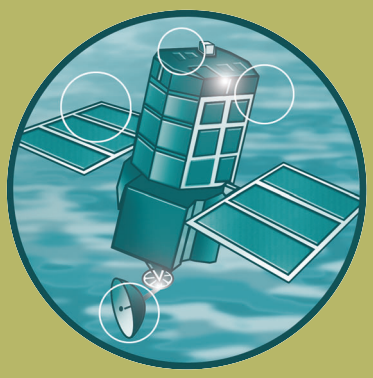
Joint Defra/EA Flood and Coastal Erosion Risk Management R&D Programme

Sustainable Flood and Coastal Erosion Risk Management

Part 2: Case studies report

R&D Technical Report FD2015/TR2



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Sustainable Flood and Coastal Management – Case Studies Report

R&D Technical Report FD2015/TR2

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Author(s):

Steven Wade, HR Wallingford
Jonathan Simm, HR Wallingford
Pam Bowker, HR Wallingford
Michael Wallis, HR Wallingford
Kasay Asmerom, HR Wallingford
Fola Ogunyoye, Posford Haskoning
Martin Budd, Posford Haskoning
David Brew, Posford Haskoning
Joseph Howe, University of Manchester
Colin Green, University of Middlesex, Flood Hazard Research Centre
Sarah Cornell, University of East Anglia
Alex Nicholls, Sd3 Ltd.

Statement of use

This report suggests principles and guidance to help flood and coastal erosion risk management policy makers and practitioners make better decisions that deliver greater environmental, social and economic benefits. It should be noted that it does not constitute official government policy or guidance, which will be provided through the developing work on appraisal under Making Space for Water. In the interim it is suggested that any application of the guidance within this report is only undertaken following consultation with Defra's Flood Management Division

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Research contractor: HR Wallingford

Defra project officer: Matt Crossman

Publishing organisation
Department for Environment, Food and Rural Affairs
Flood Management Division,
Ergon House,
Horseferry Road
London SW1P 2AL

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Executive summary

Introduction

This report is the second Technical Report produced for the project 'Sustainable of Flood and Coastal Erosion Risk Management', which was commissioned by Defra, within the joint Defra/Environment Agency R&D Programme.

Background

In March 2005 the Government launched a new UK sustainable development strategy - "*Securing the future*" that set out a new purpose and principles for sustainable development with priorities agreed across the UK, including the devolved administrations (HM Government, 2005)[1].

In the same month, the Government published its first response to "Making Space for Water", the consultation exercise for developing Government strategy on flood and coastal erosion risk management in England. The new strategy aims:-

To manage risks by using a range of measures that reflect both national and local priorities to:-

- reduce the threat to people and their property; and
- deliver the greatest environmental, social and economic benefit consistent with the Government's sustainable development principles.

The emphasis in the new strategy on managing risks and clear alignment with the Government's Sustainable Development Strategy provides an opportunity for more sustainable flood and erosion risk management in England and Wales. This report aims to develop principles and guidance to help policy makers and practitioners make better decisions that deliver the greatest environmental, social and economic benefits.

Technical Report 1

Technical Report 1 provides a discussion of the principles of sustainable flood and coastal erosion risk management and a series of topic notes on key issues.

- Topic Note 1. Sustainability Appraisal
- Topic Note 2: Community Engagement and Sustainable Development
- Topic Note 3: Appraisal of solutions & schemes with multiple objectives
- Topic Note 4: Compulsory purchase & legal aspects of flood management
- Topic Note 5. Planning and flood risk
- Topic Note 6. Rural development and flood risk
- Topic Note 7. Adaptation and resilience
- Topic Note 8. Precautionary climate change allowances
- Topic Note 9: Wise use of materials
- Topic Note 10: Using Catchment Flood Management Plans (CFMPs)
- Topic Note 11: Using Shoreline Management Plan (SMP)

Technical Report 2: Case Studies

[1] Also see http://www.sustainable-development.gov.uk

This report has the following objectives:

- To assess the potential for particular approaches or tools to improve the sustainability of flood and coastal erosion management and their limitations.
- To identify the barriers that have prevented or could prevent particular tools and approaches from achieving sustainable outcomes and ways of overcoming them.
- To provide opportunities to identify and learn lessons from past practices, whether good and bad.
- To identify improvements required to current tools and their application to achieve improved sustainability.

