a monthly basis. The data set consists of 13000 RHS sites, each covering 500m of main river section. Surveyed data includes slope, height, geology (drift and solid), altitude, fauna/flora, and water quality. Data is available for the project.

Rainfall Average data

Category	Data Required	Description	Format	Currency	Source[1]	Licensing and Cost	Comments
	Rainfall data average annual 1941 – 1970 points	Standard Average Annual Rainfall (SAAR) data from the period 1941 – 1970	Point data on a 1km grid Also available as Isohyets at 1:250000 but of moderate quality	Created July 1997	EA	Supplied to the EA by the Met Office and former Institute of Hydrology.	Met Office point data supplied by IoH believed to be good quality. Isohyets at 1:250000 also available but of moderate quality.

EA Meta data details:

Category	Dataset Name (EA)	Scale	Short Description (EA)	File Name	Coverage	Data Type	Quality	Meta No
	Rainfall - Average Annual 1941-70 (Points)	1km	Standard Average Annual rainfall for the period 1941 - 1970 obtained from IoH	rainfall_annual_1941to70_1km.shp	National	Point	Good (Met Office data as supplied by the Institute of Hydrology)	51

OS Raster Backdrop 1:50000

Category	Data Required	Description	Format	Currency	Source	Licensing and Cost	Comments
BASE DATA	OS general mapping backdrop containing information on urban areas, towns villages, farms, water and woodland and infrastructure– to act as a general location plan.	OS Raster images which mirror the OS LandRanger series. Information contained on urban areas, cities, towns, villages, farms, water and woodland.	1:50,000 image Complete coverage for England and Wales	Updated annually	EA	Available from EA as part of EA corporate license with OS, provided the correct acknowledgement together with the Consortium Member's references is shown on all graphic copies and screen images where possible, irrespective of use.	Separate data images exist for urban areas, farms, water and woodland and as separate layers for roads, canals and railways. All layers are needed

Location of flood defence assets

This data is available form the Regional offices, but is not a complete data set on the existing flood defenses in place. A number of flood defenses were not put in place by the EA and also maintenance is not in hands of the EA. In the Regional offices the data is available as a Access database and as a point data shapefile.

Category	Data Required	Description	Format	Currency	Source	Licensing and Cost	Comments
FLOOD DEFENCE	Flood defense assets	Flood defense assets from Flood Defense Management System (FDMS) database	Point data showing location of defenses	Proposed completion 12-18 months	EA	Use restricted to named project	Survey being undertaken on region by region basis to establish location and condition of existing defenses. User to enquire with relevant region as to what data is available

LIDAR

Category	Data Required	Description	Format	Currency	Source	Licensing and Cost	Comments
BASE DATA	Topography	Digital terrain information.	Grid data available at 100m or 50m resolution Complete coverage for England and Wales	50m grids updated annually	EA	Available from EA as part of EA corporate license with OS, provided the correct acknowledgement together with the Consortium Member's references is shown on all graphic copies and screen images where possible, irrespective of use.	Superfluous if LIDAR data are available for the whole catchment – this is unlikely

LIDAR data is very sparsely available for England and Wales. Availability needs to be checked with the regional offices.

Agricultural Land Classification Maps (out of date)

Category	Data Required	Description	Format	Currency	Source[1]	Licensing and Cost	Comments
	Agricultural land classification maps	Land classified into 5 grades including non-agricultural and suburban areas	Polygon information available at 1 250,000 scale Complete coverage for England and Wales	Not updated since the 1980's	EA	Not currently held but can be supplied to EA by MAFF and NAW Use restricted to named project	Many changes may have occurred to farmland since the 1980's with increasing pressure for development Useful background representation of agricultural areas within the catchment

Instead of this data set it is proposed to use the National Assets at risk database which will be updated shortly and give detailed information on the agricultural land values.

Appendix E

Outcome of meetings on 25th and 29th June 2001

Appendix E Outcome of meetings on 25th and 29th June 2001

This Appendix contains a summary of some of the issues raised at the meetings of 25 and 29 June 2001. The comments are loosely divided into the following sections:

- CFMPs
- MDSF issues
- MDSF process
- Pilot studies
- Links with other initiatives
- Future developments of the MDSF

The comments represent views of the participants at the meetings and do not necessarily reflect the views of the MDSF Client and development team.

