Office of Science and Technology

Main Report

Foresight Flood and Coastal Defence Project

Phase 1 Technical Report
Drivers, scenarios and work plan

January 2003

This report was prepared as technical advice to the Office of Science and Technology. We would welcome comments on any part of it, to contribute to the development of this project.
1 Introduction

1.1 Aims and objectives
The aim of the Foresight project is to produce a long-term vision for the future of flood and coastal defence which takes account of the many uncertainties, but which is nevertheless robust, and which can be used as a basis to inform policy. This vision, and the work covered in the Phase 1 report:

- relates to England, Scotland Wales and Northern Ireland;
- looks 30-100 years into the future;
- covers pluvial, fluvial, coastal and fluvial/tidal flooding and coastal erosion; and
- considers economic, social and environmental impacts.

The project will address the following objectives, to:

- identify and assess the relative importance of the threats that need to be taken into account in long term planning on flood and coastal defence;
- construct a set of risk based scenarios taking those factors into account over a 30-100 year timescale and addressing social, economic and environmental issues;
- provide an overview of the responses available and key issues that determine those responses; and
- use this work to inform policy and its delivery.

In addition, the work will:

- identify implications for the future skills base;
- identify knowledge and technologies that might be transferred from other sectors and inform long-term needs for research in this area;
- consider international business opportunities from UK expertise in this area;
- inform the public understanding and debate on flood and coastal defence;
- promote an effective and enduring dialogue between the science base; and stakeholders and between those with an interest in flood and coastal defence.

Phase 1 contributes to the first two project objectives by identifying the most important drivers for future flood risk, and by scoping the work required to assess the impact of those drivers. The key tasks in this are:

- establish a logical framework to consider the drivers, their potential impact, and how future flood risk might be managed;
- identify the drivers that could affect future flood risk, how they operate and how they interrelate;
- assess their relative importance, taking into account how they interrelate;
- provide a plan for work packages to assess the potential impact of the drivers and
- work plan will include the development of scenarios for future flood risk; and
1.2 Approach to Phase 1

In Phase 1 we set out to satisfy the objectives by:

- assembling a core team consisting of an inner circle of highly experienced experts drawn from leading institutions in both academia and industry;
- initiating the project with a brainstorming session for this core team;
- engaging the wider scientific and user community through a workshop, with each of the inner circle complemented by other experts to provide depth and to cover any knowledge gaps in the inner circle;
- using the Foresight website as an open forum to invite and promote further involvement;
- providing a clear picture of the drivers, their inter-relationships and relative importance using the knowledge and judgement of the experts;
- drawing up a logical plan in conjunction with the Environment Agency’s National Centre for Risk and Forecasting, which will serve as the foundation for the whole Flooding project; and
- providing a well defined work plan for the Flooding project, which will give a route map not only to establishing the risks under the baseline futures scenarios but for the subsequent work on responses.

It should be noted that it is not the intention that Phase 1 should consider possible responses, but it should produce an outline structure and approach for their consideration in Phase 3 of the project.

The specification for Phase 1 is included at Appendix A and the process adopted for Phase 1 is illustrated below:

![Figure 1.1 Phase 1 process](image-url)
A number of useful meetings were held with the Office of Science and Technology (OST) team throughout the process. The authors also acknowledge the contribution of the project’s technical expert advisory group and high-level ministerial stakeholder group. A list of core team members and those who attended the brainstorming session and workshop, with their knowledge areas, is given below:

<table>
<thead>
<tr>
<th>Name</th>
<th>Organisation</th>
<th>Knowledge areas</th>
</tr>
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<tr>
<td><strong>Core team</strong></td>
<td></td>
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<tr>
<td>Edward P Evans</td>
<td>Consultant</td>
<td>Team Leader/catchment planning and engineering</td>
</tr>
<tr>
<td>Prof Edmund Penning-Rowseell</td>
<td>Middlesex University</td>
<td>Flood economics and social impacts</td>
</tr>
<tr>
<td>Dr Jim Hall</td>
<td>Bristol University</td>
<td>Risk management</td>
</tr>
<tr>
<td>Prof Richard Ashley</td>
<td>Bradford University</td>
<td>Urban drainage</td>
</tr>
<tr>
<td>Dr Kieran Conlan</td>
<td>Cascade Consulting</td>
<td>Environment</td>
</tr>
<tr>
<td>Dr Cath Senior</td>
<td>Hadley Centre – Met Office</td>
<td>Meteorology/climate change</td>
</tr>
<tr>
<td>Prof Colin Thorne</td>
<td>Nottingham University</td>
<td>Fluvial morphology</td>
</tr>
<tr>
<td>Ian H Townend</td>
<td>ABPMER – Marine Environmental Research</td>
<td>Estuaries and coasts</td>
</tr>
<tr>
<td>Dr Richard Young</td>
<td>Consultant</td>
<td>Estuaries and coastal engineering</td>
</tr>
<tr>
<td>Robert Thomes</td>
<td>Office of Science and Technology</td>
<td>Project co-ordinator</td>
</tr>
<tr>
<td><strong>Complementary experts</strong></td>
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<tr>
<td>Prof Trevor Baker</td>
<td>Proudman Oceanographic Lab</td>
<td>Coasts/climate change</td>
</tr>
<tr>
<td>Dr Simon Brown</td>
<td>Hadley Centre</td>
<td>Meteorology/climate change</td>
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<tr>
<td>Dr Martina Garcia</td>
<td>HM Treasury</td>
<td>Economics</td>
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<tr>
<td>Dr Trevor Hoey</td>
<td>Glasgow University</td>
<td>Rivers</td>
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<td>Prof Stuart Lane</td>
<td>Leeds University</td>
<td>Catchment modelling and geomorphology</td>
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<td>Mark Lintell</td>
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<td>Ian Meadowcroft</td>
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<td>Risk management</td>
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<td>Prof Joe Morris</td>
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<td>Agriculture</td>
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<tr>
<td>Prof Robert Nicholls</td>
<td>Middlesex University / Tyndall Centre</td>
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<td>Prof Julian Orford</td>
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<td>Prof John Petthick</td>
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<td>Phil Reaney</td>
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<td>Urban drainage</td>
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<tr>
<td>Dr Nick Reynard</td>
<td>Centre for Ecology and Hydrology - Wallingford</td>
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<tr>
<td>Keith Riddell</td>
<td>Babtie Group</td>
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<td>Dr Paul Samuels</td>
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<td>Rivers and climate change</td>
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<td>Dr Suresh Surendran</td>
<td>Environment Agency</td>
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</tr>
<tr>
<td>Prof Howard Wheater</td>
<td>Imperial College</td>
<td>Hydrology</td>
</tr>
</tbody>
</table>

Table 1.1 Phase 1 participants and knowledge areas.

This report now goes on to consider the drivers logical framework, drivers identification and descriptions, drivers ranking, the work plan for assessment of the drivers under the baseline futures scenarios, and the outline structure for the assessment of flood management responses.
2 Logical framework for analysis of drivers and responses

The logical framework provides a set of definitions and a conceptual structure for analysis of future changes to flooding and coastal erosion and, in subsequent stages in the Foresight project, analysis of responses. In the course of the project the logical framework has proved to be an essential aid to communication and has allowed expert judgement to be exercised in a rigorous manner.

2.1 The flooding system

The proposed framework is based on the concept of a flooding system, which encompasses all of those physical and organisational systems that influence or are influenced by flooding. Figure 2.1 shows a hydraulic view of the flooding system, illustrating the process of precipitation, marine storms and water flows that result in flooding. However, the hydraulic view of flooding is not the unique perspective on the flooding system. Transfers of sediments can, from some points of view, be regarded as being as influential as transfers of water. Moreover, the flooding system encompasses not only physical processes but also the organisational systems that influence or are influenced by flooding (Hall et al. 2002), such as:

- **physical attributes of the earth’s surface involved in the water cycle**: that is the processes of rainfall, snow melt and marine storms that lead to fluvial and coastal flooding, runoff from the land, groundwater flows and flood inundation in fluvial floodplains and coastal lowlands;
- **man-made systems of drainage, storage and flood defence** intended to convey flood discharges and resist or control inundation of floodplains;
- **economic, social and environmental assets that are located in floodplains** and are impacted by flooding and/or have an impact on the flooding process;
- **organisations with a statutory responsibility for managing flood risk**. These may be government organisations or other organisations with duties or powers to manage flood risk,
- **Insurers**, who provide cover for flood risks,
- **Broader stakeholder groups** with an interest or role in the impacts (both positive and negative) of flooding and the actions that may be taken to manage flooding.
Figure 2.1: A hydraulic perspective of the physical flooding system

**System descriptors**
The flooding system is continuously changing through time. At any point in time the system can be thought of as having an instantaneous state. This is a ‘snapshot’ of the flooding system. That state can be captured in terms of a series of descriptors. Typical descriptors might be flood defence levels, numbers of properties in the floodplain, etc.

Some descriptors may be naturally fluctuating, for example rainfall intensity or tide level in an estuary. Therefore in a given state these descriptors will be characterised by probability distributions. The notion of state in this sense relates to stable (stationary) time-averaged behaviour, and is the one used in this report.

**Flood risk**
In any given state, the flooding system will have a stable level of flood risk associated with it, where risk is thought of in the conventional sense of being a function of probability and consequence of flooding. The risk estimate will in general be a multi-attribute descriptor encompassing economic, health, social and environmental impacts. Although risk is usually thought of as relating to harmful impacts this is not necessarily the case. Some impacts of flooding will be beneficial, particularly to the environment. These beneficial impacts can also be captured using a risk measure.

**Insurance in the UK**
Our society has developed certain ‘buffers’ to protect people and property from flood risk and damage. In this respect the universality of flood insurance in domestic insurance policies is almost unique worldwide. But there are complications: some 50% of people in the lowest UK income decile do not have flood insurance in this way, because they do not have household contents insurance. Hence, drivers enhancing risk will have a differential effect across society.

**Pluvial flooding**
Conventionally defined, flooding is a threat in certain fairly clearly designated and predetermined areas, termed ‘floodplains’. These occur along all rivers and at the coast, and represent the natural overflow areas where flow in excess of channel capacity will congregate, or where coastal storms drive water inland. Increasingly important, however are floods generated simply from extreme rainfall events that cannot discharge water quickly enough away into watercourses, or where watercourses have been culverted underground and cannot carry the large volumes that come, for example, from summer thunderstorms. This ‘pluvial flooding’ occurs both in urban areas, resulting from inadequate sewer capacity, culverted watercourses, or in rural areas where the rainfall accumulates on agricultural land and in towns and villages – sometimes for days or weeks - causing damage and disruption.

