Joint Defra/EA Flood and Coastal Erosion Risk Management R&D Programme

Review of impacts of rural land use and management on flood generation

Research Plan

R&D Project Record FD2114/PR1

Environment Agency

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Department for Environment Food and Rural Affairs

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Management R&D Programme

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Executive summary

This report should be read in conjunction with ‘FD2114/TR: Impact Study Report’, in which the FD2114 project is introduced and there is a comprehensive review of the impacts of rural land use and management on flood generation. Project FD2114 is part of the Broad Scale Hydrology Modelling Programme (Calver and Wheater, 2001).

This, FD2114/PR1 for the FD2114 project, is a research plan which maps a way forward in defining and implementing best practice in flood prevention and mitigation associated with rural land use change and management practices and for operational assessment of the likely effects of prevention and mitigation measures. The research is designed to meet the needs of those involved in policy development and catchment management and also to create a sound platform for future research and development. In developing the research plan, the users' needs were assumed to be related to the following (not in order of priority):

1. Learn what can be learned about the flood impacts of changes in rural land use and management that have taken place in the past;
2. Identify catchments vulnerable to flooding as a result of changes in rural land use and management;
3. Document best practice in selecting prevention and mitigation measures to meet specific needs and in promoting these measures to land managers;
4. Develop decision-support tools for estimating the likely outcomes of implementing prevention and mitigation measures and the outcomes when policies and promotions are used to encourage the uptake of measures;
5. Build a solid research base to support the above needs now and in the future.

In satisfying these needs, consideration is given to the wider context of the work, including the Water Framework Directive, and to sustainability and cost/benefit analysis.

The research plan comprises 16 projects, in two programmes: a medium term near-user programme (11 projects) running over a period of five years, and a longer term programme (5 projects) running over a period of ten years. The bulk of the funding (70%) is allocated to data collection, assembly and various forms of analysis, and the remainder (30%) to developing and testing the necessary models.

Contents

1. Introduction

This, the FD2114/PR1 for the FD2114 project, is a research plan which maps a way forward in defining and implementing best practice in flood prevention and mitigation associated with rural land use change and management practices and for operational assessment of the likely effects of prevention and mitigation measures. This report should be read in conjunction with the report 'FD2114/TR: Impact Study Report', in which the FD2114 project is introduced and there is a comprehensive review of the impacts of rural land use and management on flood generation.

1.1 Project FD2114

Project FD2114 is part of the Broad Scale Hydrology Modelling Programme (Calver and Wheater, 2001). The programme of work for the project is divided into 2 parts, each with an overall objective:

Part 1 Objective: To review the factors contributing to runoff and flooding in the rural (managed, not natural) environment, and to scope out the research needed to improve the identification of the management policies and interventions to reduce the impact of flooding.

Part 2 Objective: To deliver in the short term an improvement in the estimation of the effects of changes in rural land management on flood generation to the CFMP (Catchment Flood Management Plans) programme.

The scope of the work required to address the Part 1 Objective is defined by the set of Tasks prescribed in Table 1.1. The reporting follows the logical progression of these Tasks, and is divided into two reports:

FD2114/TR constitutes the Impact Study Report (Tasks 1-7).

FD2114/PR1 constitutes the Research Plan (Tasks 8-12).

The Part 2 Objective is addressed in **FD2114/PR2** and **FD2114/PR3,** dealing with the development and implementation of a Short-term Method for predicting the impacts of land use and management on flooding within CFMPs.

This document, FD2114/PR1, is structured in relation to the Tasks as follows:

- The Task 8 Research Plan is addressed by FD2114/PR1as a whole;
- Tasks 9, the recommended research projects on the Defra/EA Shortform template, are provided in Appendix A, with supporting arguments provided in the main body of the document. This has been performed in accordance with Task 10, which requires the presentation of the projects within a logical framework of user needs, serving users concerned with both long-term catchment planning and land management;

- Task 11, which requires funding limitations to be addressed by prioritising the recommended projects, is dealt with in Section 5;
- Task 12, the requirement that all research projects carried forward are truly necessary, responsive to user needs and provide good value for public money, is dealt with in Sections 1.3, 2 and 5.

Given the large scope of the project, a multidisciplinary consortium has been assembled, covering agriculture, soil science, hydrology, hydrogeology and socio-economic science. The membership and expertise of the consortium members is summarized in Table 1-2.

Organization	Expertise
University of Newcastle upon Tyne (Coordinator)	Catchment experimentation and modelling, flood risk estimation
ADAS	Hydrology, Agri-environment
British Geological Survey (BGS)	Floodplain delineation; groundwater flooding
Centre for Ecology and Hydrology (CEH)	Hydrology and modelling
Institute of Grassland and Environmental Research (IGER)	Crop husbandry and soil erosion
Cranfield University: National Soil Resources Institute Institute of Water and Environment (NSRI)	Soil hydrology, soil spatial variability and pollutant transport. Resource economics and management
Lancaster University	Hydrology, modelling, and uncertainty

Table 1.2 Consortium members and expertise

Task 1	Carry out a comprehensive literature review of field, analytical and model sources across soils, agriculture and flood hydrology disciplines via a multidisciplinary team, bringing together all the main strands of research and practice in this field.
Task 2	Carry out a comprehensive review of on-going initiatives not yet encapsulated in the literature.
Task 3	Develop an understanding of the current state of managed rural land in England and Wales from the viewpoint of flood risk. List the potential land management measures and other interventions that might be adopted to mitigate this. Impacts on water resources should be assessed and any clashes noted. Include an appreciation of the uncertainties involved in such forecasts.
Task 4	Carry out a review of likely future change scenarios. Comment on how desirable changes from the point of view of using land management measures for flood management might be achieved in social, financial and institutional terms, and the practicability of these. This should include consideration of Environmental Futures. Foresight, Office of Science and Technology (DTI, 1999). These futures were used in developing the EA's new strategy for water resources: Water Resources for the Future: A Strategy for England and Wales (Environment Agency, 2001b).
Task 5	Identify key UK data sources on impacts.
Task 6	Carry out a critical assessment of the overall picture provided by assembled sources, encompassing both scientific and rural socio-economic issues.
Task 7	Draft a report covering individual impact study information in succinct form, the conclusions drawn from this, and the rationale of the derivation of the conclusions.
Task 8	Draft a Research Plan for the recommended research programme for the impacts of rural land use on flooding. Hydrological research may be both within FEH and in continuous simulation runoff modelling. This should, like the BSM hydrology scoping study, propose a medium term near-user programme that could be funded by Defra/EA and a longer term programme perhaps encompassing longer field work projects which could be discussed with NERC and other Research Councils. This should include recommendations as to how ongoing programmes such as LOCAR and CHASM could be used to forward this research area.
Task 9	Produce clear descriptions of all recommended research projects on the Defra/EA Shortform template, suitable as the specification for tender documents and include in the draft Research Plan. These should include the objectives, key customer purpose and descriptions of all research projects.
Task 10	Present the projects within a logical framework of user needs, serving users concerned with both long term catchment planning and land management.
Task 11	Address funding limitations by prioritising the projects recommended.
Task 12	Ensure that all research projects carried forward are truly necessary, responsive to user needs and provide good value for public money.
Task 13	Circulate the draft Impact Study report and Research Plan and consult with users and experts. This could include setting up a project website.
Task 14	Finalise, print and disseminate the Impact Study report and Research Plan. This should include a small coloured flysheet to publicise the research programme.
Task 15	Carry out all measures to ensure uptake of the research is in accordance with the Defra / EA requirements following its research on Improving the Implementation and Adoption of Flood and Coastal Defence R&D Results (Defra/EA, 2002).

Table 1.1 Tasks defining scope of review and research plan

1.2 Summary of impact study report findings

In FD2114/TR, the current state of knowledge on the impacts of rural land use and management on flood generation was assessed, and the following conclusions drawn:

Conclusion 1 Significant changes in land use and management practices in the last fifty years have resulted in the intensification of agricultural land use. These changes have been driven to a significant degree by EC and UK agricultural policy. There is much evidence to confirm that patterns of land use and farming practices are a direct response to the incentives provided by agricultural policy, modified by local and farm factors.

Conclusion 2 There is substantial evidence that changes in land use and management practices affect surface runoff generation at the local scale, but the effects are complex. Field drains, for example, may either increase or decrease the surface runoff from an event, and cultivation techniques can serve to reduce surface runoff where plough lines follow contours, or increase it where wheel tramlines run downslope.

Conclusion 3 There is only very limited evidence that local changes in runoff are transferred to the surface water network and propagate downstream. This may be because there have been very few studies in which evidence has been sought, or because such studies (of, for example, afforestation or land drainage) have produced inconsistent or uncertain conclusions. However, in comparison with natural climatic variability, it would appear that land use management effects are of second order importance.

Conclusion 4 Analyses of peak runoff records has so far produced very little firm evidence of catchment scale impacts of land use management. However, such analyses have not focussed on areas where changes in land cover or management practices are likely to have been greatest (other than in forested headwater catchments) and have not considered the possible effects on the storm-to-storm variability or seasonality of flooding events.

Conclusion 5 There are many measures that can be taken to mitigate local flooding by delaying runoff, such as using grass buffers, temporary ponds, and appropriate ditching. An integrated approach is needed in applying these measures so that the maximum overall benefit is gained for flood and pollution mitigation and erosion reduction.

Conclusion 6 There is considerable uncertainty about how effectively land managers will respond to any promotions or policies related to particular flood prevention or mitigation measures. There is evidence, however, to suggest that the effectiveness can be increased if compliance with specified flood prevention and mitigation measures is used as a condition of support to farm incomes.

Conclusion 7 Rainfall-runoff modelling to predict the effects of changes in rural land use and management on flood generation is in its infancy: there is no generally-accepted theoretical basis for the design of a suitable model, it is not known which data have the most value, and there are limitations in the methods available for estimating the uncertainty in predictions. The modelling should be distributed and be capable of running continuous simulations. It should also be partly or wholly physically based so that the properties of local landscapes, soils and vegetation can be represented, and it should include detailed modelling of surface water flow so that the effects of changes can be tracked downstream. A considerable amount of high-quality field data on runoff generation, the local effects of change, and the way that changes propagate downstream will be needed to support the development of robust modelling and the use of this modelling in predicting flood impacts.

Conclusion 8 The uncertainty in the response of land managers noted in Conclusion 6 needs to be accounted for when modelling the overall outcomes when flood prevention and mitigation practices are promoted.

1.3 Users' needs

The proposed research is designed to meet the needs of those involved in policy development and catchment management. FD2114/TR showed there has not been a concentrated research effort into the nature and scale of the effects of rural land use change and management practices on local and downstream flooding. That report therefore does not provide answers to some fundamental questions, and had to rely in places on piecemeal evidence drawn from studies where the focus was on other problems and not on flood generation or flooding. The users need to know, for example, if there are effects only on local scale flooding, or if there are also effects on downstream larger-scale flooding. They also need to know if the effects are likely to be serious, and if they are more closely associated with certain (small or large) regions of the country, or with certain catchments or types of landscape. FD2114/TR is not complete or adequate as a research basis for answering these fundamental questions, so it is recommended that a solid research base is built, involving concentrated research effort.

From the perspective of the Environment Agency, for example, rural land use management has a role and value within their flood risk management strategy (Burch, T., Environment Agency, Personal Communication). The objectives in applying the strategy are to alleviate (mitigate) existing flood risks and avoid (prevent) increasing flood risk. These risks, as defined in the Part A Report, take into account the economic and ecological consequences of any flooding, as well as the flood probability as defined by a flood frequency curve. The Agency must therefore be able to quantify the effects of changes in rural land use and management, so that appropriate decisions are made about which changes to encourage and discourage for specific locations. These decisions must be taken in context, allowing for relevant economic, ecological, social, and engineering issues, as well as issues related to the management of diffuse pollution and soil erosion. Part of this context relates to the scale of the flooding that is to be avoided or alleviated, because the impact of given changes will be scale dependent and some of the conventional flood control measures, e.g.

engineered barriers, are more appropriate at some scales than others. The Agency has commissioned a National Flood Risk Assessment (NaFRA) which will give information on the distribution of floods and the relationships between catchment size and the magnitude of the existing flood risk.

In developing the research plan, the particular needs of the users were assumed to be related to the following (not in order of priority):

1. Learn what can be learned about the flood impacts of changes in rural land use and management that have taken place in the past;
2. Identify catchments vulnerable to flooding as a result of changes in rural land use and management;
3. Document best practice in selecting prevention and mitigation measures to meet specific needs and in promoting these measures to land managers;
4. Develop decision-support tools for estimating the likely outcomes of implementing prevention and mitigation measures and the outcomes when policies and promotions are used to encourage the uptake of measures;
5. Build a solid research base to support the above needs now and in the future.

The following five recommendations correspond to these five needs, and take into account the conclusions drawn in FD2114/TR.

Recommendation 1 There is a need to learn what can be learned about the flood impacts of changes in rural land use and management that have taken place in the past. In particular, there is a need to apply modern modelling and statistical techniques to examine existing rainfall-runoff records and isolate and quantify flood impacts. Also, there is a need for multiscale monitoring in catchments to build up the knowledge base related to how catchments function and in particular how the effects of changes in land use and management propagate downstream.

Recommendation 2 For general use in research and in impact assessment and policy making, there is a need for an electronic map identifying the catchments that are vulnerable to local and downstream flooding as a result of changes in rural land use and management.

Recommendation 3 There is need for field trials of flood mitigation measures, to build up the knowledge base. There is also a need for best practice to be established, both for selecting which flood prevention and mitigation measures should be used to meet local needs and how these measures should be promoted.

Recommendation 4 A coherent approach is needed in modelling the flood impacts of changes in land use and management. Ideally, this would represent socio-economic, agricultural and hydrological effects and responses. It would be in the form of a decision-support tool for estimating the likely outcome of implementing flood prevention and mitigation measures and the outcomes when policies and promotions are used to encourage the uptake of measures. The tool would take account of uncertainty, could be used to examine future scenarios for climate, land use and management, and would give a basis for rigorously testing rainfall-runoff modelling so that issues related to the theoretical basis of modelling and the value of data can be addressed.