E.1 CFMPs

Scope

- CFMPs set policy for flood management.
- CFMPs are primarily concerned with flooding.
- Engineering options are an important part of flood management "policy". An example of an engineering option is to create broader flood plains by moving flood banks.
- All important issues relevant to catchment flood management which consultees are aware of should be taken into account:
  - Key local issues should be represented including non-riverine flooding.
  - Note that modelling will not pick up fine detail.
  - Issues should be included in the scoping stage.
- Specific concerns include:
  - The future of farming and impact on land use.
  - The issue of mining subsidence, which can involve large areas with subsidence of up to 3 to 4m.

Links with other initiatives

- CFMPs are high level plans which must feed into strategies and schemes.
- The link between CFMPs and Section 105 Surveys should be made clear (S105 Surveys are detailed studies to establish flood risk areas).
- **Links must be disseminated to the whole Flood Defence community** with an explanation of:
  - Purpose of each component (CFMPs, S105, etc).
  - How the components fit together.
  - How each component should be used.
- Link with Environmental Assessment?

Approach

- There will be a variable amount of work for each catchment.
- What is the optimum size for CFMPs?
- Is there a need for consistency between CFMPs?
- Is there a need to make national comparisons between CFMPs (eg for prioritisation of funding)? This is an Agency/DEFRA issue.
- Flood management policies will have implications for local authorities (eg impact of strategic flood storage). Need to involve all relevant local authorities.
- CFMPs should feed information into planning system.
- The decision trail should be recorded and clear.

The future

- Need to develop criteria for choosing next group of CFMPs and prioritise.
- Need to plan overall programme.
- The Agency should assess outcome of pilots and lessons learnt.
- Issue of overlap between the new programme of CFMPs and lessons learnt from pilots.
- Optimise the utilisation of consultants by letting them know what is coming and helping them to plan.

E.2 MDSF issues

Scope

- The MDSF must link to the CFMP Guidelines.
- Need to state **what the system will and will not do.**
- Need to manage the expectation of what will be achieved.
- The MDSF must work well.
- The MDSF is a decision support system.
- Need to ensure that the MDSF is what Agency and consultants want, and ongoing dialogue is needed.
- The system should have an "Intelligent front end" – invites people to use it.
- The MDSF provides guidance on models but is not compulsory.
- The application of the MDSF will depend on how much time is available for each task. A suggestion is given below.

Item	Man-weeks of available effort
Scoping	6
Hydrology	6
Hydraulics and mapping	8
Social/economics	4
Options	12
Consultation/dissemination	8
Contingency	6
TOTAL	50

- A demonstration of what system looks like would be helpful.
- Edward Evans is to prepare a simple paper for the web site and Agency intranet.

Technical issues

- Everyone must use the same software versions, and this should be Agency led.
- Important issue of scales. Smaller catchments more sensitive to changes (eg land use, development, etc) – issue of how to divide and manage catchments and sub-catchments.
- Type of flooding and predictability. This will affect public expectations and flood management solutions.
- Information on standards of protection is incomplete and inconsistent. A pragmatic approach is needed (based on indicative standards of protection?).
- There are risks associated with the way in which flood storage areas are operated.

The future

- There is an important learning process in the application of the MDSF, to find out what the best tools are and uncertainties in their application. In addition, information on the sensitivities of different catchments will be obtained. All this will inform future stages of CFMP and MDSF development.
- There is a need for adequate resources and skills within the Consultants and Client organisations.
- The Agency will have to use the MDSF in the future to update CFMPs.

E.3 MDSF process

Overall process

- Need for feedback loops:
  - Sensitivity tests for catchments.
  - Possible further division of catchments into sub-catchments if needed.
- Dissemination and non-dissemination of outputs. Some outputs are only required for internal processing and should not be disseminated externally (for example, the flood risk maps will differ from the Section 105 maps).
- One approach to the presentation of flood risk maps might be to present results as comparative in the "public" version.
- Different effects of different floods (eg low T, high T, extreme).
- Importance of 'what if' scenarios for demonstration etc.
- Guidance will be needed on how to interpret uncertainty outputs.
- Training/information seminars are suggested for Agency, Consultants' and other relevant staff.