As noted above insurance forms an important element of flood risk management in the UK, and is based on a careful assessment of risk and the exposure of insurance companies, via the analysis of floodplain maps. Yet in the autumn 2000 event it is suggested that up to 50% of the 11,000 properties flooded were not in designated floodplains, but in small groups spread right across the country (and probably affected mostly by pluvial flooding). Indeed Environment Agency data shows that 50% of postcode locations flooded had less than three properties affected, and only 12.5% of all locations had more than 20 properties flooded.
Uncertainty
The logical framework must therefore be based on the concept that at any instance the flooding system (nationally, regionally or locally) can be described in terms of a set of descriptors and if the descriptors have given values there is a corresponding stable risk estimate, which captures all of the information on potential flood impacts (harmful and beneficial) that are of interest from a decision-making point of view. Naturally there will be uncertainty in estimates of descriptors, in how we map from these to risk estimates and in how we value the various impacts of flooding. The risk estimate for a given set of descriptors will therefore be stable but uncertain.

2.2 Change: Drivers and responses
The flooding system is constantly changing, and this is reflected in changes in the system descriptors over a range of time scales. Any phenomenon that may change the time-averaged state of the flooding system is referred to as a driver. Some of these drivers will be under the control of flood managers e.g. construction and operation of flood defence systems, or use of flood warning systems to reduce the consequences of flooding (that is, reduce the number of human receptors). Many other system descriptors, e.g. rainfall severity, or increasing values of house contents, are outside the control of flood managers and even government in general. A change in system state will usually result in a change in the corresponding estimate of risk.

The Foresight project seeks to address two aspects of change to the flooding system:
- long-term changes e.g. climate change or socio-economic changes that are expected to result in significant changes in flood risk; and
- policy responses to potentially harmful changes, which will change system state variables in order to reduce flood risk.

The distinction between these two types of driver is not crisp and in terms of policy relates to the extent to which government has power to influence change and the level of government at which power is influenced (Figure 2.4). For example local flood defence improvement decisions are devolved to local decision-makers, whereas decisions to limit emissions of greenhouse gasses are taken at a national and international level.

2.3 Definitions
Before describing the logical framework we introduce the following definitions.

Logical framework: The formal system for the analysis of drivers of flood risk and evaluation of responses.
Flooding system: All of those physical and human systems that cause, influence, or are influenced by flooding.
Sources: Weather-related phenomena (rainfall, marine storms, snow melt etc.) that generate water with flooding potential.
System descriptors: Measurable characteristics of the flooding system.
Pathways: Mechanisms by which water is transmitted from its source to places where it may impact receptors (e.g. runoff, fluvial flows, sea defence overtopping, floodplain inundation).
Receptors: People, industries, built and natural environments that can be impacted upon by flooding.
Flood Risk: A combination of the probability and consequences of flooding. To estimate flood risk will require a system model (which may be conceptual or quantified) that includes sources, pathways and receptors.

Risk dimensions: The points of view from which flood risk may be evaluated e.g. economic, safety, social, environmental.

Drivers: Any phenomenon that may change the state of the flooding system e.g. climate change, urbanisation, changing agricultural practices. A driver may change sources, pathways, receptors or a combination thereof.

Responses: Changes to the flooding system that are purposefully implemented to reduce flood risk. Responses are a sub-set of drivers.

Scenarios: A storyline of a set of changes to the flooding system that is consistent with the scenario label.

It should be noted that in our definition of the flooding system as shown in Figure 2.1 and described in the text, we take the weather-related sources as the “upstream” boundary of our system. We do not consider their drivers nor any feedback which may exist between the flooding system and weather.

The action of the drivers on the flooding system to change flood risk under a given futures different scenario and flood management policies is illustrated in Figure 2.2.

**Figure 2.2: Drivers, flooding system and flood risk under futures scenarios**

### 2.4 The Source-Pathway-Receptor model

A well-established framework in environmental risk assessment is the source-pathway-receptor model (DETR et al. 2000), which is based upon the causal linkage between the source of environmental hazard (for example a pollutant), the mechanism by which it is transmitted (for example in the groundwater) and the receptor, which suffers some harmful (in the case of pollution) impact. The same framework is useful in the context of flooding, as it reflects the physical processes by which flooding occurs. In the case of flooding:

- **Sources** are the weather events or sequences of events that may result in flooding (e.g. heavy or sustained rainfall, marine storms)
• **Pathways** are the mechanisms that convey flood waters that originate as extreme weather events to places where they may impact upon receptors. Pathways therefore include fluvial flows in or out of river channels, beach processes and failure of both fluvial and sea defence structures.

• **Receptors** are the people, industries and built and natural environments that may be impacted upon by flooding.

Figure 2.3 illustrates how different system descriptors, introduced above, can be related to sources, pathways or receptors. The division between sources, pathways and receptors is not definite and depends upon the context of the analysis, though this indeterminacy should not in principle be problematic.

### Figure 2.3: Time stationary Source-Pathway-Receptor framework for flood risk analysis

#### 2.5 Development of the logical framework

The objective of the logical framework is to provide a rational mechanism for analysis of future changes in the flooding system.

The Pressure-State-Impact-Response (P-S-I-R) model, based on the Pressure-State-Response model developed in the 1970s by the Canadian statistician Anthony Friend, is a well-established model for the analysis of long-term change in environmental and social systems, and has subsequently been adopted by the OECD's *State of the Environment* group. It underpins the Environment Agency’s State of the Environment reporting. In the PSIR model:

- socio-economic drivers lead to environmental pressures;
- environmental pressures lead to changes in environmental state;
- changes in environmental state are reflected in environmental and socio-economic impacts; and
- stakeholder gains/losses from impacts lead to policy responses.

The logical framework developed here is an adaptation of this approach. ‘Socio-economic drivers’ and ‘environmental pressures’ in the PSIR model are collectively referred to in the logical framework adopted in this report as ‘drivers’. We have developed our analysis of the system state in more detail by decomposing the system state using the Source-Pathway-Receptor (S-P-R) model. Thus drivers result in changes in system descriptors within the S-P-R model (Figure 2.4). Impacts are measured in terms of a risk estimate.
As pointed out above the distinction between these “drivers” and “responses” is not crisp and relates to the extent to which government has power to influence change and the level of government at which power is influenced (Figure 2.5):

Figure 2.4: Flood system changed by action of drivers

Figure 2.5: Some key flood drivers and other factors affecting flood risk classified according to degree of control
Thus finally we have a logical framework which is valid for the consideration of both drivers and responses:

![Diagram of the logical framework]

**Figure 2.6: The logical framework**

The figure includes an arrow from the risk estimate to responses, representing the completion of the feedback loop between the state, pressure, impact and response.

There may be other feedback and iteration loops in the flooding system, particularly as the consequences of an impact on the environment, which may result in an alteration of the pathways (and potentially sources) that then may have profound effects on future S-P-R relationships. For example, in estuarine systems there are feedback loops in salt marshes and mud flats between the biota, sedimentation and morphology which could over time significantly change the flood risk. This is particularly important for climate change where many of the more profound impacts are likely to result from iteration of biological processes (e.g. increasing desertification, greater inundation etc.) perhaps leading to wholesale changes in land use, aquatic character etc. It is often the subtle interaction of socio-economic and environmental drivers that cause the greatest changes – e.g. land use change, change in drainage patterns after the war etc. It is conceivable that these may represent some of the greatest long-term threats and opportunities for flood management.

### 2.6 Coastal erosion

The logical framework is generic in being in principle applicable to both flooding and coastal erosion. It has however been described above solely in terms of flood risk. As previous studies have demonstrated (MAFF, 2000), the direct economic loss from coastal erosion is currently small, though the harmful impact of coastal erosion on coastal communities is potentially much more significant.
2.7 Risk to the environment

There are two elements to this issue:

- The environment is not at risk as such as it will evolve with changing circumstance and adapt to a new set of driving criteria. For example, although riverine and floodplain habitats, communities and species may be influenced by a change in inundation level or periodicity, leading to a dynamic shift in ecosystem structure, it may be a positive rather than a negative contribution. As such, there is no real “risk” to the ecosystems themselves, rather a change in circumstance.

- However, the public perception of changes to the environment and its “natural” ecosystems may well represent a risk, influence the ranking (magnitude and significance) of flood impacts. In recent years there has been a move towards protection and restoration of aquatic and floodplain ecosystems. This has included actions to maintain and enhance certain populations (e.g. salmon) and measures to increase ecosystem diversity. The corollary of these actions is a perceived risk to the ecosystems and the dynamic changes that can occur, which in some circumstances can and should be argued as having a real influence on ecosystem integrity (e.g. canalisation, channel re-sectioning etc.). It is these environmental “risks” that are considered further here.

It is likely in the future that public perception of environmental issues will lead to even greater constraints on anthropogenic/forced human intervention and moves to a less harnessed ecosystem. Strangely this may well be achieved by greater manipulation of the ecosystem to return it to a more “pristine” state, as defined for example in the Water Framework Directive.

Although it cannot be predicted with any certainty, it is possible to see a time when the potential for change due to an alteration in flooding characteristics will lead to active management to prevent such change. With this scenario, the ecosystems of the UK may be constrained in the next 100 years on the basis that “restoration” to pre-determined states (e.g. pre-industrialisation) is the most suitable target. If this logic were carried through, the dynamic changes in flooding and flood management brought about, for example by climate changes (natural or man-induced), would be actively constrained by ecosystem considerations. This could have a profound affect on the ecosystems, management of the environment and flooding. Some signs of this affect have been seen recently with the “no net loss” philosophy for SACs, which could influence choice of options for flood alleviation or shoreline management.

This maintenance of a pre-existing state, pegged to recent historic records, would inevitably create conflicts for future flood management strategy and practices. This has been illustrated in recent years when trying to maintain a number of SAC, Sites of Special Scientific Interest (SSSI) etc. nature conservation designated sites in favourable conditions, often in the face of external and changing dynamic systems.
Conversely, it may be possible to demonstrate to the environmental stakeholders that evolutionary, dynamic change to ecosystems is a natural and acceptable process. This could allow more natural fluvial, estuarine and coastal change over time without the need for significant engineering interventions to harness and arrest those changes.

It is probable that a mid-ground between these two views will be accommodated. The key to a sensible balance is likely to be the growing involvement of stakeholders in the decision-making process, particularly given the statutory requirements of the Water Framework Directive. As the influence of interest groups increases, as we are witnessing today, the emphasis on ecosystem considerations and protection will strengthen. One challenge will be balancing the views of all the different interest groups.
3 Scenarios analysis

The use of scenarios for policy analysis far into the future is well established. Given the aim of the Foresight Flood and Coastal Defence project to look on a time horizon 30 to 100 years into the future, a scenarios-based approach is appropriate. Flood and coastal defence is an interesting application of the scenario based approach because it involves integrated use of two different types of scenario:

- climate change predictions are based on emissions scenarios. Climate change is the key driver relating to the ‘source’ descriptors in the S-P-R model; and
- socio-economic scenarios provide the context in which flood management policy and practice will be enacted.