Recommendation 5 A solid research base must be established and maintained if real progress is to be made in assessing the flood impacts of changes in rural land use and management and in establishing best practice for flood prevention and mitigation. It is essential therefore, that the research work in the research plan should be designed to leave a high-quality, useful and comprehensive legacy in the form of project reports, specification documents, datasets, open-source software, user manuals, and guidance

There is considerable complexity surrounding the problem of managing the effects of rural land use change and management practices on local and downstream flooding, and the users' needs, including the Environment Agency's needs for their flood risk management strategy, must be considered in this context:

a) Consideration must be given to the wider context of the work, including the water quality and water resources aspects of the Water Framework Directive. For example, the way that the effects of policies and promotions for flood prevention or mitigation are assessed needs to be compatible with the way that assessments are made for any accompanying beneficial or detrimental environmental impacts through their effect, for example, on diffuse pollution and aquifer recharge. The Water Framework Directive is likely to increase the need for river restoration as part of the ‘programme of measures’ which Member States are required to develop to achieve the targets of ‘good ecological status’ or ‘good ecological potential’ for their ‘water bodies’ which are at risk due to physical modifications carried out in the past (e.g. ecological damage from mid 20th century arterial agricultural land-drainage and flood alleviation schemes);
b) Consideration must be given to sustainability and cost/benefit analysis, so any policy or promotion for flood prevention or mitigation can be compared against alternatives such as installing flood defence barriers. An assessment of sustainability might, for example, have to take into account whether and to what extent land managers will perform regular high-quality work over several decades to maintain a multitude of temporary storage ponds designed to delay fast surface runoff. To give another example, what will be the long-term outcome of any policy or promotion if there is a continuing move to monoculture or continuing climate change?

The scope for FD2114/TR: Impact Study Report was restricted to meet the objectives and tasks specified for the FD2114 project, so the context within which the needs of the users' is considered here extends beyond that considered in the Impact Study Report. For example, river modification and flood plain management are covered only briefly in the Impact Study Report (in Appendix F). Also, there is no detail on how water runoff is the deriving force for pollution and sediment transport, or on the substantial common ground that exists between the needs and mechanisms for flood management and those for the management of pollution and erosion. Although not included in any of the formal recommendations, or in any of the projects in the research plan, there is a clear need to extend the review in the Impact Study Report to cover all the areas relevant to the users' needs in a coherent and consistent fashion. This wider review would strengthen the research planning.

2. Approach

The research plan must take a wide view of how decisions about flood prevention and mitigation measures will be made in the future, including how an integrated whole-catchment approach to decision making will evolve. Because flood prevention and mitigation involve the management of both land and water they will increasingly be considered alongside other functions such as water resources planning, pollution prevention, bio-diversity, and so forth, and the effects of rural land use and management on flooding will be considered in a general context alongside river engineering, flood plain management, habitat creation, and other aspects of flood management. The research plan cannot therefore be based solely on the knowledge review presented in FD2114/TR, as the prescribed scope of that report was strictly and narrowly limited to a review of impacts of rural land use and management on flood generation.

So that the work is of the most direct practical use, the research plan is based around the development of easy-to-use computer-based tools. These are to be supported by field research and detailed modelling and uncertainty analyses. The tools are designed for use in policy making (e.g. national vulnerability maps) and in operational technical use and decision-making. The philosophy behind this approach is that the best way to guarantee that the outcome of the research will be practically useful within a whole-catchment multi-function decision support system is to ensure that the research products are closely defined, clearly specified, appropriately simple, and clearly documented computer-based tools.

It is tempting to be ambitious and to begin working directly towards an integrated system in which, for example, the water flow modelling used in predicting the flood impact of land use and management change is also used when simulating the transport of pollutants and sediment, and there are integrated national maps for vulnerability to flooding and pollution by nutrients. This, however, would be a mistake. Developing tools which can really aid decision-making, is undoubtedly a very difficult task, and it would be all too easy to be too ambitious and to get weighed down with difficult software and technology problems. The research plan therefore concentrates on the development of tools for flood impact assessment and mitigation only. But, as described above, the work will be carried out in a way that makes it as widely useful as possible.

A considerable amount of preliminary work will be needed to make sure that the tools are appropriate and are developed in an efficient manner. For example, for a coherent and consistent approach, the vulnerability maps must link to the tools for predicting water flows and must also link to the tools for predicting framer's responses to policies and promotions. The research plan has therefore been developed as a team effort by the consortium of experts from the organizations in Table 1.2 (with support and feedback from the Steering Group), so that there is an integrated overall design for the research plan and for the computer-based tools and supporting research.

As noted earlier, FD2114/TR should be read in conjunction with this report. It introduces the work and contains extensive lists of definitions and references. The number of new definitions and references introduced here has been kept to an absolute minimum. Sixteen research projects are proposed. The supporting arguments for these projects refer to FD2114/TR and its conclusions, but do not reproduce reference lists or detailed arguments from FD2114/TR. For many of the proposed projects, especially those involving rainfall-runoff modelling, there is considerable scope for using any of a wide range of different techniques and approaches. Care has therefore been taken not to prescribe the project work too narrowly, to give scope for the skills and experience of individual research scientists and groups.

2.1 Deliverables

For each of the 16 projects, the deliverables are listed in the short forms in Appendix A. These comprise project reports, specification documents, datasets, software, user manuals and guidance notes, and are designed so that the projects leave the most suitable and comprehensive legacy. The commissioning of the development of software as part of the project work needs careful consideration. Wherever possible the software should be fully documented and open-source.

Consideration also needs to be given to the general move towards open-architecture (i.e. plug-and-play) systems for catchment and regional modelling, in which a wide range of types and levels of sophistication of model components can simply be plugged in and run, automatically making use of common data sets created for the modelled catchments and common graphical tools for visual presentation of the input data and results. Open-architecture systems have several obvious advantages, especially when developed to use harmonised interfaces, such as the harmonIT framework (www.harmonIT.org; due for proof-of-concept testing in 2005) being developed in the EU CatchMod cluster of projects.

There is a need, however, for a note of caution. It is often thought that when using a modular open-architecture approach that legacy code can readily be adapted for use in modules and integrated models can be developed by non-experts simply by selecting and plugging in several modules. The reality may well be quite different. In a review of modular and modern approaches to environmental modelling, Argent (2004) noted that there has been *"a rash of poorly designed modelling tools that have been produced and rarely used"*.

One of the central purposes of the modelling in the projects in this research plan is to represent the complexity of the link between land use and management practices and local and downstream flooding, including effects associated with the spatial and temporal variability of the catchment's runoff response. In general terms, the main difficulty in modelling complexity and variability using a modular open-architecture approach lies in controlling the feedback between modules. This might not be a serious problem in simple, conceptual, modelling, but simple modelling will not be adequate to represent the necessary complexity and variability.

Experience in developing and using physically-based distributed modelling has shown that complex feedback pathways develop within detailed simulations, which control and link different self-organising zones in the catchment. These pathways and zones characterise the complexity of the physical response of the catchment. Two conclusions can be drawn based on experience gained using generic interfaces designed to allow direct, distributed, timestep-level coupling between the physically-based distributed model SHETRAN and other models (Ewen, 2002):

(1) Developing modules is an extremely difficult task, requiring complicated routines to be written for robustly handling the wide range of module-to-module interactions that may arise;
(2) It is unlikely that the process of building a model suitable for simulating the complexity and variability of runoff is going to prove, in the near future, to be as simple as picking the correct modules and plugging them in. Significant advances are needed in the modelling methods used within modules and a significant investment is needed in module design, construction and testing.

It should be noted that these conclusions hold no matter how good and comprehensive the harmonIT and other open-architecture interfaces prove to be in practice.

2.2 Programme Delivery

The specified requirements in Task 8 (Table 1-1) are for "*a medium term near-user programme which could be funded by Defra/EA and a longer-term programme perhaps encompassing longer fieldwork projects which could be discussed with NERC and other Research Councils*". The medium-term near-user programme is described in Section 3 and the longer-term programme in Section 4. Projects M1-M11 in Appendix A are the medium term projects, and Projects L1 to L5 are the longer term projects.

There are three main relevant funding bodies: the Engineering and Physical Sciences Research Council (EPSRC); the Natural Environment Research Council (NERC); and the European Union (EU).

EPSRC acknowledges the need to improve cross-disciplinary research with the environmental and social sciences and is supporting a number of projects to provide a forum for academics and practitioners to discuss the best way forward for research and development in the UK and to promote more effective dissemination of results and best practice to users.

NERC promotes and supports basic, strategic and applied research, survey, and long-term monitoring, in environmental disciplines. It funds several projects of relevance here, including LOCAR (Lowland Catchment Research;

www.nerc.ac.uk/ funding/thematics/ locar) which is investigating the hydrological functioning of lowland catchments, particularly stream-aquifer interactions, and the linkages with aquatic ecology. Intensive monitoring is being performed in two Chalk catchments in southern England and a sandstone catchment in the Midlands.

One initiative worth particular note is the Flood Risk Management Research Consortium (FRMRC), an interdisciplinary research consortium being supported by EPSRC in collaboration with the Defra/EA Joint R&D programme on flood and Coastal Defence, UKWIR, NERC and the Scottish Executive (http://defra.gov.uk). This initiative is quite substantial and wide ranging and has several relevant elements, including: land use management; stakeholder and policy; and risk and uncertainty.

Also of note is NERC's Flood Risk from Extreme Events (FREE) programme (http://www.nerc.ac.uk/funding/thematics/free/). FREE aims to develop essential scientific building blocks addressing three central problems: (1) Estimation of the probability, and associated risks, of extreme events leading to flooding occurring in the period from minutes to weeks ahead. (2) Changes in the intensity and frequency of flooding, and associated weather regimes, resulting from natural and anthropogenic climate change over the next century.
(3) Integrated clouds-to-catchment-to-coast flood simulation.

CHASM (Catchment Hydrology And Sustainable Management; www.ncl.ac.uk/chasm) is being supported with NERC Joint Infrastructure Funding (JIF). Its purpose is to gain new understanding of how catchment responses change with scale, and establish new protocols for linking field experimentation, landscape classification, modelling and prediction. Multiscale monitoring and experimentation is being carried out in four predominantly upland catchments (~100 km^2), and a key issue is how, what and where to sample so as to reduce predictive uncertainty. One of the aims in CHASM is to gain a better understanding of the natural controls on the flood frequency curve, and to build this into new physically based approaches to flood risk estimation.

The EU is a major source of funds for research related to the rural environment, flooding, and the development of models and tools for prediction and decision support.

Other sponsors of related research include the Welsh Assembly, which is sponsoring research by CEH Bangor at Pontbren. The work at Pontbren includes a contribution to the FRMRC on local scale impacts of upland land management.

2.3 Timescale

The timescale of the overall vision of BSM is as follows (Calder and Wheater, 2001):

1. In the short-term, flood management practice will continue to employ current methods of proven ability, including the FEH suite of methods (the Short-term Method described in Reports C1 and C2 is an extension to the FEH suite of methods);
2. In a three to five year time frame significant technical advances over existing methods should come to fruition (this can be achieved by the medium term near-user programme described in Section 3 of this report and using early results from the longer term programme described in Section 4);
3. After this phase, there will then be a period in which the levels reach maturity through a process of review, testing and scientific acceptability (including continuing work under the longer term programme described in Section 4).

A wider-scale user migration to BSM methods is expected towards the end of a 10 year period.

Details on the timing of the research projects are given in Section 5.

3. Medium-term near-user programme

The research programme described here (Table 3-1) involves developing computer-based tools which can be made available to users in 3 to 5 years time. The following subsections give background information complementing the outline specifications in Appendix A. These projects relate to all five of the users' needs listed in the introduction. The budget, timetable and priority for the projects is given in Section 5.

Project	Title
M1	Analysis of historical data sets to look for impacts of land use and management change
M2	National datasets
M3	National mapping of vulnerability to land use and management change
M4	First generation DPSIR prediction tool
M5	Testing the DPSIR tool
M6	Distributed rainfall-runoff modelling
M7	Best practice and future scenarios
M8	Risk-based assessment of prevention and mitigation measures
M9	Multiscale monitoring
M10	Farm-scale integrated runoff management
M11	Characterising runoff generation

Table 3.1 The medium term near-user projects

The medium-term programme was developed as a package, so the projects are not independent. There are, though, only a few essential dependencies (marked by the symbol ■ in Table 3-2).

		Outputs from										
		M1	**M2**	**M3**	**M4**	**M5**	**M6**	**M7**	**M8**	**M9**	**M10**	**M11**
Inputs to	**M1**	--										
	M2		--									
	M3	K	D■	--	C		C					
	M4	K	D	D	--	T■	T■		T■	D/K	D/K	D/K
	M5		D		T	--				D	D	D
	M6		D	C			--			D	D	D
	M7							--			D	
	M8	K	D				T■		--	D		D
	M9									--		
	M10										--	
	M11											--

C - should be consistent with; D - data; K - knowledge; T - tools and/or tool testing ; ■ - essential dependency

Table 3.4 Substantial and essential dependencies between the medium term near-user projects

As can be seen in Table 3-2, Project M4 (First Generation DPSIR Prediction Tool) is central to the programme and can make use of inputs from most of the other projects. In contrast, Projects M1, M2, M9, M10 and M11 (the main data-based projects) require no substantial inputs from the other projects, so could, if necessary, be run as independent projects.

Some consideration was given as to whether there would be anything to gain from using simple modelling and carrying out simple analyses (sensitivity studies for example) prior to developing a detailed research plan. It was concluded, taking into account the reviews in FD2114/TR, that it is very likely that no new knowledge could be gained, and no new conclusions could be drawn, from simple modelling or analyses. What is needed is to start immediately making progress towards having detailed models and tools, backed by field data, that can be used in rigorous analyses and can be used with some confidence for operational purposes and in policy development.