System and general comments

- The "Front end" will impose discipline on the user.
- Do not prevent use of other models providing the system delivers acceptable results.
- Issue of linking model results and database.
- MDSF team to obtain Andrew Brookes' planning diagram.

Data

- Need for consistent datasets which are easily accessed.
- Must bring in nationally available data sets: they are consistent and readily available.
- There will be inaccuracies in raw data. It is suggested that rating curves are derived at scheme scale using best available sites. Flows from locally derived rating curves should be compared with MDSF hydrological predictions.
- Use will be made of information on flood defences prepared for the NAAR study. These data will be added to the datasets used for CFMPs.
- There is variation in data quality. Estimated uncertainty will inform decision making.
- Concern about taking the SOS as given (flag up in guidance).
- Solutions/scenarios will change the SOS.
- Average household income is a possible social indicator.

Hydrology

- Need to automate some of multiple storm runs in iSIS hydrology.
- Is there a need to calculate flood volumes? This may be useful for storage options at catchment scale.
- Is the 200 year flood large enough? A large flood(s) is needed for the analysis and also for understanding the catchment. For example, PPG25 suggests 1000 years. There is a constraint on extreme flood prediction in the FEH.
- Concern about inter-catchment transfer at high flows.

Models for hydrology/hydraulics

- Issue of integration of existing models (but avoid over complication of the process).
- If you have model do you simplify it or use it directly? An issue for Consultants' judgement.
- Issue of models linking to each other in terms of calibration.
- Washlands: The reliability of resultsdepends on how they are modelled.
- The best use should be made of existing models and data, eg
  - Use S105 models to provide rating curves.
  - Use BSM models to determine sensitivities and then apply results to more detailed models.

Flood management options

- Look at impact on <u>actual</u> floods, not just theoretical floods.
- Impact of uncertainty on ranking of options.
- If uncertainty large, may need to re-visit CFMP (or inform strategy plans).

Flood maps

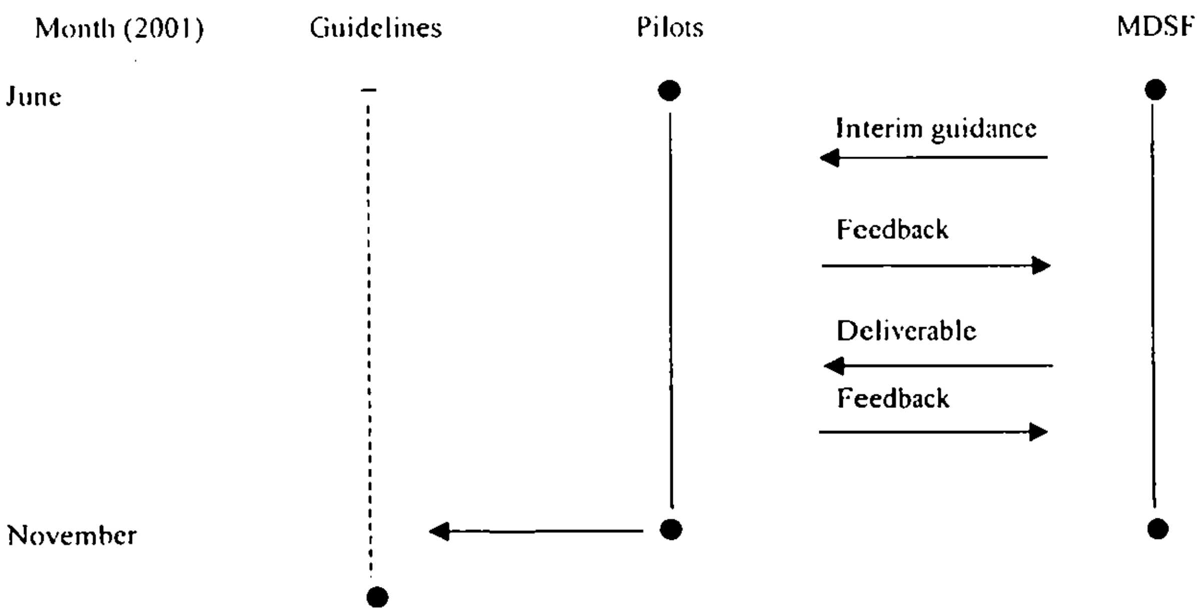
- Credibility issue of straight lines on flood maps (or wide fuzzy line?).
- Issue of how to deal with flood defences and link with the DTM.