The main part of the project, which will now follow, is divided into two distinct phases.

Firstly in Phase 2 the impacts of the drivers will be assessed, which we will call the baseline assessment. This will increase understanding of the drivers, their impacts and relationships by adding additional qualitative and quantitative analysis to that carried out in Phase 1. In order to carry out the analysis of baseline impacts which is required in Phase 2 of the project we have to make some assumptions as to the future course of flood management in the UK.

Secondly, in Phase 3, different flood management responses will be explored, in order to provide policymakers with indicators as to possible policy directions in the future. The testing of responses will involve assessing the impacts on flood risk of varying these flood management responses, against a background of different futures scenarios, and of uncertain climate change.

3.1 Climate change scenarios

We have employed the UKCIP02 climate scenarios (Hulme et al., 2002), which are based on four emissions scenarios: Low emissions, Medium-low emissions, Medium-high emissions and High emissions. The correspondence between these UKCIP scenarios and the Special Report on Emissions Scenarios (SRES) scenarios used by the Intergovernmental Panel on Climate Change (IPCC) is illustrated in Table 3.1. Figures 3.2 and 3.3 illustrate the global carbon emissions and changes in global mean temperature associated with the SRES scenarios.

<table>
<thead>
<tr>
<th>UKCIP02 scenario</th>
<th>Low emissions</th>
<th>Medium-low emissions</th>
<th>Medium-high emissions</th>
<th>High emissions</th>
</tr>
</thead>
<tbody>
<tr>
<td>SRES scenario</td>
<td>B1</td>
<td>B2</td>
<td>A2</td>
<td>A1F1</td>
</tr>
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</table>

Table 3.1: Summary of UKCIP02 scenarios (after Hulme et al., 2002)
Figure 3.2: Global carbon concentrations in SRES scenarios (from Hulme et al., 2002)

Figure 3.3: Annual global-average surface air temperature relative to 1961-1990 average (grey). The dotted green and black curves represent the full IPCC range of global temperature change when both emissions uncertainties and model uncertainties are considered (from Hulme et al., 2002).
The main predictions from the UKCIP02 scenarios relevant to flooding are summarised as follows:

- average annual temperatures across the UK may rise by between 2º and 3.5ºC by the 2080s. In general there will be greater warming in the south east of the UK;
- annual average precipitation across the UK may decrease slightly, by between 0 and 15% by the 2080s depending on scenario;
- the seasonal distribution of precipitation will change, with winters becoming wetter and summers becoming drier, the biggest relative changes being in the South and East. Under the High Emissions scenario winter precipitation in the South East may increase by up to 30% by the 2080s;
- by the 2080s the daily precipitation intensities that are experienced once every two years on average may become up to 20% heavier. No guidance is given on the effects of climate change on more extreme precipitation events;
- by the 2080s and depending on scenario relative sea level may be between 2cm below and 58cm above the current level in western Scotland and between 26 and 86cm above the current level in South East England; and
- for some coastal locations a water level that at present has a 2% annual probability of occurrence may have an annual occurrence probability of 33% by the 2080s for Medium-High emissions.

It should be noted that the climate change scenarios included within UKCIP02 do not include allowance for model error and do not therefore represent the maximum potential range of climate change effects. Due allowance should be made for this in specifying the climate change scenarios within the overall futures scenarios to be used as tests in the next two phases of the Foresight flooding project.

It may be worth noting that such large changes in temperature and water availability will have significant impacts on biological systems beyond the issue of increased extent and frequency of inundation and changes in water velocities, levels and wave action, although the implications are not well understood. Any changes in aquatic and terrestrial biological community structure in response to the more general features of climate change could have knock on effects on flood management.

### 3.2 Socio-economic scenarios

The Foresight Futures scenarios developed by researchers at the Science and Technology Policy Research, University of Sussex (SPRU) for the Office of Science and Technology (OST, 2002) are represented on a two-dimensional grid (Figure 3.4). On the vertical dimension is the system of governance, ranging from autonomy where power remains at the national level, to interdependence where power increasingly moves to other institutions e.g. up to the EU or down to regional government. On the horizontal dimension are social values, ranging from individualistic values to more community-oriented values. The four Foresight Futures that occupy this grid are summarised in Tables 3.2 and 3.3. Further estimates of future socio-economic parameters are available from OST (2002).
Table 3.2: Summary of Foresight Futures (OST 2002)

<table>
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<th></th>
<th>World markets</th>
<th>National</th>
<th>Global</th>
<th>Local</th>
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<td>Enterprise</td>
<td>responsibility</td>
<td></td>
<td>stewardship</td>
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<td>Social values</td>
<td>Internationalist, libertarian</td>
<td>Nationalist, individualist</td>
<td>Internationalist, communitarian</td>
<td>Localist, co-operative</td>
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<td>Governance structures</td>
<td>Weak, dispersed, consultative</td>
<td>Weak, national, closed</td>
<td>Strong, co-ordinated, consultative</td>
<td>Strong, local, participative</td>
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<td>Role of policy</td>
<td>Minimal, enabling markets</td>
<td>State-centred, market regulation to protect key sectors</td>
<td>Corporatist, political, social and environmental goals</td>
<td>Interventionist, social and environmental</td>
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<td>Economic development</td>
<td>High growth, high innovation, capital productivity</td>
<td>Medium-low growth, Low innovation, Maintenance economy</td>
<td>Medium-high growth, high innovation, resource productivity</td>
<td>Low growth, low innovation, modular and sustainable</td>
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<tr>
<td>Structural change</td>
<td>Rapid, towards services</td>
<td>More stable economic structure</td>
<td>Fast, towards services</td>
<td>Moderate, towards regional systems</td>
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<td>Fast-growing sectors</td>
<td>Health &amp; leisure, media &amp; information, financial services, biotechnology, nanotechnology</td>
<td>Private health and education, Domestic and personal services, Tourism, Retailing, Defence</td>
<td>Education and training, Large systems engineering, New and renewable energy, Information services</td>
<td>Small-scale manufacturing, Food and organic farming, Local services</td>
</tr>
<tr>
<td>Declining sectors</td>
<td>Manufacturing, agriculture</td>
<td>Public services, civil engineering</td>
<td>Fossil fuel energy, Traditional manufacturing</td>
<td>Retailing, tourism, financial services</td>
</tr>
<tr>
<td>Unemployment</td>
<td>Medium-low</td>
<td>Medium-high</td>
<td>Low</td>
<td>Medium-low (large voluntary sector)</td>
</tr>
<tr>
<td>Income</td>
<td>High</td>
<td>Medium-low</td>
<td>Medium-high</td>
<td>Low</td>
</tr>
<tr>
<td>Equity</td>
<td>Strong decline</td>
<td>Decline</td>
<td>Improvement</td>
<td>Strong improvement</td>
</tr>
</tbody>
</table>
Table 3.3: Snap shot statistics for 2010 from Foresight Futures (OST 2002)

<table>
<thead>
<tr>
<th></th>
<th>Today</th>
<th>World markets</th>
<th>National Enterprise</th>
<th>Global responsibility</th>
<th>Local stewardship</th>
</tr>
</thead>
<tbody>
<tr>
<td>GDP growth per year</td>
<td>2.5%</td>
<td>3.5%</td>
<td>2%</td>
<td>2.75%</td>
<td>1.25%</td>
</tr>
<tr>
<td>Total investment - % of GDP</td>
<td>19%</td>
<td>22%</td>
<td>18%</td>
<td>20%</td>
<td>16%</td>
</tr>
<tr>
<td>Agricultural activity (% of total activity)</td>
<td>2%</td>
<td>1%</td>
<td>2%</td>
<td>1.5%</td>
<td>3%</td>
</tr>
<tr>
<td>Newly developed land – hectares per year</td>
<td>6500</td>
<td>6000</td>
<td>4500</td>
<td>3000</td>
<td>1000</td>
</tr>
<tr>
<td>Primary energy consumption (tonnes of oil equivalent)</td>
<td>230 million</td>
<td>280 million</td>
<td>270 million</td>
<td>230 million</td>
<td>230 million</td>
</tr>
<tr>
<td>Primary energy consumption – average change per year</td>
<td>+1.7% pa</td>
<td>+1.5% pa</td>
<td>+0.1% pa</td>
<td>+0.1% pa</td>
<td></td>
</tr>
</tbody>
</table>

3.3 Correspondence between climate change and socio-economic scenarios

There is no direct correspondence between the UKCIP02 scenarios and the Foresight Futures 2020, not least because the Foresight Futures are specifically aimed at the UK whereas the emissions scenarios used in UKCIP02 are global emissions scenarios. However, an approximate correspondence can be expected, as shown in Table 3.4.

Table 3.4: Correspondence between UKCIP02 scenarios and Foresight Futures

<table>
<thead>
<tr>
<th>SRES</th>
<th>UKCIP02</th>
<th>Foresight Futures 2020</th>
<th>Commentary</th>
</tr>
</thead>
<tbody>
<tr>
<td>B1</td>
<td>Low emissions</td>
<td>Global responsibility</td>
<td>Medium-high growth, but low primary energy consumption. High emphasis on international action for environmental goals (e.g. greenhouse gas emissions control). Innovation of new and renewable energy sources.</td>
</tr>
<tr>
<td>B2</td>
<td>Medium-low emissions</td>
<td>Local stewardship</td>
<td>Low growth. Low consumption. However, less effective international action. Low innovation.</td>
</tr>
<tr>
<td>A2</td>
<td>Medium-high emissions</td>
<td>National enterprise</td>
<td>Medium-low growth, but with no action to limit emissions. Increasing and unregulated emissions from newly industrialised countries.</td>
</tr>
<tr>
<td>A1F1</td>
<td>High emissions</td>
<td>World markets</td>
<td>Highest national and global growth. No action to limit emissions. Price of fossil fuels may drive development of alternatives in the long term.</td>
</tr>
</tbody>
</table>
3.4 **Baseline flood management policy**

As noted earlier we have to make some assumptions as to the future course of flood management in the UK in order to allow the analysis of baseline impacts required in Phase 2 of the project to be carried out in a rational and consistent manner.

It would in theory be possible to construct a set of four different flood management futures consistent in some way with the four Foresight Futures scenarios. However, this would run the danger of being confusing in two senses. Firstly the baseline impacts when assessed would not be relative to a single easily recognisable flood management policy. Secondly, there is a danger that in the baseline assessment stage, Phase 2, the project would in effect be starting to look at future flood management responses without having established a stable and identifiable baseline against which to assess them.