3.1 Analysis of historical data sets to look for impacts of land-use and management change (Project M1)

As much as possible needs to be learned about the nature and magnitude of actual impacts. It was noted in FD2114/TR that previous analyses of historical rainfall-runoff data have not been able to isolate impacts in the data because of noise, natural climatic variations, and the limitations of the rainfall-runoff models. Modern modelling and statistical techniques should be applied to this problem.

Traditionally, analyses of land use and management change impacts at the catchment scale have employed 'batch mode' analysis and modelling of the rainfall-runoff relationship. Recursive data analysis and modelling approaches in which the data are processed one observation at a time might help to reveal time variant behaviour in the rainfall-runoff relationship associated with impacts (Young et al., 2001; Young, 2003).

If the volume of surface runoff is affected by changes in land use and management, this will affect the small-scale water balance and the partitioning between surface and subsurface runoff. Through the effect on antecedent moisture conditions, (e.g. higher pre-storm groundwater tables) even small changes may have a significant effect on the storm-to-storm variability in runoff response, and there may even be an effect on the seasonality of the runoff response. This could be investigated using data based and model based analyses of field and catchment scale water balances and the variability of runoff response, for datasets where change is known to have occurred.

The identification of change is contingent on a number of important issues: uncertainties in the measured inputs and outputs; lack of information about the nature of the land management and flood protection infrastructure changes that have taken place; and flood impacts on channel form and hydrograph timing. It will therefore be important to start by studying the limits of identifiability of changes in hydrological response in catchments where the nature of land management change has been well documented.

3.2 National datasets (Project M2)

FD2114/TR summarised the current state of farming in the UK and highlighted a number of practices that appear to cause increased field-scale runoff. However, data relating to the extent and variation of these practices across the UK are either very limited or non-existent.

National datasets are needed on the different cultivation and harvesting practices, surface cover strategies and water management (both irrigation and drainage) for the grassland and the range of arable, horticultural and fruit crops grown in the UK. These datasets would have several potential uses, including use in creating the national vulnerability map in Project M3 and as input to the decision support tool being developed in Project M4.

National land cover data sets should be developed using satellite land cover data derived at regular time intervals. The same, or consistent, procedures should be used when creating each set, so the sets will provide good basic information on land use change and will, perhaps, show the areas where land management practices are changing.

Data are required on the number of different types of stock kept on different types of grassland and on the grazing periods and grassland management strategies used.

Using the ADAS (2003) comprehensive review on underdrainage in England and Wales for the period 1951 to 1993 it possible to assess the likely field drainage that has been installed and estimate its effectiveness. This needs to be supplemented with data on the renewal of secondary drainage treatments, an aspect that has become more important in the last twenty years now that very little pipe drainage replacement takes place. Bearing in mind that the mid 20th century arterial agricultural land drainage and flood alleviation schemes were grant aided by MAFF and its predecessors there may be records of such schemes which could be of use.

Data on hedgerow length and field size is a component of the CEH Countryside Survey and requires to be integrated with other land management datasets.

To get the maximum use from national datasets, the various sets need to be available in a consistent format. Ideally, for modelling purposes, where the data are related to geographical location, they should be on a 1km, or finer, grid.

3.3 National mapping of vulnerability to land use and management change (Project M3)

The ideal is a national map on which each location (pixel) has numerical indices showing the vulnerability to flood impacts (local and downstream) associated with changes in land use and management. One of the first tasks in this work would be to define vulnerability in this context. The indices could be based on existing databases and tools, such as soils databases held by NSRI and the national nutrient maps and land management tools previously developed for Defra/EA in the PIT, Physic and Magpie projects. The methods used to produce the map should be consistent with the decision support tool in Project M4 and the rainfall-runoff modelling in Project M6.

It is not a simple task to define vulnerability as simple indices, especially given that flooding can be a problem at several locations (and spatial scales) in a catchment, there can be storm-to-storm and seasonal variability of hydrological response, and there is a wide range of different natures and types of changes which can be made in land use and management. Vulnerable catchments where there is a threat to valuable downstream assets should be identified as a priority.

One potential starting point for vulnerability mapping is the HOST soil hydrological classification scheme, but a wealth of information is needed (e.g. the national datasets in Project M2), including data on the nature and behaviour of the surface flow network. Another starting point is the Environment Agency's maps showing settlements at risk from flooding. Consideration should also be given to seeing how the Catchment Flood Management Plan and Risk Assessment for Strategic Planning processes can be used to help.

3.4 First generation DPSIR prediction tool (Project M4)

This tool should have a Driver-Pressure-State-Impact-Response (DPSIR) structure, linking through all the socio-economic and technical aspects and contributing factors from government policy and market forces, to the quantification of flows and uncertainty in flow modelling, and finally to the likely outcomes, such as flood impact, associated with prevention and mitigation measures. The DPSIR framework (Figure 3.1) was introduced in FD2114/TR. Land use and management evolves in response to climatic, socio-economic and technological forces; these forces (the Drivers) can be characterised using scenarios representing possible alternative futures. The Drivers create Pressures which then act on the State (i.e. the landscape and hydrological functioning of the catchment) to create flood Impacts. The Response is then the policy interventions needed to prevent or mitigate these impacts.

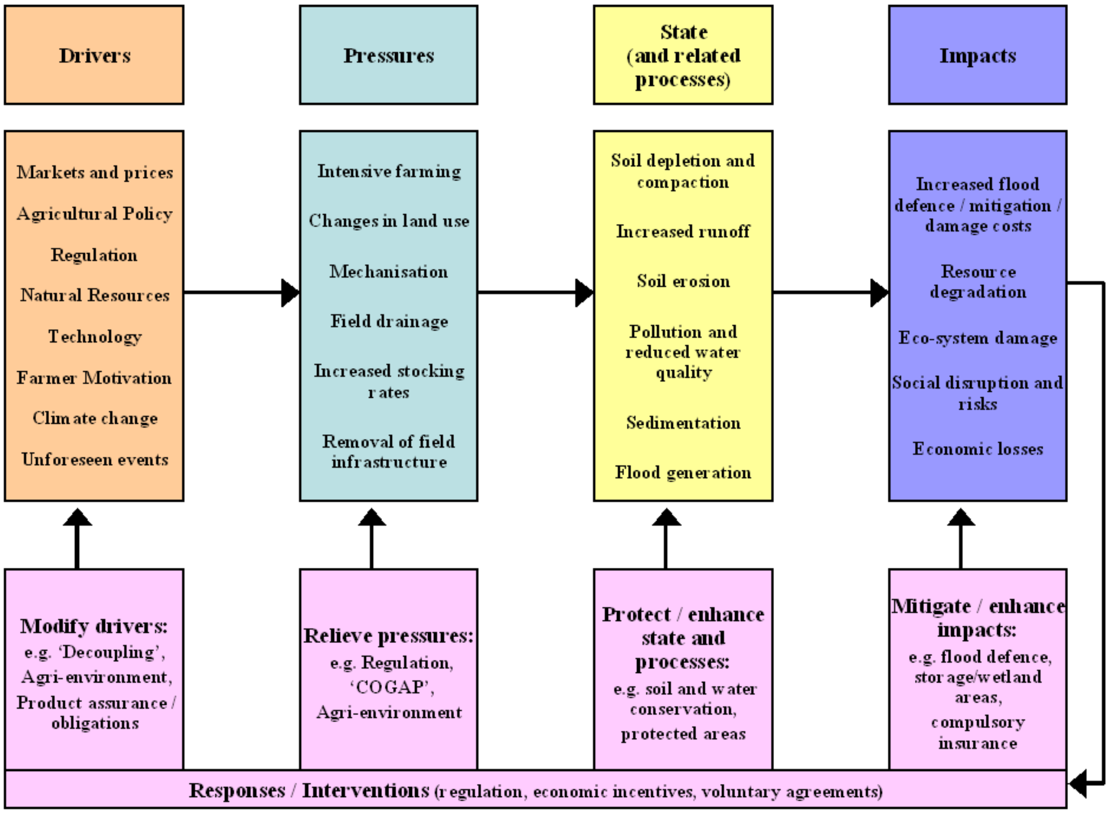

Figure 3.1 The DPSIR framework (reproduced from FD2114/TR)

The DPSIR tool is the main product of the medium term near-users programme and will use or include most of the information and models produced in all the other medium term projects. It should be designed to be meet several practical operational and research needs such as evaluating the likely effectiveness of prevention and mitigation measures applied at particular sites or in particular regions and for use in sensitivity studies to gain insight into the relative values of the different types of available information and data. Defining and meeting these practical needs should be the central drive in the design of the tool.

It would be unwise here to be too specific about the fine details of the tool or the technology on which it should be implemented because decisions of that sort are best left to the design stage, so they are appropriate to the skills and experience of the developers, and use the most appropriate technology available at the time. There are however, some further details on the DPSIR tool in Appendix B, and some general comments are made below.

a) There is need for discussions with the research sponsors and the potential users of the tool to define the overall purpose and function of the tool;

b) The tool should be modular, comprising sub-tools for rainfall-runoff modelling and so forth;

c) What is important is that a complete tool is developed and used. It is likely that far more will be learned and gained in the medium term by having and using a complete, albeit flawed, tool than would be gained by getting bogged down trying to solve all the difficult problems before a complete tool is ever built. For example, pragmatic approaches will have to be developed for estimating the uncertainty in the predictions;

d) Several generic problems need to be tackled: (1) representing the nature of land use and management change in a consistent and coherent fashion; (2) quantifying change in a consistent way within the DPSIR modelling framework; (3) integrating information of different types and for different scales in a consistent way; and (4) making the fullest use of the available information by extrapolating information from well studied catchments and regions to less well studied catchments and regions. These generic problems will be difficult to solve, especially problems 3 and 4, and pragmatic approaches will need to be developed. Some fundamental aspects associated with these problems are considered in Projects L1, L2 and L5 in the long term programme;

e) The following is an example of a pragmatic approach to integrating information of different types. Three examples of very different types of data which could be used in the DPSIR tool are: (1) measurements of soil permeability; (2) a catchment manager's estimations, based on experience and the available guidance, of the degree to which a given mitigation measure would be properly and comprehensively implemented by the land managers in a given catchment; and (3) estimates of the potential changes rural land managers may make for their own business purposes. The second and third data are inherently "softer" than the first. A visual parameterisation approach could be used for soft information. This would involve "hiding" a hard parameterisation behind visual diagrams (called decision support matrices). For example, the degree of implementation could be represented on a scale running from 0 to 1 (on an axis of a diagram) and the associated hard parameters could comprise the area fraction over which the measure is likely to be adopted and values for the physical properties to be used in the hydrological modelling of the effects of the measure. One advantage of this approach is that non-specialist modellers can use the tool in a simple fashion without having to understand or set values for the "hidden" parameters, but simply need to choose points on diagrams in the tool's graphical user interface.

3.5 Testing the DPSIR tool (Project M5)

The DPSIR tool in Project M4 should be tested by the tool developers and by persons independent of the developers. Data from Projects M9, M10, M11 and L2, L3 and L5 should be used. Ideally, the testing would be comprehensive, covering a wide range of different scales, scenarios and regions of the UK. FD2114/TR showed, however, that there are few data available, so there will inevitably be some testing against expert opinion and assessment.

Part of the later stages of the development work on the DPSIR tool should involve sensitivity and assessment studies in which the value of the various types of data are investigated and the relative value of various prevention and mitigation measures are assessed.

3.6 Distributed rainfall-runoff modelling (Project M6)

There is a clear role and need for distributed rainfall-runoff modelling in predicting the local and downstream flood impacts of changes in land use and management, whether the changes are proposed for agricultural management, flood management, pollution management, or any other requirement. This is increasingly the case now that management is viewed on a whole-catchment integrated basis supported by detailed electronic maps and databases (e.g. catchment flood management plans, catchment abstraction management strategies and WFD river basin management plans and their programme of measures). What comes out clearly from FD2114/TR is that existing rainfall-runoff models have serious limitations. The fundamental problems associated with using rainfall-runoff modelling to predict flood impact are considered in Project L1. What is needed for the medium term is a pragmatic approach in which appropriate modules (i.e. model components) are developed, or existing modules or models are adopted, for use in the DPSIR tool in Project M4 and in developing vulnerability maps (Project M3). The modelling can be tested using existing data and data from Projects M9, M10 and M11.

The same general recommendation made for the DPSIR tool can be made again here. It would be unwise to be too specific about the fine details of the design of the modules or the technology on which they should be implemented because decisions of this sort are best left to the design stage, so they are appropriate to the skills and experience of the developers, and use the most appropriate technology available at the time. There are, however, some general comments that can be made.

a) To be consistent with Project L1 in the long term programme, especially for future use in open-architecture systems, the existing models and modules considered for use in this modelling should be limited to those with open source codes or where the model developers are willing to cooperate (actively) in discussing their data requirements and in designing interfaces between their models and common databases and graphical tools. The rainfall-runoff modelling will be needed early in the medium term programme so that it can be incorporated in the DPSIR tool, leaving enough time for testing. Ideally, prototypes of the rainfall-runoff modules should be working by the end of the first year of the programme. Given this requirement, and the continuing need to adapted and adjust the modelling once the DPSIR tool is being tested, it is probably best if the rainfall-runoff modules are kept as simple as practical and are custom designed and built by experienced hydrological model builders, either working from scratch or adapting their own existing codes;
b) Modelling with a physical basis should be given some priority, so that direct links can be created between the modelling and point scale properties and measurements;
c) A detailed module is needed for the surface water network, so downstream propagation can be investigated. This need not be based on full hydraulic modelling, although such modelling would have advantages if flood plain flow and the effects of channel modifications and river restoration are to be

simulated. Ideally, for research purposes, this should be capable of representing dense networks in quite fine detail, down to the scale of field-edge drainage ditches;

d) A soil physics and hydrology module will be needed so that soil conditions and local landscapes can be represented. This should include modelling of the surface, subsurface and underdrainage and should include modelling of infiltration, transpiration and surface and subsurface runoff to the surface water network;

e) A surface module will be needed, to handle rainfall and meteorological forcing and evaporation;

f) There may be a need for regional aquifer modelling if larger-scale groundwater floods are to be modelled.