Socio economics

- Damage and losses will take account of population, property and infrastructure.
- Issues related to flood defences include standards of service, defence type and condition, and risk of failure.

E.4 Pilot studies

- The Pilot Studies are intended to test methodologies using available information.
- The Pilot Studies are likely to continue after October.
- The Pilot studies should use the interim guidance initially, and the MDSF when it is available.
- There is a need for the Consultants to log problems as they undertake the CFMPs.
- Stakeholders (Agency, Consultants, MDSF team, etc.) should be aware of other stakeholders needs and constraints.
- Feedback in the application of interim guidance and the MDSF should be provided to the MDSF team. This will influence the development of the MDSF.
- Need to ensure systems are fully piloted.
- Where Consultants decide to use other methods it would be helpful if they would explain the reasons why.
- Co-ordination between the CFMP Guidelines, the Pilot Studies and the MDSF is indicated below.



- Need to formalise communication between the MDSF team, the Agency team (Trevor Linford and project managers) and the Consultants' team (Chris Wotherspoon and project managers).

E.5 Links with other initiatives

- Non-riverine flooding could be linked to the Met Office research on severe weather.
- Possible future link with river habitat data.
- Link with (future) NFCDDB, to be investigated by the MDSF team.
- Link with Section 105 and other existing studies. It is noted that S105 studies do not provide full coverage and they are not justified in all catchments.
- Link to PPG25.
- Link with the Concerted Action for data.

E.6 Future developments of the MDSF

- Geomorphology should be considered in the future, including the integration of land use and topography. A data layer on geomorphological issues was suggested to include sediment sources and sinks, links to flood plains, and localised issues.
- It will be important to establish the geomorphological sensitivity of each catchment. Whilst many catchments may not be very sensitive, geomorphology is important in some. Issues include land use, flow frequency, sediment movement and dredging.
- Consideration of the future use of continuous simulation.
- Possible convergence of models in the future?
- Future updating of modules will be needed.
- Keep system open to permit development of "add-ons" by other organisations.

Web site
The web site address is **mdsf.co.uk**

Appendix F

Review of the European Flood Occurrence and Total Risk Assessment System (EUROTAS)

Appendix F Review of the European Flood Occurrence and Total Risk Assessment System (EUROTAS)

F.1 Background

The European River Flood Occurrence and Total Risk Assessment System (EUROTAS) was a three-year research programme funded mainly by the European Union with contributions from the Environment Agency and the Ministry for Agriculture, Fisheries and Food. The overall objective of the EUROTAS project was to provide generic tools for the assessment and management of current and future flood risks. A principle output of the research was a prototype Integrated Catchment Modelling (ICM) system that included a Decision Support System (DSS) for the procedures developed in the course of the research. The various components of EUROTAS are discussed below.

F.2 Integrated Catchment Modelling (ICM) system

The EUROTAS Integrated Catchment Modelling (ICM) system is based on ArcView 3.1, Spatial Analyst 1.1 and Dialog Designer 1.0. The ICM forms the core of the larger Decision Support System (DSS). The ICM is used to 'import', 'manipulate' and 'export' the data in a generic format that can interface with various hydrological and hydraulic modelling software. It is geared to use of hydraulic models e.g. branch data, cross-section data, catchment data, time-series point data, boundary point data and time series data files.

The components of the ICM are very much centred on providing a GIS framework for the generation of hydrological and hydraulic modelling model data. This is not a primary requirement of the Modelling and Decision Support Framework (MDSF). The data formats specified by the ICM system may however be considered as appropriate in specifying 'future development' issues for MDSF.

F.3 Decision Support System (DSS)

The EUROTAS Decision Support System (DSS) is targeted at providing a framework to assist planners and decision-makers in undertaking a catchment study to assess flood risk for various scenarios. It involves the acquisition and management of data and generated results, managing the analysis being carried out and making decisions as to the direction of the study.