For these reasons it is recommended that the current pattern of expenditure and technical approach is applied as the baseline flood management policy in all four scenarios.

In the spirit of futures analysis, we are not supposing that this is the most likely way in which flood management will evolve in the future. Nor are we imposing any value judgement as to its value. This future is merely proposed to provide a clear and simple starting point for the analysis of responses in Phase 3 of the Foresight Flood and Coastal Defence project.

The baseline analysis to be carried out in Phase 2 is shown diagrammatically in Figure 3.5, which shows the impacts of the drivers “funnelled” through the current flood management approach:

*Figure 3.5: Baseline impacts (Phase 2) analysis*
4 Drivers identification and interpretation

As indicated above, we use the term ‘driver’ to denote any phenomenon that may change the state of the flooding system over the next 30-100 years. Drivers can be meteorological, geomorphological, hydrological, environmental, socio-economic or institutional. They include both elements of the current system, and human responses that seek to change that system.

Table 4.1 summarises some twenty drivers which we have judged could significantly change the state of the flooding system over the next 100 years, either for better (i.e. less flood risk) or for worse (more flood risk). Appendix B gives a short description of each driver.

Of course these drivers are strongly interrelated, as will be illustrated with the following three examples:

- In terms of drivers that primarily affect the source of flooding within the S-P-R framework, temperature and precipitation are strongly correlated, each being in turn a function or an expression of global warming.
- Within the pathways there is a host of complex interrelations. For example, the extent and type of regulations affect land use and urbanisation, through the planning system and other institutional arrangements, which in turn reflect and affect stakeholder behaviour. In turn urbanisation affects the extent of our non-urban environment, and through this the extent of natural or semi-natural ecosystems and habitats. At the coast the sediment supply affects the interaction between waves and threats to the coastline, and regulation affects the extent to which engineering responses can be implemented.
- Receptors are impacted by floods, but these impacts are multifaceted: the economic impacts are affected by compensation/insurance systems, but currently these do not cover ‘social’ impacts and the effect on personal health. Yet the public has expectations of protection, both for themselves and for vulnerable infrastructure and the environment. Our technological capacity can alter pathways to provide this protection, using conventional and innovative technology, but our increasingly urbanised and congested country means that protecting people could be at the expense of protecting environments.

What is apparent from Table 4.1 is that the drivers are as much socio-economic as to do with the natural or human-modified environment. We have concluded that the main forces affecting flood risk in 30-100 years time arise from the interaction of human activities with the flood generating forces that come from the atmosphere and from the sea and that, in the main, these human activities are the dominant drivers of flood risk.

One of the main reasons for this conclusion is that these socio-economic drivers (e.g. the economy; public expectations) are likely to change at a greater rate than even the expressions of climate change such as temperature and precipitation. For example, real personal economic wealth could grow by 16 times over the next 100 years, assuming 2% compound growth, whereas current predictions for the increase in fluvial flood flows are in the region of 25%, and even those flows would not generally result in a 25% increase in flood depth across our floodplains. There will, of course, be cases where the rate of change of physical elements of the flood system will be
high, such as perhaps with sea level rise in constricted estuaries, but this generally does not look typical of most flood and coastal flooding situations.

The environment will act as a driver here (for example Water Framework Directive) that may have profound influence on flood management over the longer term. In the longer term protection and enhancement of the environment may be expected to increase in significance (we only have to look at progress with environmental protection over the past 30 years to extrapolate forward for the next 100 years). The drive towards more dynamic "natural " evolution of floodplains, rivers and coastal areas may therefore come to dominate catchment and coastal planning over the next century. This is likely to have a significant influence on the flood management practices adopted and the measures implemented. Thus flood management may evolve as much as through integration with better environmental management, which is more likely to be the preferred direction, as through a response to growing wealth.

The progression of this argument would suggest that increased wealth and protection of the human environment must in the future be reconciled with protection (i.e. allowance for dynamic change) of aquatic and wetland ecosystems. Few data are available to support the determination of flood management policies with such integration in mind, but one of the elements of the project should perhaps be to define, in a broad-brush fashion, the possibilities and opportunities.

Another characteristic of this analysis of drivers is that it tends to focus on phenomena that have not received much research attention in relation to long-term flood and coastal defence policies. This means there is considerable uncertainty with regard to the future strength of many of these drivers and their interrelations.
<table>
<thead>
<tr>
<th>No.</th>
<th>SPR element</th>
<th>Driver</th>
<th>Driver description and meanings*</th>
<th>Certainty/uncertainty*</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Source</td>
<td>Precipitation</td>
<td>Changes in UK precipitation (rain and snowfall), especially intensity, varying with season, brought about by global warming from human-induced increases in greenhouse gases (increases in winter and decreasing summer rainfall, the latter in the south).</td>
<td>Significant uncertainty owing to model uncertainty and other factors.</td>
</tr>
<tr>
<td>2.</td>
<td>Source</td>
<td>Waves and surges</td>
<td>Temporary increases in sea level above the expected tidal level caused by reduced atmospheric pressure and the action of strong winds on the water surface, induced by global warming from human-induced increases in greenhouse gases.</td>
<td>Significant uncertainty (some climate change projections only).</td>
</tr>
<tr>
<td>3.</td>
<td>Source</td>
<td>Relative sea level</td>
<td>Changes in mean sea level relative to the land as a consequence of increased global temperatures arising from human-induced increases in greenhouse gases. Some of the changes result from land subsidence caused by isostatic adjustment.</td>
<td>Very certain about some change; full magnitude remains uncertain.</td>
</tr>
<tr>
<td>4.</td>
<td>Source</td>
<td>Temperature</td>
<td>The changes in global atmospheric temperature arising from human-induced increases in greenhouse gases, with a seasonal effect (principally hotter summers).</td>
<td>Very certain about some change; the magnitude remains uncertain.</td>
</tr>
<tr>
<td>5.</td>
<td>Pathway</td>
<td>Regulation</td>
<td>The policy directives, frameworks and guidance affecting pathways, including both the direct regulatory effects on flood and coastal defence (e.g. standards; impediments to implementation) and the effect of indirect regulation on processes such as urbanisation, agriculture and environmental protection (e.g. planning and policy guidance; CAP regulations). Ranges over spatial scales from the local to the pan-EU.</td>
<td>Very difficult to predict overall path of all regulation over 100 years.</td>
</tr>
<tr>
<td>6.</td>
<td>Pathway</td>
<td>Stakeholder behaviour</td>
<td>Changes in the behaviour of all the actors concerned about, involved in or affected by flooding and coastal erosion: institutional actors; corporate actors; professionals; NGOs and local organisations; landowners; etc. Includes market-affected, community and wider political behaviour.</td>
<td>Quantification is difficult; unlikely to be amenable to accurate prediction.</td>
</tr>
<tr>
<td>7.</td>
<td>Pathway</td>
<td>Environment, ecosystems and habitats</td>
<td>The character of river and coastal environments and the effectiveness therefore of the way that floods are carried along the pathways to the receptors, in terms of the nature of flora and fauna, the habitats that they occupy, and the resistance or otherwise that they present to the free flow of flood waters.</td>
<td>We can be certain that this driver will change over a 100-year time horizon.</td>
</tr>
<tr>
<td>8.</td>
<td>Pathway</td>
<td>Morphology / sediment supply-coastal</td>
<td>The erosion, movement and accretion of material of material and sea shore both through natural processes and through human activities such as dredging, reclamation and setback. Flooding and coastal erosion pathways affected adversely by the loss of material rather than by gain.</td>
<td>High natural uncertainty. Better scientific understanding will clarify importance.</td>
</tr>
<tr>
<td>9.</td>
<td>Pathway</td>
<td>Land use (incl. urbanisation)</td>
<td>Land use influences the hydrology, hydraulics and sediment dynamics of catchment and coastal flooding systems. Urbanisation is at one extreme, creating conditions of low retention and extra-rapid runoff. Forestry might be at the other extreme. This driver significantly affects the volume and speed of flood flow.</td>
<td>A large research literature is available; predicting trends is difficult.</td>
</tr>
<tr>
<td>10.</td>
<td>Pathway</td>
<td>Morphology / sediment supply-rivers</td>
<td>Inland morphological changes involve the adjustment of river systems to sediment supply and the way that this affects the capacity to convey in-bank flood flows. At the coast sediment dynamics affect the ability of the coast to protect itself from wave attack and therefore cushion flooding impacts.</td>
<td>Research literature is available; predicting trends is difficult.</td>
</tr>
<tr>
<td>11.</td>
<td>Pathway</td>
<td>Agriculture and rural land management</td>
<td>Changes in agricultural activities affect the hydrology, hydraulics and sediment dynamics of catchment and coastal flooding systems, influencing local runoff characteristics. The effect may be limited to the more minor floods. Sediment dynamics also affected, which in turn affect pathway efficiency.</td>
<td>The precise effects are uncertain; predicting trends is difficult.</td>
</tr>
<tr>
<td>No.</td>
<td>SPR element</td>
<td>Driver</td>
<td>Driver description and meanings*</td>
<td>Certainty/uncertainty*</td>
</tr>
<tr>
<td>-----</td>
<td>-------------</td>
<td>--------</td>
<td>----------------------------------</td>
<td>------------------------</td>
</tr>
<tr>
<td>12.</td>
<td>Pathway</td>
<td>Vegetation</td>
<td>This is a product of the physical attributes of the location in which it is found, consequently inter-related to other drivers (e.g. 4, 11 and 7). Affects volume and rate of run-off within catchments and affects the inland encroachment of seawater and rates of erosion. Flood plain vegetation can prevent channel bank erosion and within the channel can hold back flood waters, naturally protecting downstream areas.</td>
<td>Highly inter-related nature of driver makes predictions difficult other than extrapolating to that found further south (for climate change only).</td>
</tr>
<tr>
<td>13.</td>
<td>Receptor</td>
<td>Economics and sectoral</td>
<td>The aggregate wealth of the UK, expressed as the Gross National Product of the country and/or the average income of the average citizen and their assets potentially at risk from flooding. Includes the breakdown of that wealth by sectors, which will be differentially affected by flooding.</td>
<td>Rapidly changing; readily quantifiable. Foresight predictions available</td>
</tr>
<tr>
<td>14.</td>
<td>Receptor</td>
<td>Urbanisation</td>
<td>The development of urban areas and the way that this is effected. Includes building layout, urban densities, building form, green belts, and the way that these affect the vulnerability of communities and assets in areas of flood or erosion risk.</td>
<td>Predictable in the near term (e.g. new housing targets). Regulation affects long term.</td>
</tr>
<tr>
<td>15.</td>
<td>Receptor</td>
<td>Infrastructure</td>
<td>The services that support the economy, including transport, telecoms, utilities, emergency services and other activities that may be disrupted by flooding causing indirect flood losses in the economy. Includes Annex I and II activities under the EIA regulations (e.g. nuclear power stations; oil/chemical and port facilities).</td>
<td>A divers driver, difficult to measure and predict in aggregate.</td>
</tr>
<tr>
<td>16.</td>
<td>Receptor</td>
<td>Environment</td>
<td>The aquatic, wetland and floodplain ecosystems and habitats that can be harmed or enhanced by flooding and coastal erosion, which alters the dynamics of ecosystem equilibrium.</td>
<td>Well researched but difficult to predict over 100 years.</td>
</tr>
<tr>
<td>17.</td>
<td>Receptor</td>
<td>Risk compensation/insurance</td>
<td>The availability (spatially) and cost of flood insurance or some other form of loss compensation. This driver does not alter the risk but affects its distribution over time and across risk-bearing communities. Currently a private sector activity in the UK but with some uncertainty as to universality in the future.</td>
<td>Readily available and quantifiable; future in some doubt.</td>
</tr>
<tr>
<td>18.</td>
<td>Receptor</td>
<td>Social</td>
<td>The social character of the population at risk from flooding and coastal erosion, in terms of their demographic characteristics (age; gender; family structure; ethnicity) in so far as this affects the vulnerability of the population to flood impacts.</td>
<td>Some research available; difficult to predict over 100 years.</td>
</tr>
<tr>
<td>19.</td>
<td>Receptor</td>
<td>Public expectations</td>
<td>The expectations and attitudes of the public towards flood risk and their propensity to accept risk and its consequences. The public already finds flooding increasingly unacceptable, and tends to change their behaviour and react politically to prevent it. This is likely to become enhanced with increasing affluence.</td>
<td>Important but not easy to measure or predict; trends appear to be ‘hardening’.</td>
</tr>
<tr>
<td>20.</td>
<td>Receptor</td>
<td>Public attitudes</td>
<td>The changing ways in which people perceive risk and the way this may modify behavior over time may affect their expectation of protection and the consequent pressures on institutions to provide that protection. Perception highly related to “actual” level of flood risk and other public preferences.</td>
<td>Very difficult to predict due to links with “actual” risk and the dynamics of public preference.</td>
</tr>
<tr>
<td>21.</td>
<td>Receptor</td>
<td>Agriculture</td>
<td>Treated here as a sector of the economy susceptible to flood impacts through direct damage to crops and livestock regimes, or indirect damage through flooding or erosion affecting the fertility of the soil and the ability of farmers to sustain cultivation on their land.</td>
<td>Well researched and not difficult to predict as impacts are crop-specific.</td>
</tr>
<tr>
<td>22.</td>
<td>Receptor</td>
<td>Institutional</td>
<td>The framework of bodies directly or indirectly responsible for flood and coastal defence and dealing with the consequences of flooding, including public organisations (DEFRA; EA) and less well defined groups such as the insurance, engineering, and building industries, and nature conservation, amenity organizations and ‘flood action’ groups.</td>
<td>Relatively slowly changing, but amenable to unpredictable political ‘step changes’.</td>
</tr>
<tr>
<td>No.</td>
<td>SPR element</td>
<td>Driver</td>
<td>Driver description and meanings*</td>
<td>Certainty/uncertainty*</td>
</tr>
<tr>
<td>-----</td>
<td>---------------------------</td>
<td>---------------------------------------</td>
<td>----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td>----------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>23.</td>
<td>Pathway and Receptor</td>
<td>Science, engineering and technology</td>
<td>Our ability to understand the operations of and to change those pathways that influence flood risk or coastal defence, including urban drainage design and standards, flood defence technology, flood management systems (e.g. integrated catchment management) and coast defence technology (flood barriers; rock groynes; etc). The way that responses to the risk may diminish or exacerbate risk in other parts of the flooding systems, either over time or over space, by impacting pathways. Includes changes in channel capacity, changing maintenance regimes, river restoration, or coast protection schemes that disrupt sediment transport, as well as hydrologic/hydraulic technology (models) that help pathway understanding. Our ability to understand and manage the consequences of flood risk through technology, including risk identification, forecasting/warning, and technologies for flood defence (at regional, community and building level), including both generic, location-specific, long–term and temporary (e.g. demountable) systems. The sciences affecting receptors include the communications sciences and the social sciences (Economics, Sociology, etc) which add understanding to the overarching relationships between flood impacts and people (e.g. heath impacts) and the economic systems and linkages that are disrupted.</td>
<td>Some elements relatively slowly changing, therefore amenable to prediction. Many aspects generally very location-specific and unpredictable, but greater scientific understanding allows some very important generalization over space. Some elements relatively slowly changing, and therefore amenable to prediction. More ‘blue skies’ development far less easy to predict, but could be very important.</td>
</tr>
</tbody>
</table>