3.7 Best practice and future scenarios (Project M7)

For the development of the "drivers", "pressures", and "responses" elements of the DPSIR tool in Project 4, a sound understanding needs to be developed on the socio-economic factors affecting the efficiency and effectiveness of the policy instruments and promotions that can be used for preventing and mitigating flood impact. This understanding must then be interpreted in terms of algorithms and decision support matrices.

FD2114/TR showed that a mix of agricultural policy and market drivers have encouraged changes in land use and farming practices. Although there is a general understanding of what are suitable land uses and ‘good’ agricultural practices for prevention and mitigation, the extent to which these find acceptance amongst the end-user community of land managers is not clear. In particular, three factors which influence adoption must be taken into account when analysing existing data and when predicting the outcome of specific policies and promotions for prevention and mitigation: (1) the characteristics and motivations of land managers; (2) the characteristics of the proposed measures; and (3) how good practice is promoted amongst the target group.

FD2114/TR showed that land managers acquire knowledge and develop a persuasion towards a new technology or practice before deciding to adopt or reject. Economic incentives and voluntary schemes are likely to prove the most cost effective way to encourage adoption. Research is needed to determine how prevention and mitigation measures can be included within the existing framework of agri-environment schemes and/or made a condition for other forms of income support such as area payments and single farm payments. The role of extension services and specialist advisors is critical to support the adoption process, working with individuals or groups of farmers. Existing governmental and non governmental advisory services, including organisations such as the Rural Development Service (RDS) and Farming and Wildlife Advisory Group (FWAG) have an important role, as do farmer organisations such as the National Farmers Union, local farmer clubs, opinion leaders and ‘champion’ farmers. A generic strategy is needed for promoting measures and good practice, with guidance on how these can be modified to suit local conditions.

The DPSIR tool needs to be able to make recommendations for particular sites or regions, so must have databases of best practice, which take into account the acceptability to users. Projects M10, L3 and L5 should provide some, limited, data for use in testing these databases.

The datasets and algorithms used to represent the "drivers", "pressures", and "responses" in the DPSIR tool should include estimates of uncertainty.

3.8 Risk-based assessment of prevention and mitigation measures (Project M8)

The hydrological predictions needed in the "impacts" elements of the DPSIR tool in Project M4 should include flood frequency curves and uncertainty estimates, so that the tool can be used in flood risk estimation. Cameron et al. (2000) have provided a methodology for assessing the impacts of climate change scenarios on flood frequency using continuous simulation in a way that allows for uncertainty in modelling the current hydrology. There is an important additional issue of the uncertainty introduced when model parameters are changed to reflect the effects that mitigation and prevention measures have on the hydrology.

The flood frequency curve, and consequently the flood risk, will change when prevention and mitigation measures are implemented, or when land managers make changes to meet their own business needs. Stochastic rainfall models are being developed elsewhere within the BSM programme, and these can be linked with the rainfall-runoff model from Project M6 to create a method for estimating changes in the flood frequency curve based on simulating the runoff response of the catchment. Ideally, the stochastic rainfall models should allow the effects of climate change to be represented, in conjunction with assessments of the effect of climate change on cultivation and harvesting practices and so forth (Project M2), and of the effect on runoff generation (Project M11).

FD2114/TR concluded that there are serious limitations in the methods for calculating the uncertainty in predictions made using rainfall-runoff models. This fundamental problem will be addressed using ensemble modelling in Project L1 in the long-term programme. Here, a simple, robust method is needed for estimating the uncertainty in runoff simulations. It is likely that this will have to rely in the first instance on an algorithm which uses a limited number of simulations and is designed based on expert judgement.

Risk-based assessment is considered further in Project L5 in the long-term programme.

3.9 Multiscale monitoring (Project M9)

It is clear in FD2114/TR that one of the most poorly understood and investigated features is the way that effects propagate downstream within the catchment. The distributed modelling in Project M6 (and Project L1 in the long term programme) addresses this from a modelling perspective, but supporting field information is needed.

The most efficient way to obtain high-quality field information in the medium term is to take advantage of the methods and equipment being used in ongoing multiscale field monitoring programmes such as CHASM and LOCAR and, effectively, to extend the work of those programmes to include a study of the effects of land use and management change. It should be noted, though, that one limitation of the instrumented CHASM and LOCAR catchments is that they are not representative of the lowland landscapes most affected by flooding. They do, however, represent source areas for runoff generation. Further multiscale monitoring, including the instrumentation of new catchments, is considered in Project L2 in the long-term programme. Further details on the CHASM programme are given in Section 4.2, as part of the background information for Project L2.

3.10 Farm-scale integrated runoff management (Project M10)

Interventions that delay runoff, such as creating temporary flood storage ponds and permanent wetlands, are likely to be important components of any future integrated runoff management plans designed for on-farm pollution, sediment, and flooding control. The cost/benefit of such interventions, from a flood mitigation point of view, can be considered in the DPSIR tool developed in Project M4, provided data are available on the costs of the interventions and provided their effects on flow can be represented in the distributed rainfall-runoff modelling developed in Project M6. There is, however, only a very limited amount of information in FD2114/TR that can be used to quantify the costs and effects of such interventions. Farm-scale experimentation and monitoring is therefore needed so that data can be collected for use in designing and testing the necessary cost calculation algorithms and runoff modelling.

Farm-scale integrated runoff management, and its modelling, needs a multidisciplinary approach, combining hillslope hydrology and hydraulics with soil conservation engineering and so forth.

An efficient way to obtain high-quality field information in the medium term is to take advantage of the Earth Systems Laboratory Initiative on Sustainable Farms being run by the University of Newcastle in which an advanced integrated runoff management plan is to be implemented at Nafferton Farm, near Newcastle (partly supported by the Northumbrian Area Environment Agency). Further fieldwork along these lines is included in Project L3 in the long-term programme. The advantage of the Nafferton Farm site is that it is quite compact and the interventions being assessed have a substantial effect on the total runoff from the site. This makes it possible to design robust experiments, giving concrete results over the short term. For Project L3, however, it would be appropriate to review the sites available for the longer-term work.

3.11 Characterising runoff generation (Project M11)

Data are required for the soil physics and hydrology module of the rainfall-runoff model developed in Project M6, so that infiltration and runoff can be properly represented for a wide range of different land uses, soil conditions and management practices. This will then allow the consequences of different decisions about land use and management to be considered using the DPSIR tool developed in Project M4. There are some data quoted in FD2114/TR, and further data in the source material considered in that report, but these are inadequate. Point-scale and field-scale experimentation and monitoring will therefore be required to supplement the existing data. This will involve making measurements for a wide range of different land uses, soil conditions and management practices.

A fundamental problem in characterising runoff generation within distributed models is how to account for the relationship between point-scale measurements and data (e.g. measurements made using a soil permeameter) and the grid, patch, field, or hillslope behaviours represented in the soil physics and hydrology module. The (inadequate) approach taken in most distributed, physically based modelling is simply to assume that the point-scale measurements apply directly at the grid, patch, field, and hillslope scales. For example, infiltration properties measured at a point within a grid are simply assumed to apply uniformly across the grid, because in general there is no information about the spatial heterogeneity of the hydrological characteristics of the soil or the geology of the catchment. This lack of information makes it very difficult to justify or test any methods proposed for aggregating the effects of point scale processes to larger scales. Some simplifying assumptions are therefore always made when modelling complex temporal and spatial patterns of infiltration, saturation, and runoff in heterogeneous areas.

4. Longer-term programme

The research programme described here is designed to run in parallel with the medium term near-user programme described in Section 3, but to continue over a longer time period. It comprises research projects which tackle the fundamental problems associated with understanding the effects of rural land use and management on flood impact and incorporating this understanding in computer-based tools.

The fundamental problems highlighted in FD2114/TR are:

a) There is no generally accepted theoretical basis for a design of rainfall-runoff model suitable for predicting impact;
b) It is not known exactly which data are essential to predicting impact;
c) There are serious limitations in the methods available for estimating uncertainty in predictions of impact made using rainfall-runoff models;
d) There is a lack of data at the local scale and for downstream propagation of impacts;
e) There is considerable uncertainty about the necessary scope for long term scenarios for use in policy making, including uncertainty about how efficiently prevention and mitigation measures will be taken up by land managers.

It is proposed that these fundamental problems should be tackled by creating an open-architecture hierarchical structure of models (Section 4.1; **Project L1)** which can be rigorously tested using currently available data and new data collected for this task (Section 4.2; **Project L2**). The new data should include results obtained in trials where a range of mitigation measures are tested (Section 4.3; **Project L3**). New measurement technologies should be developed and tested (Section 4.4; **Project L4**), especially technologies that allow rapid or remote measurement. Finally, longer-term perspectives should be considered and long-term scenarios developed for the assessment of the likely effects of policies, promotions, practices, river restoration, climate change, and other relevant factors (Section 4.5; **Project L5**).

The following subsections give background information complementing the outline specifications for the longer term projects, Projects L1 to L5, in Appendix A.

4.1 Open-architecture hierarchical rainfall-runoff modelling (Project L1)

In the ideal modelling system, continuous simulation rainfall-runoff modules of a wide range of types and levels of sophistication can simply be plugged in and run, automatically making use of common data sets created for the modelled catchments and common graphical tools for visual presentation of the input data and results. Using this plug-and-play (i.e. open-architecture) approach, an enormous range of different data types and modelling approaches could to be used and tested efficiently. This would allow different modelling approaches to be compared directly, and progress to be made towards a generally-accepted theoretical basis for a design of model suitable for predicting impact.

One of the main advantages of the system is that any model with the correct interface can be used, so no type of model or modeller is excluded and costly mistakes associated with creating or adopting dedicated codes and data set structures can be avoided.

This above ideal is, however, some way off, and some words of caution were given in Section 2.1. What is needed in the meantime is a strong move towards this ideal, while at the same time making progress with predicting flood impacts, calculating uncertainty, and understanding the predictive value of different types of data (e.g. given a certain budget for improving the modelling of a given catchment by collecting further data, which data would be given priority?). A practical problem that was highlighted in FD2114/TR was that a method is needed which combines the many different local scale effects as they propagate downstream, so predictions can be made for the effect on large-scale flooding downstream.

Given everything said above, some general points can be made.

a) Even assuming that the goal, at this stage, is not a full scale open-architecture approach, some rationalisation of data sets and model interfaces would be justified, in preparation for a future open-architecture approach. This means that, where possible, the existing models considered should be limited to those with open source codes or where the model developers are willing to cooperate (actively) in discussing their data requirements and in designing interfaces between their models and common databases and graphical tools;

b) Ensemble modelling should be used in calculating the uncertainty in predictions of runoff. The simplest form of ensemble modelling involves running a family of simulations using a range of different data sets and models to predict a single impact in a catchment. The idea behind this is that, all else being equal, all the results have some value and conclusions about uncertainty can be drawn from the range of results. Intelligence can be added to this approach by allowing the models to interact during the simulations (assuming they are run in parallel) to make the process more general and efficient. In the simplest case, some simulations can be stopped early (e.g. because they are giving results very similar to other simulations). In more complicated cases, the models can interact in a more detailed way, such as sharing their local runoff rates, to give very powerful tools for aggregation and simplification. It may be worthwhile developing some quite general interfaces for some models so that trials can be run using this type of powerful ensemble modelling. This, again, means that where possible the models considered should be limited to those with open source codes or where the model developers are willing to cooperate in discussing their data requirements and in designing interfaces between their models and common databases and graphical tools. Some progress along these lines has been made by Beven (2002);

c) Field experimentation and data collection have traditionally been undertaken separately from modelling, which is often viewed as a follow-on activity. It is possible to argue that an integrated programme of monitoring, modelling and prediction should be undertaken in which there is feedback from modelling to monitoring (e.g. the monitoring network of river gauges could be altered or augmented if a case can be made, based on simulation results, that this would reduce the uncertainty in predictions of impact). There may be practical problems with implementing an integrated programme, especially where there is a mismatch between the rate at which models are upgraded and replaced and the rate at which data becomes available from the field. For example, there may be only one significant flooding event at a monitored catchment in several years. However, some thought should be given to integrating monitoring, modelling and prediction (Section 4.2);
d) One of the main initial uses for the modelling should be to investigate the value of different data in reducing the error and uncertainty in predictions of impact.

The various modelling approaches were discussed in FD2114/TR, so it is not necessary here to discuss the merits of the different approaches, especially given the conclusion in FD2114/TR that there is no generally-accepted theoretical basis for a design of model suitable for predicting impact. However, some general points can be made (the first two points were previously made for Project M6 in Section 3.6):

a) Modelling with a physical basis should be given some priority, so that direct links can be created between the modelling and point scale properties and measurements;
b) At least one detailed module is needed for the surface water network, so downstream propagation can be investigated. This need not be based on full hydraulic modelling, although such modelling would have advantages if flood plain flow and the effects of channel modifications and river restoration are to be simulated. The modelling should be capable of representing dense networks in quite fine detail, down to the scale of field-edge drainage ditches;
c) The central aim of this work should be to set up a model hierarchy, comprising a set ranging from simple fast-running models to more detailed and complex slow-running models. Each of the models could be complete in itself or could comprise several modules. It could be argued that the purpose of model use varies along the hierarchy, with simpler models being more appropriate for use in operational simulations and to give preliminary results, while more detailed models are more appropriate for use in research and to support the simpler models. This may well turn out to be the case. However, at this stage, given the lack of knowledge, it simply seems sensible to include models of different types and complexities and to investigate their behaviour in predicting flood impacts.