The DSS provides a framework as follows:

1. Definition of goals and checklist;
2. Setting up a 'case' – represented by a combination of land-use, climate change and engineering scenarios;
3. Link to external modelling software;
4. Analysis and importing of modelling results from external software packages;
5. Update and subsequent querying of the Catchment Study Knowledge Base.

The MDSF will also allow cases for different combinations of climatic, land use and engineering scenarios to be constructed. It should be noted that the EUROTAS DSS provides additional functionality to the ArcView system without affecting the existing functionality and operation of ArcView itself. This approach will be adopted by the MDSF.

F.4 Data Formats

The EUROTAS system adopts an 'open-system' approach to prevent it being tied to any particular modelling system. However, protocols were defined for communicating between different modelling components. Commonly agreed data formats were agreed by the EUROTAS partners for generic data (e.g. river cross-sections, time-series data). This approach enabled nationally or regionally preferred models to be incorporated in future applications of the system. The MDSF will adopt a similar 'open systems' architecture in order to maintain flexibility regarding the modelling tools and data used in the framework.

F.5 Climate Change

The climate change scenarios in EUROTAS were based on results from a global circulation model based on a 200 km x 200 km grid. The results from the global circulation model were disaggregated and used in the CEH's CLASSIC rainfall-runoff model to generate hydrographs for various climate change scenarios. The climate change scenarios used in the EUROTAS approach to estimating the effect of climate change on design hydrographs cannot be directly applied in the MDSF. This is because the hydrology tools of the MDSF will not use GIS based climate change data. However, the results of CEH and other climate change scenarios modelled by EUROTAS will be used to inform the hydrology methodology adopted by the MDSF.

F.6 Land use changes

EUROTAS offers a model of land use change based on the CORINE land use mapping. The land-use change tools in EUROTAS are primarily focussed on producing data sets for input to hydrological models. The hydrology tools used by the MDSF will not use GIS land-use data at this critical stage. However, such data may be of use in providing the user of the external tools with a greater conceptual understanding of the hydrological catchments. The outputs of the MDSF project will include guidance on approximate prediction of the impact of land use change, built into the hydrological tool.

F.7 River engineering scenario

The river engineering scenario tool provides a GIS based method for implementing measures that are designed to amend hydraulic model cross sections. Such measures may impact upon river delineation, river geometry and the operation of structures. The procedures used in defining river engineering scenarios prescribe required data and identify particular 'categories' and 'types' of measures. (A particular scenario may comprise many different individual measures).

It is notable that the use of the EUROTAS 'River Engineering Scenario Builder' tools requires that certain settings have been pre-defined in a 'eurotas.ini' file. It is understood that there is no user-guided interface for the generation of this initialisation file. It is recognised that the translation process (from generic EUROTAS format to a native flow model format) may cause ambiguity as different flow models deal with cross-sections differently.

The EUROTAS river engineering scenario identifies particular engineering measure 'categories' and 'types' that may inform such consideration of scenarios in the MDSF. However, the focus of the tool is on the generation of hydraulic model data. This is not considered to be appropriate functionality for the initial design specification of the MDSF.

F.8 Flood mapping procedures

The flood mapping procedure in EUROTAS uses the following to delineate flood extent:

- Digital ground model;
- Centre line of the main river channel;
- Cross-sections used in the hydraulic modelling.

Water levels are assumed to be constant along each cross-section. "Known points" are then distributed along the cross-section and the calculated water level is assigned to each of these points. An inverse distance algorithm is applied to fit a water surface profile through the known points.

The ground elevation is subtracted from the water level surface to produce an initial estimate of the flood extent. All grid cells with a depth greater than zero retain their value and all other cells are set to zero. A "friction" map is produced for all cells with a value greater than zero. A cost distance algorithm is used that allows the "cheapest" route to unconnected flooded areas to be established. Where flooded areas cannot be connected to the main channel they can be discarded. However, ownership issues relating to the flooding mapping code needs to be resolved with the owners of the code, Delft Hydraulics, before it can be reviewed for use in the MDSF.