* Refer to the text and Appendix B for full descriptions and meanings
5 Drivers – ranking

5.1 Ranking against baseline scenarios

We have developed a system for ranking the drivers listed in Table 4.1 so as to allow subsequent work in Phases 2 and 3 to be prioritised. We have used both a number of risk dimensions – economic, societal and environmental, and a system of simple rules (Table 5.1) to rank the drivers in relation to the impact (positive or negative) they could have on flood risk over the next 30-100 years, involving a substantial element of judgement but using a wide range of professionals during both the brainstorming session and the workshop.

Table 5.1 Rules and questions for ranking drivers

<table>
<thead>
<tr>
<th>Rule</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Rank High/Low/Medium according to impact relative to reference measures or benchmarks e.g. Current national Annual Average Damage or current number of deaths per year from flooding</td>
</tr>
<tr>
<td>2</td>
<td>Low &lt; 50% change in flood risk over current measure; Medium up to 2X; High might be over 5X and/or with a step change</td>
</tr>
<tr>
<td>3</td>
<td>How big is the change in driver? And how sensitive is the flooding system to the change?</td>
</tr>
<tr>
<td>4</td>
<td>Consider this within the SPR framework to assess how the driver propagates through the system</td>
</tr>
<tr>
<td>5</td>
<td>Assess by current societal values</td>
</tr>
<tr>
<td>6</td>
<td>Assess the importance against current conditions in the first place and then look at the effect of different scenarios</td>
</tr>
</tbody>
</table>

The baseline or ‘average’ results are given in Figure 5.1. Again, those drivers that are ranked as “high” are those that are either likely to change most during the next 30-100 years, and/or are the drivers which both are likely to show some change and are the ones to which the flooding system is most sensitive.

Our analysis of the baseline case has been complemented by a re-ranking of the drivers for the different Foresight scenarios, which is shown in Figure 5.2. This was not an easy process, and the results are inevitably somewhat more speculative.
Figure 5.1 Experts tentative ranking of drivers
Fig 5.2 Experts tentative ranking of drivers under different futures scenarios

**Source**
- Precipitation
- Waves and surges
- Temperature

**Pathway**
- Regulation
- Environment, ecosystems & habitats
- Sciences, engineering & technology development
- Agriculture & rural land management
- Existing technological capacity

**Receptor**
- Stakeholder behaviour
- Morphology/se diment supply – coastal
- Land use (inc urbanisation)
- Agriculture & rural land management
- Vegetation
- Existing technology

**High**
- Relative sea level
- Environment, ecosystems & habitats
- Sciences, engineering & technology development

**Medium**
- Temperature
- Agriculture & rural land management
- Existing technological capacity

**Low**
- Consumerism

**World Markets**
- Urbanisation
- Environment
- Risk compensation / insurance
- Public attitudes
- Institutional
- Agriculture

**National Enterprise**
- Infrastructure
- Public attitudes
- Institutional
- Social

**World Markets**
- Urbanisation
- Environment
- Risk compensation / insurance
- Public attitudes
- Institutional
- Agriculture

**National Enterprise**
- Infrastructure
- Public attitudes
- Institutional
- Social

**World Markets**
- Urbanisation
- Environment
- Risk compensation / insurance
- Public attitudes
- Institutional
- Agriculture

**National Enterprise**
- Infrastructure
- Public attitudes
- Institutional
- Social

**World Markets**
- Urbanisation
- Environment
- Risk compensation / insurance
- Public attitudes
- Institutional
- Agriculture

**National Enterprise**
- Infrastructure
- Public attitudes
- Institutional
- Social
We see from Figure 5.1 that, for example that:

- the UK continues to urbanise quite rapidly, although this is regulated, and we are increasingly dependent on critical infrastructure such as telecoms to support a rapidly modernising economy;
- as the economy develops, and floodplain assets grow in value, there is generally a one-to-one increase in flood damage potential; and
- on the other hand the rate of technological innovation in the flood and coastal defence field is quite slow, since this is already a field where the technology is quite mature. Therefore the ‘technology’ driver is less important than the ‘Economy/sectoral’ one in ‘driving’ future flood risk, but it is not unimportant in itself.

What this analysis shows is that the “high” drivers are dominated by societal dimensions, other than in the way that precipitation and sea states are key sources of flood risk that could have very significant increases over this long time period. The drivers of the critical pathways between sources and receptors are likely to be most affected by the ways that we use our land, our behaviour, and the way that we regulate both.

The re-ranking of the drivers for the different Foresight scenarios which is shown in Figure 5.2 was not an easy process, and the results are inevitably somewhat more speculative. Nevertheless what Figure 5.2 shows is that the general pattern of driver ranking changes very little, a result that we found somewhat surprising. There are a number of small-scale changes within the categories of “high”, “medium” and “low”, but there are only a dozen or so major changes between the categories, and this across all the drivers for all the scenarios. In only three cases is there a change in category to the drivers that are ranked as “high”: these are the ‘social’, the ‘environment (receptor), the ‘agriculture/rural land management’ driver, and the science and technology development driver (for the Local Stewardship case only, where it declines to “medium”).

This illustrates to us the robustness of the baseline ranking. It also shows that the way that the ‘natural’ and ‘semi-natural’ elements of the flooding system operate does not change with the extremes of climate or societal change envisaged in the Foresight scenarios. There may be ‘step changes’ in the scale of flooding but not in the way that the flooding systems ‘work’. Where there may be step changes in the total system is the interaction of knowledge and policy (through science and technology development) and the way that society works (the ‘social’ drivers) and the impacts on our more fragile environments.

This result should not be taken, however, to imply that the extent of flood and coastal risk does not change with the different scenarios: they could result in radically different flood situations. What it serves to show is that the factors driving flood risk – up or down – do not change markedly with respect to each other under the different scenarios. The absolute values of those drivers (and their impact on risk and flood losses) could be orders of magnitude apart, and this is what requires further investigation in the next phases of the project.