A case can be made, however, for the coherence of the models in the hierarchy to be as strong as possible. For example, some of the simpler models should be capable of being parameterised using results from some of the more detailed models, so the nature and robustness of simple concepts can be investigated.

4.2 Multiscale experimentation, monitoring and modelling (Project L2)

The purpose of the multiscale experimentation, monitoring and modelling is to gain further insight into the link between land use and management and local and downstream flooding and to test the modelling in Project L1 (and, if timings allow, for use in testing within the medium-term programme). A comprehensive programme is required, covering a number of catchments, to ensure that data are collected for a wide range of different land uses, soil conditions and management practices.

The most appropriate template is the CHASM and LOCAR programmes, in which in excess of £5M has already been invested in multiscale monitoring infrastructure. In CHASM, a Generic Experimental Design (GED) approach has been developed and is being used to identify the dominant flow processes and controls within catchments and to investigate how these vary with scale.

The GED could be used in this work to identify, for example, the dominant local runoff processes and the processes controlling downstream propagation of impacts. In the GED, the catchment landscape is divided into hydrologically and/or geomorphologically distinct units and then surveyed using mobile instrumentation (GPS elevation, drilling, coring, X-band rainfall radar, and so forth). Permanent instrumentation for meteorological and hydrological monitoring is then installed. Further instrumentation (including piezometers and soil moisture probes) is sited at representative sites in each unit and is used to test hypothesis about the site and unit, and moved and augmented as necessary. Short-term measurement campaigns (e.g. tracer tests and stream flow monitoring at multiple sites) are used to provide supplementary information. A key feature of the GED is that the understanding of the catchment, in particular the way it is divided into units and how each unit is characterised using the collected data, is continually reassessed and the instrumentation altered as required.

One limitation of the instrumented CHASM and LOCAR catchments is that they are not representative of the lowland landscapes most affected by flooding, so although the CHASM and LOCAR data and instrumentation would be of use, some new catchments will need to be instrumented.

To gain the maximum benefit from the multiscale experimentation, monitoring and modelling it is important that is has a very clear role and purpose, either as part of an integrated model development and monitoring programme (Project L1), or for testing specific clearly-defined hypothesis about the impact of land use and management change, or for concept development (e.g. for developing and testing conceptualisations for representing downstream propagation of impacts in simple models). It might, perhaps, be possible to include the testing of specific mitigation measures (Project L3) within one or more of the catchments being used for multiscale experimentation, monitoring and modelling.

4.3 Trials of mitigation measures (Project L3)

The ideal is a set of intensively instrumented experiments in which the effect of promising mitigation measures are studied in detail at the local scale and for their effects downstream.

The central problem to be overcome is how to measure the effects of a mitigation measure, given that implementing the measure destroys the "unchanged" landscape so direct comparisons between the changed and unchanged landscape are not possible. The design of the trials will therefore need to be considered in detail, fully taking into account the variability of rainfall, climate and the landscape and how these will affect the trial results. There are no obvious or guaranteed solutions to this problem, but a practical approach could be developed after analysing the candidate approaches and methods, which include: (1) testing at matched paired "changed" and "unchanged" sites; and (2) closely characterising a site, through long term monitoring, before implementing a change.

4.4 New measurement technologies (Project L4)

Measurement technology is improving continually and new technology should be exploited.

The most difficult problem to be overcome is measuring the properties and responses of the subsurface. There is a primary problem about how to get access to the subsurface and a secondary problem of how to define and measure area-average properties and responses. New non-invasive techniques and aggregation theories are badly needed. This, however, (especially the development of non-invasive techniques), is probably beyond the scope of the research which should be included in Project L4.

Rapid cost-effective methods are needed for streamflow measurement. These could be used operationally in ungauged and poorly gauged catchments and could also be used to build up detailed pictures of the spatial variation of runoff in research catchments. Portable ultrasonic gauges offer considerable potential in this regard.

A rapid and robust technique is needed for estimating the local infiltration and runoff properties in agricultural fields, to provide data for the soil physics and hydrology modules in the rainfall-runoff modelling in Project M6.

Remote sensing should be exploited. Remote soil moisture measurements could provide key information on spatial patterns that reflect land use management practices, such as the distribution of saturated areas associated with soil compaction.

Mobile radars could be used to characterize catchment-scale space-time variability of rainfall, to help reduce the uncertainty in the inputs to rainfall-runoff models.

The 'Green Machine' concept developed in CHASM could be exploited further by mounting non-invasive survey instruments on tractors and all-terrain vehicles operated by farmers.

The potential of emerging developments such as a 'Smart Dust' and nanotechnology should be assessed.

4.5 Longer term perspectives (Project L5)

The Foresight Flood and Coastal Defence Project (Office of Science and Technology, 2004) has recently reviewed long term futures (for the 2050s and 2080s) and the implications for flood risks and policy responses, and Defra are currently reviewing long term futures for agriculture as part of a Horizon Scanning Strategy (Defra, 2002). These investigations adopt a scenario-based approach to mapping possible futures in terms of alternative patterns of governance and social motivation.

The flood risk associated with rural land use and management should be considered using alternative likely future scenarios, including climate change. This should include estimates of the uncertainty in the nature and effectiveness of prevention and mitigation measures, promotions and policies, including uncertainty in the efficiency with which promotions and policies are adopted by land managers. The DPSIR tool proposed in Section 3 (Project M4) as part of the medium term near-user programme could be used for this purpose. There will be a need, however, for the methods used in the tool to be reviewed and strengthened to meet the needs of this work, especially in the way that uncertainty is handled and assessed.

5. Timing, funding and priority

Table 5-1 shows the timing and funding for the projects in Appendix A, over a 10-year period. Each asterisk (*) in the table represents approximately £25K. The bulk of the funds (70%) is allocated to data collection, assembly and various forms of analysis, and the remainder (30%) to developing and testing the necessary models.

The priorities in the table are 1-higher and 2-lower. For the medium-term near-user programme (Projects M1 to M11) the rationale for the priority ranking is that higher priority should be given to exploiting existing data and developing the DPSIR tool so it can be used to explore the nature and extent of the problem and be integrated with other tools for whole-catchment integrated management. For the longer term programme (Projects L1 to L5) the higher priority is given to field-work which could contribute significantly to the understanding of the link between rural land use and management and flooding impact.

Project		Budget for year (£K)										Total (£K)	Priority
		1	2	3	4	5	6	7	8	9	10		
M1	Analysis of Historical Data Sets to Look for Impacts of Land Use and Management Change	***	***									150	1
M2	National Datasets	**	**	**								150	2
M3	National Mapping of Vulnerability to Land Use and Management Change	***	***	**								200	2
M4	First Generation DPSIR Prediction Tool		**	****	****	****						350	1
M5	Testing the DPSIR Tool				***	**						125	1
M6	Distributed Rainfall-Runoff Modelling	***	***	*	*	*						225	1
M7	Best Practice and Future Scenarios	***	***									150	1
M8	Risk-Based Assessment of Prevention and Mitigation Measures			***	***							150	1
M9	Multiscale Monitoring	*	*	*	*							100	2
M10	Farm-Scale Integrated Runoff Management	*	*	*	*							100	2
M11	Characterising Runoff Generation	****	****									200	2
											Total	**1,900**	
L1	Open-Architecture Hierarchical Rainfall-Runoff Modelling			****	****	***	*	*	*	*	*	400	2
L2	Multiscale Experimentation, Monitoring and Modelling			**** ****	**** **	****	****	****	**	**	**	800	1
L3	Trials of Mitigation Measures			****	****	***	**	*	*	*	*	425	1
L4	New Measurement Technologies			****	****	****						300	2
L5	Longer Term Perspectives						*	**	**	**	***	250	2
											Total	**2,175**	

Table 5.1 Timing, funding and priority for the research projects

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Appendix A: outline project specifications

The outline specification for Projects M1 to M11 and L1 to L5 are given here:

A.1 Project M1: analysis of historical data sets to look for impacts of land use and management change

TITLE: Analysis of Historical Data Sets to Look for Impacts of Land Use and Management Change		
Purpose (Key Customer) - Why is the R&D needed? There is an almost complete lack of knowledge as to the nature and extent of the effects on flooding caused by the changes in rural land use and management practices made in the past, particularly for the effects on flooding at the larger scale, downstream of where the land use and management changes were made. If flooding effects can be isolated and quantified in historical rainfall-runoff data, this would be a major step forward in understanding and would help to support policy decisions and the operational methods used to predict the likely impacts of measures proposed in the future for flood prevention and mitigation.		
Summary (Overall) Objectives Develop and apply methods for analysing rainfall-runoff data to isolate and quantify flooding effects caused by changes in rural land use and management practices.		
Context (Background) Past analyses of historical rainfall-runoff data have not revealed trends that might have resulted from the effects of changes in rural land use and management practices, but physical reasoning suggests there have been effects, including changes to the flood peak flows and the hydrograph shape, and also changes in the variability of flood response, perhaps including changes in the seasonality of flooding events. If the effects of rural land use and management practices are to be quantified using rainfall-runoff modelling, they must be distinguished from modelling artefacts and from the effects of flood plain management, channel modification, and climatic variability. An inadequate treatment of modelling artefacts and climatic variability probably explains why the past analyses were unsuccessful.		
Main Outputs / User / Benefits Database containing the rainfall-runoff datasets, and other data, used in the study. Detailed specifications for the methods used in the analysis of the data (including software, if possible). Recommendations summarising the outcome from the work and specifying how the results can be used to support policy decisions and operational methods used to predict likely impacts of flood prevention and mitigation measures.		
Timescale / Costs / Costs by year: Total cost: £150K		
Other Funders (internal or external)?		
PREPARED BY: Project FD2114 consortium.		
Which one of the following types of R&D would this project come under:		
Operational	Policy	Strategy
Which would be the main EA Theme that this project would come under:		
Adapting to Climate change	Reducing Flood Risks	Ensuring the Air is Clean
Using Natural Resources Wisely	Improving Inland/Coastal Waters	Protecting / Restoring the Land
Greening the Business World	Quality of Life	Enhancing Wildlife
Principal Defra / EA Theme: Broad-scale modelling		

A.2 Project M2: national datasets

TITLE: National Datasets

Purpose (Key Customer) - Why is the R&D needed?
National datasets are required to support operational modelling, and policy development, for the flood impact of changes in rural land use and management.

Summary (Overall) Objectives
Document the requirements for datasets, including geographically distributed data (i.e. maps), needed to support operational modelling, and policy development, for the flood impact of changes in rural land use and management. Where required, augment existing datasets and create new sets.

Context (Background)
Many existing datasets contain information useful in assessing the flood impact of changes in rural land use and management, such as soils data sets (e.g. sets held by NSRI), land use maps, and data on hedgerow length and field size (e.g. sets held by CEH). As far as practical, these need to be made available, in a consistent format, for use in operational use and in creating future scenarios for use in policy making. The existing datasets will need to be augmented with some new sets.

Main Outputs / User / Benefits

- Document summarising the existing datasets, including their availability, coverage, reliability, and potential use in assessing the flood impact of changes in rural land use and management, and details of how the data can be handled in a consistent fashion, where appropriate on, say, a 1km grid. Should also identify which new datasets are needed.
- New dataset describing the different cultivation and harvesting practices, surface cover strategies and water management (irrigation and drainage) for grassland and the range of arable, horticultural and fruit crops grown in the UK.
- Improved national land cover mapping from satellite images at regular time intervals.
- New dataset describing the types and numbers of different stock kept on different types of grassland and on the grazing periods and grassland management strategies used.
- New dataset on secondary drainage treatments, to augment the existing ADAS data on underdrainage.
- A dataset is needed on the nature of surface water networks, so this can be used in assessing the likely flood impacts downstream in flood vulnerability mapping and in operation assessment of the outcome when given flood prevention and mitigation practices are applied. Consideration needs to be given as to the nature of these data and whether a map of these data can be created based on existing maps.

Timescale / Costs / Costs by year: Total cost: £150K

Other Funders (internal or external)?

PREPARED BY: Project FD2114 consortium.