F.9 Lessons learnt from EUROTAS

The following lessons have been learnt from EUROTAS and will be incorporated in the MDSF:

- EUROTAS used an open system approach so that it was not tied to any particular modelling system. However, commonly agreed data formats for communications were specified. This approach will adopted for the MDSF;
- The MDSF will allow the construction of cases for different climatic, land use and engineering scenarios in a similar manner to EUROTAS. These cases will form a database stored by the MDSF;
- The MDSF will be based on Arcview. Similar to the EUROTAS system the MDSF will provide additional functionality to the ArcView without affecting the existing functionality and operation of the software;
- The EUROTAS approach to estimating the effect of land use change on flood risk cannot be used. A method based on current research and applicable to UK conditions will be included in the hydrological tool in the MDSF.
- The focus of the EUROTAS river engineering scenario tool is on the generation of hydraulic model data. This is not considered to be appropriate functionality for the initial design specification of the MDSF, given the pre-existence of a large number of hydraulic models, including coverage of many of the most important reaches by Section 105 models.
- The EUROTAS flood mapping procedure may be transferable to the MDSF. However, this is dependent on its functionality and issues of proprietary.

Appendix G

Soil and land use data

Appendix G Soil and land use data

Soil and land use data for the MSDF Customised Database

G.1 Description and Availability

G.1.1 Soil

Digital spatial soil data is available for the entire land surface of England and Wales via the *NATMAP II Database* at a scale of 1:250,000. The dataset defines the distribution and nature of 297 soil map units, each of which is composed of between two and eight soil types. Polygons and line work are accurately registered to Ordnance Survey topographic mapping at 1:50,000 scale (including specially generated coastal and inland water outlines). Associated datasets define a range of soil chemical, physical and hydraulic characteristics for each soil type in the spatial dataset under each of four broad land use categories: Arable; Short term rotational grassland; Long term grassland; Other semi-natural land uses.

These data are the property of Cranfield University Soil Survey and Land Research Centre (SSLRC) and can be made available to the CFMP demonstrator project through SSLRC's Framework agreement with the Environment Agency -Issue No. 1a, 24-02-00 (SSLRC).

G.1.2 Land Use and cropping

Digital Land Use data is available for the whole of England and Wales via the *Land Cover Map of Great Britain* (1990). This provides a classification of land cover types into 25 classes, at a 25m (or greater) resolution (see table below). The map is based upon data collected by the Landsat Thematic Mapper data, and records 25 cover types, consisting of sea and inland water, beaches and bare ground, developed and arable land, and 18 types of semi-natural vegetation. Most of the map has been produced by combining summer and winter data, which can improve classification accuracy over single-date analyses.

The 25 'target' cover-types on the 25 m resolution dataset have been aggregated into 17 'key' cover-types in the 1 km summary data

A new map, using data collected in 2000, is expected to be available around the end of October 2001.

Key for the 25 m resolution map

1c	Sea / Estuary	14	Scrub / Orchard
2	Inland Water	15	Deciduous Woodland
3	Beach and Coastal Bare	16	Coniferous Woodland
4	Saltmarsh	17	Upland Bog
5	Grass Heath	18	Tilled Land
6	Mown / Grazed Turf	19	Ruderal Weed
7	Meadow / Verge / Semi-natural	20	Suburban / Rural Development
8	Rough / Marsh Grass	21	Continuous Urban
9	Moorland Grass	22	Inland Bare Ground
10	Open Shrub Moor	23	Felled Forest
11	Dense Shrub Moor	24	Lowland Bog
12	Bracken	25	Open Shrub Heath
13	Dense Shrub Heath		

These data are the property of The Centre for Ecology and Hydrology (CEH) who are associated contractors of the CFMP demonstrator project.

A digital cropping dataset for England and Wales is available through the *ADAS National Land Cover and Land Use Database*. This dataset has been develop at a resolution of 1 km x 1 km grids by combining the CEH Land Cover dataset with data from the MAFF Parish Agricultural census for 1997, resolved to 2 km x 2 km grids. The database defines the proportion of individual agricultural crops and other land use categories within each grid cell. It was created by ADAS on behalf of the Ministry of Agriculture Fisheries and Food (MAFF) and could be made available for the CFMP demonstrator project through negotiation with MAFF (now included within the Department of Environment, Food and Rural Affairs, DEFRA) and ADAS.