The role of drivers on the coast, as distinct from inland flooding, has been the subject of specific scrutiny, as the coastal situation differs in important respects. Of concern on the coast are both coastal flooding to low-lying coastlands and estuaries, and loss...
of coastal land due to erosion. The impacts of these processes are distinct, and in terms of magnitude of harm coastal flooding is far more significant. However, the processes themselves are intimately linked. Of prime importance is the role of sediments in coastal dynamics. This is not to suggest that fluvial sediment dynamics are not of importance, but at present river sedimentary processes are intensively managed in the UK so the role of sediments is not highly recognisable. Meanwhile on the coast, very large scale movements of sediments on beaches, the foreshore and the sea bed persist in a highly energetic environment. These sediment movements have, particularly over the last century, become highly disrupted due to works of coastal engineering. Particularly influential has been the artificial protection of eroding cliffs, reducing sediment supplies; the introduction of beach control structures (such as groynes) inhibiting long-shore drift; the construction of harbour breakwaters and dredging of harbour entrances and widespread reclamation of the margins of estuaries.

Analysis of drivers on the coast has reflected the central role of coastal morphology and engineering intervention therein. From this perspective key drivers in changing the system are changes in loads on the system, the most influential being waves and tide levels (including surges). The role of precipitation as a source term in coastal risk is minimal. Increased precipitation will be expected to increase coastal cliff instability, reducing the average angle of coastal cliffs. However, this effect is marginal, particularly once cliff form has readjusted to a new precipitation regime.

Analysis of pathways is dominated by understanding of morphology and the ways in which the coast has been engineered in the past and may be re-engineered or de-engineered in future. Coastal habitats are intimately linked with coastal morphological processes and engineering intervention in those processes.

Many drivers influencing receptors of coastal flooding and erosion are common to the fluvial case. Particularly, important infrastructure is located on the coast, including ports, fishing harbours, industrial plants processing bulk goods that arrive by ship or in sub-sea pipelines (such as oil refineries), estuary transport links (bridges for road and rail), sewerage treatment works that discharge into the sea, nuclear power stations and other facilities requiring large quantities of cooling water. An increase in the use of coastal waters as sources of renewable energy (wind, wave and tidal power) is expected in the coming decades. These facilities are potential risk receptors if marine storms become unexpectedly severe. Whilst the agricultural industry may be very seriously impacted upon by coastal flooding, the impact of coastal erosion on agriculture will be very small under all scenarios.

5.2 **Role of science engineering and technology in the baseline scenarios**

As explained it is necessary to make an assumption about the future course of flood management in order to consider the impacts of the drivers in the baseline case. The assumption proposed for Phase 2, baseline impacts assessment, is that the present level of expenditure and approach would continue to be followed. The impacts of existing flood management science, engineering and technology under this assumption are therefore in effect neutral or of low impact as shown on the drivers ranking figures.
Although the Phase 1 specification requires only the setting up of an outline structure and approach to Phase 3, the assessment of flood management responses, some comments are given below on the role of science, engineering and technology in future responses in view of Foresight’s focus on this area.

Until comparatively recently flood management in the UK was focussed largely on the design and construction of local flood defence structures and stand alone flood forecasting and warning systems. This is now changing radically in response to the more challenging framework in which flood management is likely to have to work in the future.

The UK has resolved to adopt a broad-scale catchment and coastal cell approach to flood management planning, and to tie flood management more closely to land management and urban development planning. The Water Framework Directive will shortly apply in UK. Within these frameworks flood management planning, implementation and operation are likely to demand more subtle and integrated solutions to answer the environmental and stakeholder pressures outlined earlier in this report.

The current interest in using the rural landscape to reduce flooding at source is a case in point. This will require the ability to model and predict the performance of whole flood defence systems, and the framing of suitable land management policies to implement the scientific measures. Increased knowledge of the underlying processes, advances in mathematical modelling, e-science and remote sensing will all have large parts to play in this.

In operations, improved real-time prediction of flooding using the similar advances, will become more important, as will the use of mobile telecommunications technology in emergency management and damage reduction. The application of control theory and the movement towards a rational risk-based approach to asset management will become more important. The social sciences must not be left behind in this, witness the importance in land management of securing sustainable means of managing the landscape reliably over long periods and the part they will play in flood damage reduction via better preparedness and emergency response planning.

Science, engineering and technology development is a matter which is towards the controllable end of the drivers / responses spectrum, and is likely to be an essential part of any response package. Although it is therefore by our definition a response rather than a driver it is included in the driver figures and tables for the sake of completeness.
6 Work Plan for baseline scenarios impact assessment

The work on the drivers Logical Framework, drivers identification and ranking has provided an intellectual framework in which discussions about the drivers and their relationships can be structured, and established what are the most important drivers of future flood risk on the basis of structured expert judgement. Four baseline scenarios have been established against which future flood and coastal erosion risks can be assessed.

This section presents an outline work plan for a more quantitative assessment of the impacts of the changes to flood risk under the baseline scenarios to be carried out in Phase 2 of the project.

The proposed approach is a tiered one and is illustrated in Figure 6.1. The work is divided into a number of packages, which are reviewed below.

It is recommended that each package should have two parts; the first relating to setting up the methodology and assessing the impacts of the baseline scenarios; the second related to applying the methods during the Responses phase of the project.

Participation in the mid-term review should be included for each package, for which each package contractor should prepare an interim working paper. The mid-term review will provide the opportunity to confirm the content and detailed approach to the second part of each package.

Outline proposals for the various packages are contained in the following sections.
**Working Paper**

**Figure 6.1 Flow chart showing approach to baseline scenario impacts assessment**

**Package 1: Drivers studies and quantification**

<table>
<thead>
<tr>
<th>Environment/ Agriculture and rural land management/ Urbanisation and land use</th>
<th>Regulation/ Stakeholder behaviour/Social impacts/ Public expectations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Morphological/ Sediment supply/ vegetation</td>
<td>Precipitation/ Waves and surges / Relative sea level / Temperature</td>
</tr>
<tr>
<td>Economic/ Infrastructure/ Risk-Insurance/ Institutional</td>
<td></td>
</tr>
</tbody>
</table>

**Package 2: National broad brush assessment of economic and population impacts of drivers on fluvial, estuarial and coastal receptors using RASP, and cost model.**

**Package 3: National broad brush assessment of intra-urban economic and population impacts of drivers.**

**Package 4: National broad brush assessment of environmental impacts of drivers**

**Package 5: National broad brush assessment of coastal erosion risk**

**Package 6: Case studies to interpret impacts on the ground and explore barriers and opportunities in implementing the baseline Flood Management scenarios- Fluvial Estuarial Coastal Intra-urban**

**Package 7: Broad brush comparison studies of Wales, Scotland and Northern Ireland.**

**Package 8: Management and coordination of packages.**

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35
6.1 **Baseline impacts work packages**

Short descriptions of the proposed work packages are given below. More detailed descriptions can be found in Appendix C.

*Package 1: Driver studies and quantification*

In the first package a number of studies have been marshalled into five groups of like topics. It is suggested that in order to reduce the complexities of management and ensure compatibility of approach these should be awarded to a consortium of experts, managed by a single person. This approach would also stimulate more radical thinking by juxtaposing disciplines which do not normally work together. The aim of this work package is to fill out the driver descriptions derived in Phase 1. Where possible the magnitude and impacts of drivers should be quantified, though it is recognised that within the timescale of the Foresight project this can only be approximate. Thus, for instance, the UKCIP02 predictions of precipitation increases might be translated into increases in runoff, into flow increases at receptor locations and then into approximate changes in the probability of flooding defended communities.

As explained in the next section, it is proposed that Package 2 should centre round the use of a national broad-brush quantified risk assessment methodology. The inputs to this system are essentially Standards of Protection (SOP), defence condition, economic value of assets at risk and population data. Wherever possible the Package 1 work should provide inputs into this system by translating the impacts of their drivers into these variables.

Some drivers, which might be described as being of a policy nature, do not lend themselves as easily as others to quantification and might best be viewed as barriers and opportunities to flood management implementation, rather than independent variables in the flooding system. Changes in regulation might be seen in this way, though some attempt may be possible at guessing the effect of more extreme forms of regulation on the national ability to provide flood defence by feeding effects on standard of protection.

In the case of others such as coastal morphology only a part of the richness of understanding of the risks, and how they work, can be fed into effects on SOP. This package therefore has an independent purpose in increasing understanding of the risks posed by the drivers.

*Package 2: National broad brush assessment of economic and population impacts of drivers on fluvial, estuarial and coastal receptors and cost model*

Two national scale assessments of assets at risk from flooding have been conducted to date in England and Wales. The first was conducted for MAFF (MAFF, 2000) using a broad-brush assessment based on (often incomplete) knowledge of nominal flood defence Standards of Protection at a river-reach scale. The most recent study is currently being completed, using a methodology developed during a DEFRA/EA research project called RASP (Risk Assessment of Flood and Coastal Defence for Strategic Planning). The so-called RASP High-Level methodology (Sayers et al., 2002) makes use of the Environment Agency’s new National Flood and Coastal Defence Database, which contains information on defence location, type and condition. It uses geographically indexed land use and occupancy data and the Social Flood Vulnerability Indices of Tunstall et al. (2002). The method produces geographically indexed estimates of economic and social flood risk due to failure of
flood defences on coasts and main rivers. These estimates can be aggregated to regional and national scales. The method does not estimate the impacts of local pluvial or urban sewer flooding, nor does it address the environmental impacts of flooding. The accuracy of the resulting risk assessment is limited by the availability of data on a national scale, but when aggregated nationally the results are believed to be reasonably unbiased.

RASP provides the opportunity for quantified risk assessment of drivers, provided drivers can be resolved in terms of input parameters to the RASP model. The Geographical Information System (GIS) implementation of RASP means that scenarios can be tested by searching and replacing all instances of a given parameter (for example land use) in the national database. However, whilst some drivers, such as defence standard or land use, are readily resolved in RASP, other key drivers are not directly reflected in the input parameters. It is sometimes possible to infer changes to RASP parameters as a consequence of drivers. For example an increase in flood frequency may be reflected in terms of decrease in defence Standard of Protection. The more remote a driver becomes from the relevant RASP parameter(s) the more tenuous these ‘proxy’ representations will be.

It is possible, using the GIS query facilities in RASP, that some quite sophisticated scenarios could be examined, for example by associating a lower defence standard with land use of low value to simulate the extensive managed abandonment of such land under some flood management response scenarios.

The package will include a broad brush cost model of the flood management scenarios.