Which one of the following types of R&D would this project come under:

Operational	Policy	Strategy

Which would be the main EA Theme that this project would come under:

Adapting to Climate change	Reducing Flood Risks	Ensuring the Air is Clean
Using Natural Resources Wisely	Improving Inland/Coastal Waters	Protecting / Restoring the Land
Greening the Business World	Quality of Life	Enhancing Wildlife

Principal Defra / EA Theme: Broad-scale modelling

A.3 Project M3: National mapping of vulnerability to land use and management change

TITLE: National Mapping of Vulnerability to Land Use and Management Change		
Purpose (Key Customer) - Why is the R&D needed? National maps giving indices of the relative vulnerability to flood impacts associated with changes in land use and management are needed when developing policy and regional and catchment management plans and as a starting point for operational decision making about specific catchments and prevention and mitigation measures.		
Summary (Overall) Objectives Produce and document electronic maps giving the relative vulnerability to flood impact (local and downstream) associated with changes in land use and management.		
Context (Background) Different catchments and different locations within a catchment will have different vulnerabilities to changes in land use and management. For example, the outcomes might be quite different if the same flood mitigation measure is applied to the same extent over the same total area at two different locations. These differences in outcomes between locations will depend on several factors, and for any one location the outcome for local flooding might be quite different to that for downstream flooding. Indices for the vulnerability to local and downstream flooding can be derived using algorithms that use as input nationally available data, such as land use, HOST soil class, underdrainage extent and efficiency, and average ground slope. These algorithms should be hydrologically sound and be consistent with modern hydrological modelling practice, including in the way that the surface water network is described and downstream flooding is represented. The algorithms and presentation methods for the maps should allow, as far as possible, for gradual improvements to be made over time. They should, for example, include mechanisms so that local knowledge, such as knowledge on known flooding sites and vulnerabilities, can be used to modify the indices.		
Main Outputs / User / Benefits • National maps (one per index), in electronic form. • Detailed specification for how the maps were created (including software, is practical). • Guidance and training material for using the maps to assess the local and downstream effects of land use change and management practices, including descriptions of how the vulnerability indices can be modified using new and local information.		
Timescale / Costs / Costs by year: Total cost: £200K		
Other Funders (internal or external)?		
PREPARED BY: Project FD2114 consortium.		
Which one of the following types of R&D would this project come under:		
<u>Operational</u>	<u>Policy</u>	Strategy
Which would be the main EA Theme that this project would come under:		
Adapting to Climate change	<u>Reducing Flood Risks</u>	Ensuring the Air is Clean
Using Natural Resources Wisely	Improving Inland/Coastal Waters	Protecting / Restoring the Land
Greening the Business World	Quality of Life	Enhancing Wildlife
Principal Defra/ EA Theme: Broad-scale modelling		

A.4 Project M4: first generation DPSIR prediction tool

TITLE: First Generation DPSIR Prediction Tool
Purpose (Key Customer) - Why is the R&D needed? Catchment management decision making for rural land use change and management practices, including flood mitigation practices, must be based on a wide range of socio-economic, agricultural and hydrological information. Given the particular complexity of the problem, a custom-designed computer-based tool is needed in the medium term. This will allow the complexity and uncertainty associated with this problem to be investigated, and a version of the tool can be made available for operation use and as an aid to policy making. This tool would integrate the best available knowledge, experience, and data, and would include modelling for estimating the change in local and downstream flood risk associated with rural land use change and management practices. In the longer term this tool, or its components, could be integrated within computer-based tools developed elsewhere for other aspects of decision making for catchment management.
Summary (Overall) Objectives To create, test and document a computer tool for research and operational use for catchment management decision making for rural land use change and management practices, including flood mitigation practices, that integrates the best available knowledge, experience, and data, and includes modelling for estimating the change in local and downstream flood risk associated with rural land use change and management practices.
Context (Background) The outcome when a particular flood prevention or mitigation policy or promotion is applied in a particular catchment will depend on many factors such as the nature and landscape of the catchment, the current land uses and farming practices, the nature and efficiency of the water pathways, including underdrainage, on-farm drainage and the downstream surface water network, and also on the way that the land managers respond to the policies and promotions, which will depend on how the policies and promotions are presented and supported. Predicting the outcomes, in the form of a change in flood risk, say, is therefore a complicated task and it is subject to many different sources of uncertainty. The Driver-Pressure-State-Impact-Response (DPSIR) structure, within a computer-based DPSIR tool, can be used to represent and analyse the complexity of this problem, including wider issues associated with the evolution of landscapes and the effects of climate change, which need to be considered in policy development. Climatic, socio-economic and technological forces are the Drivers, which can be characterised using scenarios representing possible alternative futures. These then create Pressures which then act on the State (i.e. the landscape and hydrological functioning of the catchment) to create flood Impacts. The Response is then the policy interventions needed to prevent or mitigate these impacts. The main components of the tool are: (1) standardised data input interface for geographical and timeseries data; (2) link to an existing stochastic rainfall generator or to data sets produced by a generator; (3) scenario manager, to set up links between data sets and models and to define scenarios; (4) ensemble manager, to set up ensemble simulations for estimating uncertainty; (5) interfaces for modules for rainfall-runoff modelling; (6) database for prevention and mitigation best practice, and data specific to flood impact, such as data on soil degradation; (7) library of information and guidance, including standard results; (8) graphical user interface, including decision support matrices which allow rapid use of the tool by non experts; and (9) customisation interface, allowing users to adapt and extend the functioning of the tool, such as introducing data with a new format or coupling to a socio-economic model.
Main Outputs / User / Benefits • The first-generation DPSIR tool. • User guide. • Document on the interfaces, including the interfaces between rainfall-runoff modules and the tool's core. • Document on test methods and the history of testing. • Guidance and training material on how the tool can be used for research and operational use for catchment management decision-making and policy development for rural land use change and management practices.
Timescale / Costs / Costs by year: Total cost: £350K
Other Funders (internal or external)?
PREPARED BY: Project FD2114 consortium.

Which one of the following types of R&D would this project come under:		
<u>Operational</u>	<u>Policy</u>	<u>Strategy</u>
Which would be the main EA Theme that this project would come under:		
Adapting to Climate change	Reducing Flood Risks	Ensuring the Air is Clean

Using Natural Resources Wisely	Improving Inland/Coastal Waters	Protecting / Restoring the Land
Greening the Business World	Quality of Life	Enhancing Wildlife
Principal Defra / EA Theme: Broad-scale modelling		

A.5 Project M5: testing the DPSIR tool

TITLE: Testing the DPSIR Tool		
Purpose (Key Customer) - Why is the R&D needed? The DPSIR tool (Project M4) must be tested by the developers and persons independent of the developers before the tool can be used to support policy making and operational decision making relating to regional and catchment management of the flood impacts of land use change and management practices.		
Summary (Overall) Objectives To test, and document the testing, of the DPSIR tool.		
Context (Background) It is essential that the DPSIR tool developed in Project M4, is tested by persons other than the developers, while the development team is still in place, so that the developers receive feedback which can be used to finalise the work on the tool. The testing should include studies in which the effectiveness of prevention and mitigation measures are estimated under (simulated) operational conditions. To test the value of the tool in research, the testing should also involve sensitivity studies that investigate the relative worth of various types of data in improving estimates of impact.		
Main Outputs / User / Benefits • Library of test data sets and results. • Document detailing the testing and results. • Recommendation on how the DPSIR tool should be used for research and operational use for catchment management decision making and policy development for rural land use change and management practices, augmenting the guidance and training materials produced by the tool's developers in Project M4.		
Timescale / Costs / Costs by year: Total cost: £125K		
Other Funders (internal or external)?		
PREPARED BY: Project FD2114 consortium.		
Which one of the following types of R&D would this project come under:		
<u>Operational</u>	Policy	Strategy
Which would be the main EA Theme that this project would come under:		
Adapting to Climate change	<u>Reducing Flood Risks</u>	Ensuring the Air is Clean
Using Natural Resources Wisely	Improving Inland/Coastal Waters	Protecting / Restoring the Land
Greening the Business World	Quality of Life	Enhancing Wildlife
Principal Defra / EA Theme: Broad-scale modelling		

A.6 Project M6: distributed rainfall-runoff modelling

TITLE: Distributed Rainfall-Runoff Modelling

Purpose (Key Customer) - Why is the R&D needed?
Operational catchment management requires estimates to be made for the change in local and downstream flood risk associated with the effects of changes in rural land use and management, including the effects of flood mitigation practices. Modern rainfall-runoff modelling methods need to be applied to this problem, to improve the quality of the estimates, and so that there can be a move towards an open-architecture whole-catchment multi-function computer-based approach to management decision- making.

Summary (Overall) Objectives
To create, test and document a complete set of open-source modules for use in physically-based distributed rainfall-runoff modelling for research and operational estimation of the change in local and downstream flood risk associated with changes in rural land use and management.

Context (Background)
Flood risk is related to the flood frequency curve (FFC), so the change in local and downstream flood risk associated with changes in rural land use and management depends on the difference between the FFCs for the "post-change" and "pre-change" conditions. These FFCs can be estimated using continuous simulation rainfall-runoff modelling.

Many existing models could be adopted and used without modification to create FFCs. However, given the need for transparency, quality assurance, and a move towards an open-architecture modelling environments (i.e. plug-and-play environments, where different models, modules and datasets can simply be plugged in and are automatically compatible with the rest of the modelling and datasets), a strong case can be made that what is needed is a set of open-source modules for which all details are openly published.

Distributed rainfall-runoff modelling simulates runoff rates and volumes, representing the catchment on a grid or as sets of patches or hillslopes, and includes a direct, distributed, representation of the surface water network. This is appropriate, given that many catchment data sets are held in geographical information systems (GIS), and also given the need to represent runoff at several scales, including individual agricultural fields and farms and larger areas susceptible to flooding downstream. If the modelling has a physical basis, the physical properties of the soil and surface water network and so forth can be represented, so there can be a strong and direct representation of changes in land use and management. A complete distributed model would comprise modules for the surface water network, soil physics and hydrology, groundwater, and moisture exchange with the atmosphere.

Main Outputs / User / Benefits

- Complete set modules for use in physically-based distributed rainfall-runoff modelling.
- User manual.
- Open-source documentation for the modules.
- Documentation on test methods and the history of testing.
- Guidance and training material on using the modelling for research and operational estimation of the change in local and downstream runoff and flood risk associated with changes in rural land use and management.

Timescale / Costs / Costs by year: Total cost: £225K

Other Funders (internal or external)?

PREPARED BY: Project FD2114 consortium.

Which one of the following types of R&D would this project come under:

Operational	Policy	Strategy

Which would be the main EA Theme that this project would come under:

Adapting to Climate change	Reducing Flood Risks	Ensuring the Air is Clean
Using Natural Resources Wisely	Improving Inland/Coastal Waters	Protecting / Restoring the Land
Greening the Business World	Quality of Life	Enhancing Wildlife

Principal Defra/ EA Theme: Broad-scale modelling

A.7 Project M7: Best practice and future scenarios

<table>
<tr><td colspan="3">TITLE: Best Practice and Future Scenarios</td></tr>
<tr><td colspan="3">Purpose (Key Customer) - Why is the R&D needed?
Efficient catchment management requires knowledge of the best practices, so that the best approaches are used to ensure that the best flood prevention and mitigation measures are adopted by farmers and land managers. Efficient policy making requires consideration of the longer term.</td></tr>
<tr><td colspan="3">Summary (Overall) Objectives
Develop and document: (1) a generic strategy for promoting good practice; (2) a prototype electronic library of best practice; and (3) a method for creating scenarios for how the rural landscape might evolve over the next several decades, including the influence of policies which affect flooding and the effects of climate change.</td></tr>
<tr><td colspan="3">Context (Background)
An electronic library of best practice would be a live document that can be amended and expanded. Its main purpose would be as a guide to catchment managers. The practices listed and described in the library should include methods to ensure or increase the uptake of flood prevention and mitigation measures by farmers and other land managers, as well as the best flood prevention and mitigation measures to be applied in a wide variety of different circumstances.

Policy development requires consideration of the long term outcome of decisions made for flood prevention and mitigation and consideration of the factors which will influence the development of the rural landscape over the longer term. These outcomes and the effects of these factors are best explored by developing scenarios which can be quantified and compared using models. This should draw on the work carried out by the Office of Science and Technology's Foresight Programme and the recent Foresight Flood and Coastal Defence Project.

The review in FD2114/TR: Impact Study Report is quite comprehensive and a draft guidance note can be prepared based solely on this review, making accessible a distilled version of what is currently known about the flood impact of changes in rural land use and management. This would include information on the available prevention and mitigation measures and the socio-economics aspects of managing the implementation of measures.</td></tr>
<tr><td colspan="3">Main Outputs / User / Benefits
• Draft guidance note, written in first few months of project.
• Document describing a generic strategy for promoting good practice.
• Prototype electronic library of information on best practice.
• Document describing how scenarios can be developed for how the rural landscape might evolve over the next several decades, including the influence of policies which affect flooding and the effects of climate change.</td></tr>
<tr><td colspan="3">Timescale / Costs / Costs by year: Total cost: £150K</td></tr>
<tr><td colspan="3">Other Funders (internal or external)?</td></tr>
<tr><td colspan="3">PREPARED BY: Project FD2114 consortium.</td></tr>
<tr><td colspan="3">Which one of the following types of R&D would this project come under:</td></tr>
<tr><td><u>Operational</u></td><td><u>Policy</u></td><td>Strategy</td></tr>
<tr><td colspan="3">Which would be the main EA Theme that this project would come under:</td></tr>
<tr><td>Adapting to Climate change</td><td><u>Reducing Flood Risks</u></td><td>Ensuring the Air is Clean</td></tr>
<tr><td>Using Natural Resources Wisely</td><td>Improving Inland/Coastal Waters</td><td>Protecting / Restoring the Land</td></tr>
<tr><td>Greening the Business World</td><td>Quality of Life</td><td>Enhancing Wildlife</td></tr>
<tr><td colspan="3">Principal Defra / EA Theme: Broad-scale modelling</td></tr>
</table>

A.8 Project M8: risk-based assessment of prevention and mitigation measures

<table>
<tr><td colspan="3">TITLE: Risk-Based Assessment of Prevention and Mitigation Measures</td></tr>
<tr><td colspan="3">Purpose (Key Customer) - Why is the R&D needed?
Changes in rural land use and management can affect the local runoff regime, so can change the local flood risk and the flood risk downstream. The change in risk at any location is related to the change in the flood frequency curve (FFC) at that location, and the FFC is best estimated using continuous simulation rainfall-runoff modelling. Existing methods to estimate FFCs and the uncertainty in FFCs are inadequate, so new rigorous methods should be developed, which can be applied using the best available rainfall-runoff modelling.</td></tr>
<tr><td colspan="3">Summary (Overall) Objectives
Develop, test and document rigorous generic methods for using continuous simulation rainfall-runoff modelling to estimate changes in flood frequency curves deriving from flood prevention and mitigation measures.</td></tr>
<tr><td colspan="3">Context (Background)
Continuous simulations of runoff can be used to create flood frequency curves (FFCs). Existing rainfall records can be augmented by synthetic records created using a stochastic rainfall generator, so that the simulations can be run for a long period and a wide range of flood responses are simulated. Depending on the nature of the rainfall-runoff model, simulation results will be available for the runoff rates (and volumes and river stage) at several locations in the catchment, so a single set of simulation results can be used to create FFCs at several locations where flood risk is to be assessed.