G.2 Benefits and uses

Of the three spatial datasets described above, only the CEH Land Cover dataset will be used within the current MDSF. This dataset will be used to support the development of Climate and Land-use Scenarios. However, future developments of the system are likely to include continuous flow simulation and the Environment Agency has a stated objective that such simulation should include models that can incorporate appropriate soil wetness scenarios. The identification of such soil wetness scenarios will require data on the spatial distribution of soil and land use characteristics. In anticipation of this, it is of benefit to include the necessary soil and cropping datasets at this stage of MDSF development.

Once the spatial soil and cropping datasets are incorporated into the MDSF for catchment Flood Management planning, they could have an immediate and simple application within the MDSF. As stated in the interim guidelines for CFMP's (Halcrow, Feb. 2001), key components of the methodology are: Step 4 'Understand catchment processes'; Step 6 'Identify future change in catchment processes'; step 8 'identify opportunities and constraints'; step 9 'appraise policies for each scenario. By incorporating spatial soil and cropping/land use datasets within the MDSF an immediate means of providing additional information to support the decision making process for these four steps becomes available. Simple interpretation of the soil HOST-related hydrological indices such as SPR (Boorman *et al*, 1995), possibly combined with the cropping/land use datasets to identify land with autumn-sown, spring-sown or late-harvested crops, would enable flood generation 'hot-spot' areas within the catchment to be identified. Such areas could provide 'soft' options for managing flood risk.

Reference

BOORMAN, D.B., HOLLIS, J.M. & LILLY, A. (1995). *Hydrology of Soil Types: A hydrologically-based classification of the soils or the United Kingdom.* Institute of Hydrology Report No. 126, Wallingford, UK. 137 pp.

Appendix H

Quality Assurance

Appendix H Quality Assurance

Proposed Quality Management System

H.1 Introduction

It is proposed to adopt the Quality Management System used by Halcrow. This is because Halcrow are taking the lead role in the development of the software, and the Company has been registered by third party assessors as achieving BS EN ISO 9000 series standards.

The Company has gradually developed and used a series of operating manuals over many years. These were expanded and formalised into an integrated series of operating manuals. The resulting system was first issued in January 1988.

The Business Units of Halcrow involved with this project currently has Certificate BSI /FS 20242 in force.

H.2 Quality Management System

General
The Management System establishes and maintains an economic and effective framework for the management of processes to ensure that the services provided meet the requirements of clients at all times.

The Management System takes account of the fact that each commission is unique and demands an individually planned approach to the management of the activities.

Quality Policy
The Quality Policy is expressed in the documented policy statement signed by the Company Chairman. This defines the objectives for, and commitment to the policy.

Quality Management Structure
The Company Resources Director who reports directly to the Chief Executive of the Halcrow Group heads the management structure. The Quality Manager, Business Unit quality directors and departmental quality managers support him.

Management System Documentation

- **Management System Manual**

This document provides a detailed statement of intent and contains the quality policy, the system objectives, a description of the organisation and responsibilities and the extent of application.

- **Core Procedures**

This manual contains the synopses and objectives of the procedures, the summarised responsibilities attached to posts and a list of definitions. The procedures are individually controlled documents containing the operational policies and directions relating to the management, execution and checking of the provision of services.

- **Other Manuals**

In addition to the Management System Manual, a number of other manuals give guidance and information on normal Company policies, practices and methods:

The Guidance Manual gives guidance on the core procedures.

The Safety Management System Manual contains measures to implement the Company's policy on Health and Safety and promote compliance with the Health and Safety at Work Act and other relevant statutory provisions.

- **Project Plan**

A Project Plan identifies all necessary information such as project programme, procedures, contract documents, project staff, organisation structure, external organisation, key personnel and lines of communication. The Project Plan is a working document and is regularly inspected, reviewed and updated.

- **Auditing**

The Management System is monitored and assessed through compliance audits and, if so required, by the client. These quality audits determine whether systems and activities comply with planned arrangements and with BS EN ISO 9001.

- **Feedback, Corrective and Preventive Action**

Continuous improvement forms an integral part of the system, and measures are followed to formally action positive or negative feedback on the implementation and effectiveness of the system.

- **Review**

The Management System is periodically and systematically reviewed to ensure continuing effectiveness.

System Awareness
In-house lectures on different aspects of the Management System are held for all staff.

Induction training ensures all new staff are made aware of, and become familiar with the Management System.