**Package 3: National broad brush assessment of intra-urban economic and population impacts of drivers.**

This package refers to flooding both originating and impacting within urban areas and is concerned with urban drainage. It is recognised that the picture in real life may be more complicated, with interaction between flooding originating within an urban area and flooding of outside origins. There is no national tool similar to RASP, but data gathered in satisfying the regulating authorities should provide a reasonable basis for broad-brush estimates of the future risks.

The drivers here relate to both pathways and receptor impacts. The problem of understanding better the likely changes in each of these (rates, amounts and locations of runoff and impacts) due to both climate change effects and responsive stakeholder behaviour is of the highest level of importance, principally because most people live in urban areas and it is estimated that up to 1 in 15 of these will experience flooding at some time in the next 100 years. Urban and peri-urban pathways and effects related to pluvial and coincident flooding relate principally to stakeholder behaviour, that is how the various stakeholder groups manage and operate the urban systems in which they live and work. Stakeholder reaction to perceived and real risks and impacts will to some extent control what happens (i.e. changes in risk) via a closed feedback system. Crucial here is the way in which urban planners will respond.

There is on-going work funded by United Kingdom Water Industry Research (UKWIR) dealing with climate change and the design of sewer systems, due for completion in 2004, and associated research on the whole life costs of Sustainable Urban Drainage Systems (SUDS). These projects are looking at the effects of climate
change on pathways, implications for sewer design and operation and the real costs of SUDS systems. The sewer project is utilising a number of Asset Management Plan (AMP) study catchments for which drainage area plans have already been prepared, and that are being used to address (amongst other things) properties on the water industry regulator (OFWAT) DG5 at-risk register. These studies are also considering the effects of climate change on the performance of CSOs, a primary driver under AMP3.

A number of other new projects related to urban areas are to be funded under the EPSRC/UKCIP initiative, and one of these known as AUDACIOUS relates to building and local drainage adaptation to climate change effects; development of a new runoff model accounting for climate change is to be developed; new computational models for overland flow routing through urban areas. Health risks will be addressed using the formal Health Impact Assessment according to the most recent World Health Organisation methodology and wider economic and cost-burden allocation will also be addressed.

OFWAT has recently sanctioned additional expenditure for prioritised sewer flooding control under current investments in AMP3 and are re-evaluating forthcoming priorities under AMP4. In this the cost of solving sewer-flooding problems is put at £17k - £150k per property. The problem of evaluating economic benefits was highlighted, and the inequity as a result of the less valuable household inventories of poorer people.

Package 4: National broad brush assessment of environmental impacts of drivers
RASP provides no direct output relating to impacts on environmental receptors and another broad-brush study is needed on this. While RASP produces broad-brush figures for social impacts this package will also permit a deeper exploration of these.

Phase 1 has highlighted the difficulty in predicting both the potential impacts of changes in flooding and flood management on the environment and equally the effects of the environment that may influence flood management over the next 100 years. The environment can be represented as a source, pathway and receptor in the flooding dimension, and is subject to a number of feedback mechanisms that lead to iteration of its effects. There are also potentially significant opportunities in the future to enhance environmental benefits from enlightened flood management strategies, which may prove to have positive effects on flood management practices. Recognising that the environment is integrated and iterative, with many feedback loops, a work package is proposed that seeks to identify the main driving mechanisms and interactions that may influence future flood management.

The work package should include consideration of opportunities and benefits for the environment in the future from a change in regulatory and public perception of the environment. This should cover the wider environmental context (aquatic, floodplain, wetlands, landscape etc.) and potential ecosystem/societal good of modified/different flood management practices. It is likely that stakeholder involvement over the next century will significantly influence both flood management choices and measures, which will be underpinned by environmental considerations. It is these potential outcomes that require further definition.

There is also the potential for differentiation in response to the four “futures” scenarios, which may include a north/south split in climate and other variables.
leading to different regional responses. Responses may include for example different levels of “natural” evolution through to different flood management strategies (e.g. use of floodplains). Consideration should be given to potential variation in environmental responses (e.g. growth rates, land use cover) and regional practices (e.g. suitability of measures) to define the envelope of potential outcomes.

All of the above is predicated on the availability of sound scientific data on the environmental baseline (including evolutionary change) and tools with which to predict changes. The study should identify the data and tools that will be necessary in the future to provide robust inputs into the flood management decision-making process (see also Cascade Consulting, 2002).

**Package 5: National broad brush assessment of coastal erosion risk**

A broad-brush assessment of the risks of coastal land sliding and erosion was conducted as part of MAFF’s (2000) National Appraisal of Assets at Risk from Flooding. More detailed analysis of the magnitude of erosion risk on a national scale is provided in Lee and Clark (2002). Package 5 will extend the previous research to look on at 30-100 year time scale to assess, in broad-brush terms, the:

- potential loss of coastal land; and
- impacts of coastal erosion in economic terms and on communities, heritage and habitats (the last of which may often be beneficial).

The contribution that eroded coastal sediments make to neighbouring coasts and estuaries and the potential impacts of long-term change.

**Package 6: Case studies**

The previous contracts will provide a broad national overview of future risks under the baseline scenarios. The baseline scenarios include assumed projections into the future of current flood management policies. In the context of RASP only Standard of Protection and defence condition are fed in. Nothing is said about how these policies might be implemented on the ground, and what might be the barriers and opportunities in implementing them. One aim of this package would therefore be to explore where or when existing flood management policies might become infeasible in the future. This package explores these issues through a small series of case studies. These would be carried out where data, models and people are already available to facilitate them, and might be based on one of the current pilot Catchment Flood Management Plans, a Shoreline Management Plan, an estuarial strategy, and an urban drainage study. As with the first package it is suggested that this work should be carried out by a small consortium of the consultants concerned to encourage interaction.

**Package 7: Broad-brush comparison studies of Wales, Scotland and Northern Ireland.**

RASP only covers England and Wales. In order to obtain economic and social impacts covering the whole country it will be necessary to carry out a simple extension of the RASP results by, for example, utilising nationally available population data. It would also be advantageous to require these studies, in a very broad-brush way, to identify any special issues arising from Packages 1, 3 and 4. This package will afford the UK Devolved Administrations with the opportunity to participate directly in the Foresight project.

**Package 8: Management and coordination of packages**

It is apparent that the management and coordination of these contracts is itself an important task. It is proposed that it will be carried out by OST, with expert technical
support. It is likely that one of the strategies used will be to gather the package contractors together for a briefing session to ensure that they all understand the aims of the project and their parts in it.

7 Outline structure and approach to Responses

The specification for Phase 1 (Appendix A) of the Foresight Flood and Coastal Defence project requires the production of an “outline structure and approach for the subsequent work on responses”. This is intended to establish a consistent and integrated approach to the project as a whole. In particular, it will ensure that the work packages planned for Phase 2, the baseline impacts assessment will provide the information necessary to plan in detail the work on responses. It should be noted that it is not the intention of the specification that any suggestions of possible responses should be given in Phase 1. Indeed, it would be quite wrong to make guesses at these, which might prejudice the indications which will come out of Phase 2.

The proposed approach is illustrated in Figure 7.1. In this figure new responses, combining variations in both flood management expenditure and approach, are explored. These would be planned in the mid term review, based as noted in the specification, on the information emerging from the Phase 2 work.

Figure 7.1: Responses (Phase 3) analysis
A suggested flow chart for Phase 3 is shown in Figure 7.2, with Phase 2 work and project management activities shaded in grey:

- **Phase 2 Baseline impacts analysis** (Packages 1-7, first part)
  - Package 8: Management and coordination (Phases 2 and 3)
    - Package 9: Future sciences engineering and technology development.
    - Package 10: Mid term review:
      - Review of costs and progress
      - Analysis of Phase 2 results
      - Scoping of responses, constraints and opportunities
      - Development of a small set of responses that spans the decision space
      - Outline analysis of impacts and ranking of responses
  - Phase 3: Responses analysis (Packages 1-7, second part)
  - Package 11: Synthesis and reporting

Figure 7.2 Suggested flow chart for responses phase

### 7.1 Outline of Responses work packages

**Package 9: Future development of sciences engineering and technology**

As noted earlier the future development of sciences and technologies is likely to be vital to the future of flood management and is a driver of high importance. This package would include involvement of the Research Councils in seeking novel cross-disciplinary solutions and an international workshop to review new and developing approaches. This package should build on the flooding consortium being developed by the Engineering and Physical Sciences Research Council and the joint DEFRA/Environment Agency research programme, and the work of the Hadley Centre and the Tyndall Centre.
Package 10: Mid-term review
As Phase 2, the assessment of baseline scenario impacts, draws to a close it is recommended that there should be a mid-project review. This will bring together an analysis of lessons emerging from the baseline impacts assessments and their indications for future flood management responses; a scoping of the potential future of flood management planning, implementation and operations; a detailed plan for Phase 3 including the selection of a small but representative set of responses and scenarios which span the decision space. These components are explored in outline below, and are followed by the presentation of ideas for the conduct of the rest of Phase 3.

- **Review of costs and progress**
  These will be reviewed as a matter of good project management practice.

- **Analysis of Phase 2 results**
  The first task of this component will be to analyse and synthesise the results of Phase 2, and to use this to inform the approach to the assessment of responses in Phase 3. Thus the case studies may show that certain flood management strategies may be difficult to implement under certain scenarios and drivers. They will also show that there are ‘trade-offs’ between responses. For example a choice may have to be made between protecting an important SSSI of international nature conservation and protecting a community. The task here is to categorise, and document these policy dilemmas and problems.

- **Scoping of responses, constraints and opportunities**
  The analysis of Flood Management Futures in Section 3 of this report has begun the process of scoping the range of possible flood management policies and practices in future. The Flood Management Futures have served to illustrate how flood management is implemented in a package of measures. Some are conventionally referred to as structural measures, which could be further divided into hard measures such as walls and embankments, and softer measures such as watershed management; some are referred to as non-structural and include development zoning, flood warning and emergency planning. Large scale realignment of defences and relocation of communities and infrastructure is an example of a combination of structural and non-structural measures.

Starting with the Flood Management Futures, it is suggested that the full range of structural and non-structural responses to flood risk should be elicited during a stakeholders’ brainstorm session and subsequent expert consultation. It has not been possible in the very short time scale of Phase 1 to give adequate attention to the significance of extreme events and specially vulnerable sectors and locations, and it is suggested that this should be included in the agenda for the workshop.