The change in local and downstream flood risk caused by changes in rural land use and management is related to the change in the FFC. If good estimates are to be made for the change in risk associated with flood prevention and mitigation measures, methods are needed for estimating the change in the FFC and the uncertainty in this change. A rigorous but practical approach needs to be developed which can be used with any rainfall-runoff model and overcomes some of the limitations of existing methods, especially in the way that uncertainty is estimated. The main limitations of the existing methods for estimating uncertainty is that they require Monte Carlo simulations, which may be impractically expensive for some models and applications, especially if very long simulations must be run, and rather than taking a wide view of all the factors contributing to uncertainty they associate it only with uncertainty in the model's parameters.</td></tr>
<tr><td colspan="3">Main Outputs / User / Benefits
Document specifying the details of the developed methods, how they were tested, and how the methods can be applied operationally when assessing the local and downstream effects of flood prevention and mitigation measures.
Fully documented open-source software for applying the method using any rainfall-runoff model.</td></tr>
<tr><td colspan="3">Timescale / Costs / Costs by year: Total cost: £150K</td></tr>
<tr><td colspan="3">Other Funders (internal or external)?</td></tr>
<tr><td colspan="3">PREPARED BY: Project FD2114 consortium.</td></tr>
<tr><td colspan="3">Which one of the following types of R&D would this project come under:</td></tr>
<tr><td><u>Operational</u></td><td>Policy</td><td>Strategy</td></tr>
<tr><td colspan="3">Which would be the main EA Theme that this project would come under:</td></tr>
<tr><td>Adapting to Climate change</td><td><u>Reducing Flood Risks</u></td><td>Ensuring the Air is Clean</td></tr>
<tr><td>Using Natural Resources Wisely</td><td>Improving Inland/Coastal Waters</td><td>Protecting / Restoring the Land</td></tr>
<tr><td>Greening the Business World</td><td>Quality of Life</td><td>Enhancing Wildlife</td></tr>
<tr><td colspan="3">Principal Defra / EA Theme: Broad-scale modelling</td></tr>
</table>

A.9 Project M9: multiscale monitoring

TITLE: Multiscale Monitoring

Purpose (Key Customer) - Why is the R&D needed?
A better understanding is needed of the link between local scale changes in land use and management and larger-scale downstream flooding, so that reliable methods can be developed for predicting the downstream impacts of flood prevention and mitigation measures.

Summary (Overall) Objectives
Develop an understanding of the way that changes in runoff propagate downstream. Contribute to the CHASM and LOCAR programmes and obtain the maximum available information on downstream propagation in the CHASM and LOCAR catchments.

Context (Background)
A change in land use or management practice can affect the local runoff, for example through changing the volume capacity for local storage or by increasing infiltration. Flow propagates downstream, and in a general sense, information (and the consequences of changes in land use and management) propagate downstream with the flow. One question that must be answered when assessing the flood impact of a change in land use and management is how does the change in local runoff affect what happens downstream: how does it affect the flow through the surface water network, from one confluence to the next. Methods are needed to represent this downstream propagation, but these must be based on a sound understanding on how propagation works at a range of scales, from the agricultural field scale upwards.

The CHASM and LOCAR catchments are not representative of the lowland landscapes most affect by flooding, but there is active programmes of multiscale monitoring underway in these catchments, and they do represent source areas for runoff generation. The most efficient way to obtain information on the way that changes in runoff propagate downstream is therefore to contribute to the CHASM and LOCAR programmes and to benefit from their comprehensive datasets.

Main Outputs / User / Benefits
- Document summarising concepts for the way that changes in runoff propagate downstream, supported by data, including data from the CHASM and LOCAR catchments.
- Fully documented quality-assured datasets for use in testing rainfall-runoff modelling for estimating downstream flood impact.

Timescale / Costs / Costs by year: Total cost: £100K

Other Funders (internal or external)?

PREPARED BY: Project FD2114 consortium.

Which one of the following types of R&D would this project come under:

Operational	Policy	Strategy

Which would be the main EA Theme that this project would come under:

Adapting to Climate change	Reducing Flood Risks	Ensuring the Air is Clean
Using Natural Resources Wisely	Improving Inland/Coastal Waters	Protecting / Restoring the Land
Greening the Business World	Quality of Life	Enhancing Wildlife

Principal Defra / EA Theme: Broad-scale modelling

A.10 Project M10: farm-scale integrated runoff management

TITLE: Farm-Scale Integrated Runoff Management		
Purpose (Key Customer) - Why is the R&D needed? Interventions that delay runoff, such as creating temporary storage ponds and permanent wetlands, are likely to be important components of any future integrated runoff management plans designed for on-farm control of pollution, erosion soil loss, and flooding. Trials are needed for interventions of this sort, and the results from these trials need to be interpreted in the context of the effects of rural land use and management on local and downstream flood impact.		
Summary (Overall) Objectives Contribute to the intervention trials at the Earth Systems Laboratory Initiative on Sustainable Farms being implemented at Nafferton Farm, near Newcastle, and interpret the outcome from these trials in the context of the cost versus benefit for controlling local and downstream flooding.		
Context (Background) There may be several reasons for controlling runoff from a particular farm or region, including the control of river pollution and the loss of soil by erosion, as well as to reduce the risk of local or downstream flooding. In most cases this will require the local runoff to be reduced or delayed. There is a need, therefore, for integrated runoff management, so that the full consequences of proposed interventions are considered in as wide a context as possible. The most efficient way to obtain high-quality field information of interventions is to contribute to the Earth Systems Laboratory Initiative on Sustainable Farms being implemented at Nafferton Farm, near Newcastle, where several interventions are being tested, including adding temporary storage and creating a permanent wetland.		
Main Outputs / User / Benefits • Document on the Nafferton Farm trials and the analysis of cost versus benefit for the interventions. • Fully documented quality-assured datasets for the trials, for use in testing rainfall-runoff modelling for estimating local and downstream flood impact.		
Timescale / Costs / Costs by year: Total cost: £100K		
Other Funders (internal or external)?		
PREPARED BY: Project FD2114 consortium.		
Which one of the following types of R&D would this project come under:		
<u>Operational</u>	Policy	Strategy
Which would be the main EA Theme that this project would come under:		
Adapting to Climate change	<u>Reducing Flood Risks</u>	Ensuring the Air is Clean
Using Natural Resources Wisely	Improving Inland/Coastal Waters	Protecting / Restoring the Land
Greening the Business World	Quality of Life	Enhancing Wildlife
Principal Defra / EA Theme: Broad-scale modelling		

A.11 Project M11: characterising runoff generation

TITLE: Characterising Runoff Generation		
Purpose (Key Customer) - Why is the R&D needed? The soil physics and hydrology module plays a central role in any rainfall-runoff model used to predict the flood impacts of changes in rural land use and management. Data are needed for this module, so that the effects of soil compaction and the presence of different types of vegetation and so forth can be represented by those of the module's parameters which control runoff generation, which then allows changes in land use and management to be represented as changes in those parameters.		
Summary (Overall) Objectives Create and document a data set on the infiltration properties of a range of different soil types under a range of land covers and subject to a range of farming practices. Review the existing soil and vegetation datasets suitable for use in soil physics and hydrology modules, and assess their availability, coverage, reliability, and potential use in assessing the flood impact of changes in rural land use and management.		
Context (Background) The scope of the modelling in the soil physics and hydrology modules used in rainfall-runoff modelling varies from model to model, and can include subsurface lateral runoff and underdrainage. The usual role of the modules is, however, to control transpiration and infiltration. There are various ways that infiltration is represented, but what is lacking, in general, is extensive reliable sets of data which characterise infiltration under a wide range of different soil types, land covers and management practices. There are considerable existing resources for characterising infiltration, such as permeameters, infiltration equations, and equations linking saturated hydraulic conductivity to readily measurable quantities such as particle size distribution. The real problem however involves assessing the infiltration and runoff properties of large areas. If a rapid measurement technique is adopted or developed for assessing point-scale infiltration properties, through repeated use this can be used to characterise the infiltration properties of areas (e.g. the heavily and lightly trafficked areas in an agricultural field), and the data collected can be used to build up the necessary dataset on point-scale properties. An aggregation (upscaling) procedure needs to be used to derive the large-scale infiltration properties, which, for example, takes into account the connectivity of the low infiltration areas (as these will be runoff pathways during storms). Despite there being extensive literature on upscaling, this procedure will need to be developed in a pragmatic fashion because there are no reliable existing upscaling methods.		
Main Outputs / User / Benefits • Document summarising the existing datasets for soil and vegetation data suitable for use in soil physics and hydrology modules, including their availability, coverage, reliability, and potential use in assessing the flood impact of changes in rural land use and management. Should also identify which new datasets are needed. • Document specifying how the existing data should be used in soil physics and hydrology modules. • Documentation (and prototype equipment, if appropriate) for a method for rapid measurement of infiltration properties. • Fully documented open-source software and upscaling methods for estimating large scale infiltration properties using point-scale infiltration measurements and other data. • New dataset on infiltration properties for a range of different soil types under a range of land covers and subject to a range of farming practices collected using the rapid measurement method.		
Timescale / Costs / Costs by year: Total cost: £200K		
Other Funders (internal or external)?		
PREPARED BY: Project FD2114 consortium.		
Which one of the following types of R&D would this project come under:		
<u>Operational</u>	Policy	Strategy
Which would be the main EA Theme that this project would come under:		
Adapting to Climate change	<u>Reducing Flood Risks</u>	Ensuring the Air is Clean
Using Natural Resources Wisely	Improving Inland/Coastal Waters	Protecting / Restoring the Land
Greening the Business World	Quality of Life	Enhancing Wildlife
Principal Defra / EA Theme: Broad-scale modelling		

A.12 Project L1: open-architecture hierarchical rainfall-runoff modelling

TITLE: Open-Architecture Hierarchical Rainfall-Runoff Modelling

Purpose (Key Customer) - Why is the R&D needed?
Rigorously obtaining good estimates for the change in flood risk associated with rural land use change and management practices requires rainfall-runoff modelling which gives accurate estimates for the change in the flood frequency curve (FFC), and gives accurate estimates of the uncertainty in the change in the FFC. A modern, transparent, user-friendly framework is needed so that rainfall-runoff modelling approaches can be tested for this purpose in a consistent fashion. The framework would allow the best approaches to be identified, and could be used in operational estimation of flood risk and in research designed to improve the modelling of runoff.

Summary (Overall) Objectives
Create, test and document an open-architecture hierarchical rainfall-runoff modelling system, which will have all the modelling and data handling and results presentation components and capabilities needed to model runoff in catchments using the best modelling approaches at a range of different complexities for use in assessing the effects of land-use changes and management practices on local and downstream runoff and flooding.

Context (Background)
Considerable progress must be made with rainfall-runoff modelling if good predictions are to be made for the likely effects of flood mitigation measures, changes in land management practices, and so forth. The current modelling has not been rigorously tested for such purposes and it is unlikely that existing models will prove to be reliable and adequately accurate.

A range of different modelling approaches needs to be tested rigorously and consistently, so the best approaches can be identified. There will be a "best" approach at each of several levels of complexity, from simple lumped modelling to distributed physically-based modelling, and each of these approaches will have its own strengths and uses.

There is a move in management practice towards reliance on computer-based tools that work within an open-architecture environment (i.e. a plug-and-play environment, where different models and datasets can simply be plugged in and are automatically compatible with the rest of the modelling and datasets). The open-architecture hierarchical system for rainfall-runoff modelling will allow the necessary testing to be carried out in a transparent and consistent fashion and will give rainfall-runoff modules and a modelling system that can be used in operational management decision support and in supporting policy development and can also be used in research to improve those aspects of rainfall-runoff modelling found to be inadequate.

The emphasis in the project should be, as far as practical, on the rainfall-runoff modelling rather than developing generic structures for an open-architecture environment, even if this means that the final outcome is not, from a computer scientist's viewpoint, a fully-developed open-architecture system.

Main Outputs / User / Benefits

- The core components of the open-architecture hierarchical rainfall-runoff modelling system, including input and results handling and generic (plug-and-play) interfaces for the rainfall-runoff modules.
- Complete sets of rainfall-runoff modules for a range of different modelling types and complexities.
- User manual.
- Documentation on test methods and the history of testing.
- Design documents for the rainfall-runoff modules.
- Guidance and training material for using the system to assess the effects of land use change and management practices on local and downstream runoff.

Timescale / Costs / Costs by year: Total cost: £400K

Other Funders (internal or external)?

PREPARED BY: Project FD2114 consortium.

Which one of the following types of R&D would this project come under:

Operational	Policy	Strategy

Which would be the main EA Theme that this project would come under:

Adapting to Climate change	Reducing Flood Risks	Ensuring the Air is Clean
Using Natural Resources Wisely	Improving Inland/Coastal Waters	Protecting / Restoring the Land

Greening the Business World	Quality of Life	Enhancing Wildlife
Principal Defra / EA Theme: Broad-scale modelling		

A.13 Project L2: multiscale experimentation, monitoring and modelling

TITLE: Multiscale Experimentation, Monitoring and Modelling

Purpose (Key Customer) - Why is the R&D needed?
The move towards whole-catchment integrated approaches to catchment management requires support from whole-catchment multiscale experimentation, monitoring and modelling. A better understanding is needed of the link between local scale changes in land use and management and larger-scale downstream flooding, so that reliable methods can be developed for predicting the downstream impacts of flood prevention and mitigation measures. Multiscale monitoring is currently being used in several catchments, as part of the CHASM and LOCAR programmes, but these catchments are not representative of the lowland landscapes most affect by flooding. New catchments therefore need to be instrumented and monitored.

Summary (Overall) Objectives
To instrument one or more catchments where local and downstream flooding are known to be a problem and conduct multiscale experimentation, monitoring and modelling designed to gain a better understanding of the link between local scale changes in land use and management and larger-scale downstream flooding.

Context (Background)
In management decision making the full effects of any proposed flood prevention and mitigation measures need to be considered, including the effects seen downstream. It is therefore essential that catchments where local and downstream flooding are known to be a problem should be instrumented and monitored. Data from the test catchments should be made available in a form suitable for testing methods for predicting local and downstream flood impacts.