Not all responses will be practically realisable. Constraints of the regulatory process, public acceptability (which will vary between the Foresight Futures), or the legacy of existing infrastructure and development (for example key conurbations) will restrict the ‘decision space’ of possible responses. This may be more important than the cost of a policy in terms of the national purse. The drivers identified and analysed in the Phase 1 study will be scrutinised to establish the extent to which they represent constraints on the possible responses. Clearly on a 30-100 year timescale issues that are currently regarded as constraints may change, so the Foresight Futures will be used to inform the long-term analysis of constraints. However, some constraints, for example coastal nuclear power stations, are immovable even on a 100-year timescale.
Equally important are the opportunities to combine flood management responses with other policy objectives, for example in the context of water resources or rural stewardship. Synergies and opportunities presented by flood management responses will be identified.

It will be important in this to bring in the stakeholders, notably HM Treasury, DEFRA, English Nature and their equivalents in Scotland, Wales and Northern Ireland, in deciding which scenarios to explore.

- **Development of a small set of responses that spans the decision space**
  
  Based on the analysis of constraints, a screening process will be conducted to limit the scope of possible responses to options that are realisable on a 30-100 year timescale in the context of at least one Foresight Future. The number of potential combinations of flood management response is enormous. It is therefore proposed to develop a manageably small number of internally consistent packages of structural and non-structural responses. Between them, these packages should span the possible decision space. These prototypes will include both familiar and more radical packages of flood management response.

  The establishment of this set of flood management response packages might be assisted by an expert outline analysis of the impact of potential responses carried out in a similar way to that which was done for drivers in Phase 1.

**Quantitative analysis of responses (Packages 1-8, second part)**

The outline analysis of responses will lead to the development of specifications for more detailed analysis of responses. These analysis studies will, in practice, be conducted as continuations of the analysis of drivers outlined in Section 6 above. It will involve a combination of quantified analysis of scenarios in RASP together with qualitative analysis of aspects of responses that cannot be addressed in RASP. Studies of environmental impacts, intra-urban flooding and coastal erosion, together with case studies and regional comparisons will be extended to address the impact of responses.

This more detailed analysis will consider uncertainty and robustness of responses through sensitivity analysis. The robust responses, i.e. those that are acceptable (though not necessarily optimal) under all or most conceivable fluctuations in key variables and scales of valuation, will be identified. Issues of sustainability are tackled by introducing appropriate criteria into the evaluation of options e.g. reversibility, and resilience (i.e. capacity for self-repair). Responses whose costs compound with time, passing on a heavy commitment to future generations, will be highlighted.

**Package 12: Synthesis and reporting**

Finally, the results of analysis of responses will be synthesised into an overall evaluation of options that have been, as far as possible, quantified in terms of risk (economic, social, environmental and so on).
7.2 Beneficial Impacts of Floods and Flood Management

The types of responses that can be envisaged in the future may not relate solely or indeed predominantly to the historic approach of “predicting and protecting” through hard engineered flood and coastal defence measures. There is a growing emphasis on catchment and coastal zone flood management that takes a sustainable long-term view. This is likely to have at its core the requirement to allow natural ecosystem processes to evolve dynamically, provided of course that a certain level of flood protection is afforded to the public at large. This approach would sit well with the direction of recent environmental regulation, including the Water Framework Directive, and would provide many opportunities to realise the benefits of aquatic systems for the wider community, including not only for their intrinsic value but also for recreation and as integral natural features of the landscape.

A logical consequence of such an approach is that flood management measures must be considered in the wider national context, whereby some local or regional difficulties with constraining natural evolution to mitigate flood risk may not be sustainable in the long-term, requiring difficult decisions to be made. For example, there may be coastal areas that would be better left to evolve naturally where there is presently some public pressure for protection, and within catchments it could be envisaged that areas may be better left to re-establish as natural dynamic systems rather than to continue to provide hard engineered defences.

Such an approach will require a better fundamental understanding of the interactions of the ecosystems and their environmental drivers. For example, many of the interactions of floods and coastal process dynamics on habitats, communities and species are not well understood. Tools to predict the potential ecosystem changes from different flood management practices and strategies are also lacking (Cascade Consulting, 2002).

Thus as noted earlier the development of new methods in the sciences (physical, environmental and social) and in engineering and technology will be needed to underpin new approaches such as this. Likewise sustainable, flexible and adaptable flood management strategies will be needed to implement these ideals.

7.3 Outcomes and deliverables

The project will address the following objectives, the:

- identification and assessment of the relative importance of the threats that need to be taken into account in long term planning on flood and coastal defence;
- construction of a set of risk based scenarios taking those factors into account over a 30-100 year timescale and addressing social, economic and environmental issues;
- provision of an overview of the responses available and key issues that determine those responses;
- inform policy and its delivery.

The project outcome will be a long-term vision for the future of flood and coastal defence. It will be based on a methodology which takes account of the many uncertainties, but which nevertheless aims for robustness. It will cover England,
Scotland, Wales and Northern Ireland; will look 30-100 years into the future; will cover pluvial, fluvial, coastal and fluvial/tidal flooding and coastal erosion, and will consider economic, social and environmental impacts.
8 Project management plan

8.1 Programme and costs for Phases 2 and 3

Estimated costs and durations of the work packages are summarised in Table 8.1:

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<thead>
<tr>
<th>Package No.</th>
<th>Title</th>
<th>Lower bound costs £k</th>
<th>Upper Bound costs £k</th>
<th>Duration months</th>
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<td>1</td>
<td>Drivers studies and quantification</td>
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Table 8.1: Estimated costs and durations of the work packages

An approximate programme for the rest of the project is shown in Table 8.2
### Table 8.2: Approximate programme for the Phases 2 and 3 of the Foresight Flooding Project

<table>
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<th>Package No.</th>
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<td>2</td>
<td>National broad brush assessment of economic and population impacts of drivers on fluvial, estuarial and coastal receptors - Baseline impacts</td>
<td></td>
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<tr>
<td>2</td>
<td>National broad brush assessment of economic and population impacts of drivers on fluvial, estuarial and coastal receptors - Responses</td>
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<td>3</td>
<td>National broad brush assessment of intra-urban economic and population impacts of drivers.</td>
<td>xxx</td>
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<td>4</td>
<td>National broad brush assessment of environmental impacts of drivers</td>
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<td>5</td>
<td>National broad brush assessment of coastal erosion risk</td>
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<td>6</td>
<td>Case studies to interpret impacts on the ground and explore barriers and opportunities</td>
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<td>xxx</td>
<td>xxx</td>
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<td>7</td>
<td>Broad brush comparison studies of Wales, Scotland and Northern Ireland.</td>
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<td>xxx</td>
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<tr>
<td>8</td>
<td>Management and coordination of packages</td>
<td>xxx</td>
<td>xxx</td>
<td>xxx</td>
<td>xxx</td>
<td>xxx</td>
<td>xxx</td>
<td>xxx</td>
<td>xxx</td>
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<td>9</td>
<td>Future development of sciences and technologies</td>
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<td>10</td>
<td>Mid-term review</td>
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<td>xxx</td>
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<tr>
<td>11</td>
<td>Synthesis and reporting</td>
<td></td>
<td></td>
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<td></td>
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</table>
8.2 Project risks

Flood risk and its management is a complex problem, with a long pre-existing history, and the Foresight flooding project must cover all relevant aspects at a broad brush level. The programme of work for the assessment of baseline impacts and responses is therefore challenging and not without its risks. The perceived risks and mitigation measures are shown in Table 8.3 below.

Table 8.3: Project risk table

<table>
<thead>
<tr>
<th>Work area</th>
<th>Hazard or Risk Issue</th>
<th>Initial risk level</th>
<th>Mitigation strategy</th>
<th>Mitigated risk level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technical Performance</td>
<td>Does not adequately resolve impacts outside narrow economics.</td>
<td>H</td>
<td>Inclusion of work packages for all drivers. Inclusion of environmental impacts work package.</td>
<td>L</td>
</tr>
<tr>
<td></td>
<td>Not applicable to intra-urban flooding.</td>
<td>H</td>
<td>Inclusion of work package for urban flooding.</td>
<td>L</td>
</tr>
<tr>
<td></td>
<td>Not applicable to Scotland and Northern Ireland.</td>
<td>H</td>
<td>Complimentary work package.</td>
<td>M</td>
</tr>
<tr>
<td>Other</td>
<td>Conflict of technical objectives within team.</td>
<td>M</td>
<td>Packages well specified. Regular team briefing.</td>
<td>L</td>
</tr>
<tr>
<td></td>
<td>Lack of understanding of cross disciplinary approaches.</td>
<td>M</td>
<td>Regular team briefing and reviews.</td>
<td>L</td>
</tr>
<tr>
<td></td>
<td>Lack of technical competence.</td>
<td>M</td>
<td>Careful selection of leading experts; monitor progress and performance.</td>
<td>L</td>
</tr>
<tr>
<td></td>
<td>Lack of vision.</td>
<td>M</td>
<td>Involvement of leading experts from the UK flooding community, other scientific communities and overseas.</td>
<td>L</td>
</tr>
<tr>
<td>Commercial Performance</td>
<td>Subcontractors fail to deliver on time.</td>
<td>H</td>
<td>Use established working relationships.</td>
<td>M</td>
</tr>
<tr>
<td></td>
<td>Optimistic estimates.</td>
<td>H</td>
<td>Phase 1 study carried out; review at bid stage; mid-term review.</td>
<td>M</td>
</tr>
<tr>
<td></td>
<td>RASP development and runs take too long.</td>
<td>M</td>
<td>Review at bid stage; mid-term review.</td>
<td>L</td>
</tr>
<tr>
<td>Technical Acceptance</td>
<td>Rejection by flooding community.</td>
<td>H</td>
<td>Thorough and comprehensive work plan, albeit at high level.</td>
<td>L</td>
</tr>
<tr>
<td></td>
<td>Rejection by environmental community.</td>
<td>H</td>
<td>Inclusion of established environmental experts in Phase 1 core team and workshop. Specific environmental package in Phases 2 and 3.</td>
<td>L</td>
</tr>
<tr>
<td>Institutional Acceptance</td>
<td>Non-acceptance by other government departments.</td>
<td>M</td>
<td>Regular meetings of expert advisory group and Ministerial stakeholder group. Involvement of DEFRA and HM Treasury in work.</td>
<td>L</td>
</tr>
<tr>
<td></td>
<td>Non-acceptance by other stakeholders.</td>
<td>M</td>
<td>Membership of expert advisory group and Ministerial stakeholder group.</td>
<td>L</td>
</tr>
<tr>
<td></td>
<td>Conflicting opinions from stakeholders.</td>
<td>H</td>
<td>Regular project group meetings and open access to work and outputs.</td>
<td>M</td>
</tr>
</tbody>
</table>

With the listed mitigation measures and close attention to project management, and in particular to those components with the highest risk levels it is believed that the risks can be successfully controlled.