Given that it is expensive to instrument catchments, it would clearly be sensible if the instrumented catchments are also used in related studies planned under other projects, programmes, and themes, such as studies of integrated runoff management and pollution control.

Main Outputs / User / Benefits
- Document describing the multiscale experimentation, monitoring and modelling, including the experimental design and results.
- Fully documented quality-assured datasets for use in simulating the catchments using rainfall-runoff models.

Timescale / Costs / Costs by year: Total cost: £800K

Other Funders (internal or external)?

PREPARED BY: Project FD2114 consortium.

Which one of the following types of R&D would this project come under:

Operational	Policy	Strategy

Which would be the main EA Theme that this project would come under:

Adapting to Climate change	Reducing Flood Risks	Ensuring the Air is Clean
Using Natural Resources Wisely	Improving Inland/Coastal Waters	Protecting / Restoring the Land
Greening the Business World	Quality of Life	Enhancing Wildlife

Principal Defra / EA Theme: Broad-scale modelling

A.14 Project L3: trials of mitigation measures

TITLE: Trials of Mitigation Measures		
Purpose (Key Customer) - Why is the R&D needed? One of the problems in predicting the outcome of applying a given flood mitigation measure over a given area at a given location in catchment is that the outcome depends on many factors. This means that a wide range of field trials are required to support the tools used to predict local and downstream flood impacts as part of operational decision making and policy development.		
Summary (Overall) Objectives To conduct and document a set of field trials for a range of flood mitigation measures applied in a range of different situations.		
Context (Background) When selecting the best measures for flood mitigation on a particular farm or at a particular location, the best support possible is knowledge of the outcome when the candidate measures were applied previously under similar conditions. The next best support is assessments of the likely outcomes of various measures, based on modelling which uses, and has been tested against, data from field tests.		
Main Outputs / User / Benefits • Document describing the field trials and results. • Document containing recommendations for the best practices in flood mitigation.		
Timescale / Costs / Costs by year: Total cost: £425K		
Other Funders (internal or external)?		
PREPARED BY: Project FD2114 consortium.		
Which one of the following types of R&D would this project come under:		
Operational	Policy	Strategy
Which would be the main EA Theme that this project would come under:		
Adapting to Climate change	Reducing Flood Risks	Ensuring the Air is Clean
Using Natural Resources Wisely	Improving Inland/Coastal Waters	Protecting / Restoring the Land
Greening the Business World	Quality of Life	Enhancing Wildlife
Principal Defra / EA Theme: Broad-scale modelling		

A.15 Project L4: new measurement technologies

TITLE: New Measurement Technologies		
Purpose (Key Customer) - Why is the R&D needed? The quality of predictions for the likely outcome when flood prevention and mitigation measures are applied at a particular location depend on the quality and amount of data available for that location, and on the quality and amount of data available for the catchment within which the location lies. It is not yet known exactly which data are essential to predicting flood impacts, but there is a general need for improved rapid and remote methods for measuring rainfall, soil moisture and the flow in surface water networks.		
Summary (Overall) Objectives Develop rapid and cost effective methods for: (1) measurement of streamflow; (2) characterising catchment-scale space-time variability of rainfall; and (3) characterising the space-time variability of soil moisture status and the relationship to infiltration, runoff, soil conditions and management practices.		
Context (Background) A considerable amount of data are required if the variability and complexity of a catchment's runoff behaviour are to be characterised at any significant level of detail. Some rapid and remote-sensing measurement methods are currently used for this purpose, but substantial progress is still needed. In particular, methods are needed for river gauging for use in studying the link between local changes in land use and management and downstream flooding. There is also a need for improved measurement of the space-time variability of rainfall, to reduce the considerable uncertainty introduced in rainfall-runoff modelling if the rainfall data used to drive the modelling are based on measurements taken at only a few locations. Finally, there is a need for improved measurement of the space-time variability of soil moisture conditions and the relationship to infiltration, runoff, soil conditions and management practices, so this can be used to investigate the effects of land use and management change on local runoff. There are several promising measurement technologies for this work, including: portable ultrasonic gauges for streamflow; mobile radars for rainfall; remote sensing; and mounting probes on mobile platforms (e.g. tractors) for soil moisture measurement.		
Main Outputs / User / Benefits • Documents describing the best methods to meet each of the three objectives, and the results obtained in testing. • Specification for the use of new measurement technologies in research and the operational assessment of the effect of proposed flood prevention and mitigation measures.		
Timescale / Costs / Costs by year: Total cost: £300K		
Other Funders (internal or external)?		
PREPARED BY: Project FD2114 consortium.		
Which one of the following types of R&D would this project come under:		
<u>Operational</u>	Policy	Strategy
Which would be the main EA Theme that this project would come under:		
Adapting to Climate change	<u>Reducing Flood Risks</u>	Ensuring the Air is Clean
Using Natural Resources Wisely	Improving Inland/Coastal Waters	Protecting / Restoring the Land
Greening the Business World	Quality of Life	Enhancing Wildlife
Principal Defra / EA Theme: Broad-scale modelling		

A.16 Project L5: longer-term perspectives

TITLE: Longer Term Perspectives		
Purpose (Key Customer) - Why is the R&D needed? Policy development requires consideration of the long term outcome of decisions made for flood prevention and mitigation and consideration of the factors which will influence the development of the rural landscape over the next several decades.		
Summary (Overall) Objectives Create, analyse and document integrated socio-economic, hydrological, and climatic scenarios for the development of the rural landscape over the next several decades, including the effects of policies and promotions for flood prevention and mitigation practices which affect rural land use and management.		
Context (Background) The extent of local and downstream flooding for a catchment or area within a catchment depends on: (1) factors such as the climate and the catchment's topography and soils; (2) factors within the control of the government and agencies, such as the historical and current policies related to land use and management practices and related to pollution control and so forth; and (3) how local land managers have developed and managed the land in response to all the pressures they face, including socio-economic pressures. This complexity needs to be considered when assessing the potential widespread and long term effects that might result from implementing policies and promotions aimed at flood prevention or mitigation. Future scenarios can be developed and analysed for specific catchments and regions, so that the complexity and uncertainty associated with predicting the outcome of given flood prevention and mitigation measures can be explored.		
Main Outputs / User / Benefits • Document describing the future scenarios and the analysis. • Fully documented data sets for the scenarios and the output from scenario simulations.		
Timescale / Costs / Costs by year: Total cost: £250K		
Other Funders (internal or external)?		
PREPARED BY: Project FD2114 consortium.		
Which one of the following types of R&D would this project come under:		
Operational	<u>Policy</u>	Strategy
Which would be the main EA Theme that this project would come under:		
Adapting to Climate change	<u>Reducing Flood Risks</u>	Ensuring the Air is Clean
Using Natural Resources Wisely	Improving Inland/Coastal Waters	Protecting / Restoring the Land
Greening the Business World	Quality of Life	Enhancing Wildlife
Principal Defra / EA Theme: Broad-scale modelling		

Appendix B: the DPSIR tool

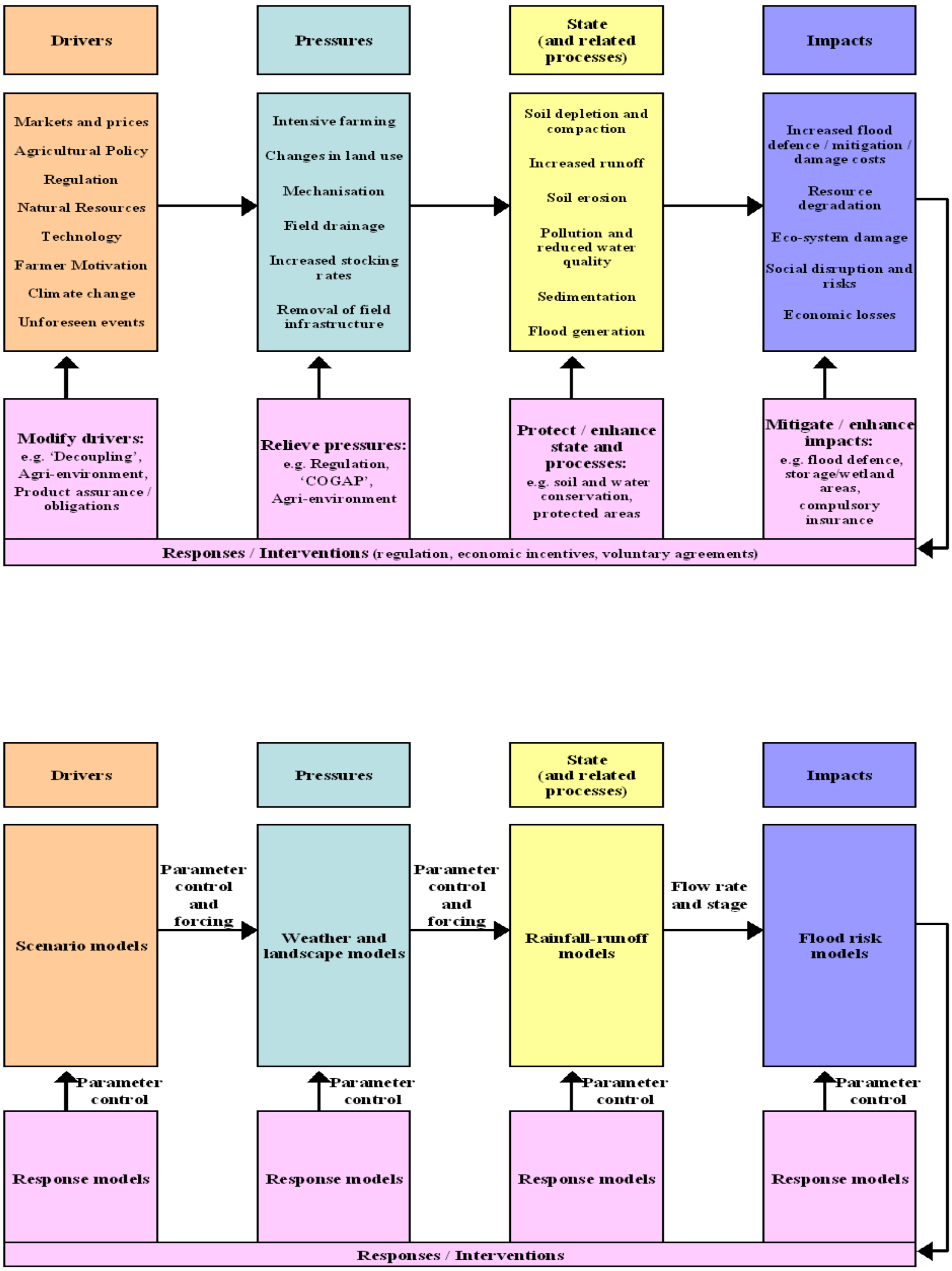
The proposed DPSIR tool is a collection of models, data and procedures that represents a distillation of what is known about the effects of rural land-use change and management practices on local and downstream flooding. It allows a wide range of general and site specific questions to be asked and answered. Figure B-1 shows the DPSIR framework, which defines the overall structure of the DPSIR tool, and also shows the basic structure of models and information transfers within the tool. The main ways that information moves within the tool is through "input control" and "parameter control". For "input control", the output from one model is used as input to another model - for example, rainfall and meteorological forcing data from a weather model are input to a rainfall-runoff model, and flow rates and stages from a rainfall-runoff model are input to a flood risk model (in which flood risk is calculated). For "parameter control", the output from one model affects the parameter values in another model - for example the stocking rates from a landscape model affects the infiltration parameters in a rainfall-runoff model.

Much of the knowledge about the effects of rural land use change and management practices on local and downstream flooding lies in the "parameter controls" (for example knowledge about the link between stocking rates, soil types, soil management practices, grassland properties and infiltration). Most of the "parameter controls" will be look-up tables, but some may use more complex forms of modelling. For the link between stocking rates and infiltration, for example, a look-up table is appropriate, linking stocking rates to infiltration parameters for a range of soil types, soil management practices, and grassland properties. The feedback loop via responses and interventions is by "response models" and "parameter control". Note that all the "response models" are connected, so the effects of any response or intervention can have an effect at any level - driver, pressure, state or impact. Typical examples of "response models" are a model for calculating flood defence barrier levels to be used in the flood risk modelling, and a model (which could be in the form of a look-up table) for the change in hydraulic properties associated with improving the drainage capacity of the local surface water network, through ditch maintenance for example.

The rainfall-runoff models and weather models will be quite complex, but many of the other models will be simple. The flood risk models need to estimate flood risk, so must include methods for creating flood frequency curves using simulation results from rainfall-runoff models and methods for assessing the consequences of flooding. It is likely that most of the "landscape models" will be quite simple, such as look-up tables linking underdrainage installation effort to the level of subsidy payments. The scenario models have two main purposes. They have to generate scenarios for periods of 50 to 100 years for investigating the effects of climate change and policy development. They also have to generate multiple data sets for static conditions for use in sensitivity analyses, such as sets defining conditions associated with different levels of farm income support.

The tool will need several generic procedures and a graphical user interface, to make it flexible enough for use in research and robust and simple enough for use in operational assessments and decision support. Two particularly important procedures are for managing scenarios and ensemble simulations. One of their main uses is for handling uncertainty associated with socio-economic factors and rainfall-runoff modelling, by exploring (through multiple scenarios and multiple simulations) the relationship between uncertainty in assumptions and parameter values and uncertainty in predictions of flood impact. The bottom diagram in Figure B1 shows only the computational "engine" of the tool. The procedures for managing scenarios and ensemble simulations control this "engine" and ensure that everything is coherent and consistent. In effect, the procedures lie at a higher level in the structure of the tool, alongside the user interface. At a similar level to the "engine", there are databases and procedures for handling spatial and timeseries data.

Figure B1 The DPSIR framework (top diagram; reproduced from FD2114/TR) and the DPSIR models and transfers (bottom diagram).



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