Six case studies are presented that explore particular sustainability issues and/or 'tools' used to help decision makers make better choices and promote more sustainable schemes (Table ES1).

Table ES1. The selected case studies

Case Study No.	Sustainability Issues / Tools	Case Study
1	Changes and potential loss of designated habitats – use of managed realignment and stakeholder consultation	Humber Estuary SMP and Paull Holme Strays managed realignment scheme (within Humber Estuary)
2	Identifying and developing sustainable solutions – use of sustainability appraisal	Moray flood alleviation scheme, Morayshire, Scotland
3	Accounting for social and environmental "intangibles" in decision making – use of multi-criteria analyses	Humber Estuary SMP and River Chet flood alleviation scheme
4a	Alternatives to formal flood defences in local flood protection – use of temporary and demountable flood protection	River Severn temporary and demountable flood protection systems
4b	Integration of land and urban management. Alternatives to formal flood defences in the management of run-off – Use of SuDS	Sustainable Water Management Systems (FLOWS) project, Cambourne, Cambridgeshire.
5	Managing the conflicts between development and natural processes – Use of SMPs and associated consultation	North Norfolk SMP and associated strategies
6	Sustainable procurement and re-use of materials and waste minimisation	Brighton to Ovingdean coast protection scheme

The case studies showed a significant difference between available best practice and general current practice in the application of sustainable management methods within flood and coastal risk management, justifying the need for guidance to disseminate best practice and support a step change in

this area. The case studies also showed the potential of particular management techniques and tools for improving the sustainability of flood and coastal defences.
In order to maximise theses potentials however, efforts should be directed not only on the processes, but on the achievement of the sustainable outcomes. Appropriate use of available good techniques, guided by application of lessons learnt from the case studies can assist in this regard. This is being achieved within the overall project by the incorporation of the outputs from the case studies into the individual guidance sheets produced to target particular sustainability issues (Technical Report 1).

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1 Introduction

1.1 Background to the Case Studies

Consistent with the UK Government's sustainable development principles, Defra has identified sustainability as one of the key principles that will underpin its approach to flood and erosion risk management in England. To provide underpinning science and guidance to assist in this cause, an R&D project titled "Sustainability of Flood and Coastal Erosion Risk Management" was commissioned by Defra, within the joint Defra/Environment Agency R&D Programme.

A scoping study was carried out as part of the earlier phase of this project. The scoping report project (HR Wallingford, 2004a) identified a number of sustainability issues which required further development in order to develop methodologies and guidance for improved sustainability. This development work was carried out as part of Phase 2 of the project. It comprised of further detailed research and case studies, both complementing each other in the ultimate aim of developing guidance and approaches to improve sustainability. This document reports on the process and outcome of the case studies.

1.2 Objectives

The case study process provides a vehicle for practical testing of the processes and tools that could be used to improve the sustainability of flood and coastal management using real cases. The aim of the overall project is to "develop practical guidance and tools for policy makers and practitioners to enable them improve the "sustainability" of flood and coastal management". Within this context, the particular objectives of the case studies are outlined below:

- To assess the potential for particular approaches or tools to improve the sustainability of flood and coastal erosion management and their limitations.
- To identify the barriers that have prevented or could prevent particular tools and approaches from achieving sustainable outcomes and ways of overcoming them.
- To provide opportunities to identify and learn lessons from past practices, whether good and bad.
- To identify improvements required to current tools and their application to achieve improved sustainability.

The ultimate purpose of the case studies is to inform the overall guidance on improving the sustainability of flood and coastal management, injecting a good measure of practicality and focus into its development.

Particular objectives have been developed for each case study to focus on particular sustainability issues. These individual objectives are outlined within Section 3.

1.3 Case study details

1.3.1 The Selected Case Studies

Following the procedure outlined in Appendix 1, a number of key sustainability issues identified from the scoping study were selected to be further developed by the testing of tools and approaches for managing them at appropriate sites. The selected case study sites and associated sustainability issues are outlined in Table 1.1 below:

Table 1.1 The selected case studies

Case Study No.	Sustainability Issues / Tools	Case Study
1	Changes and potential loss of designated habitats – use of managed realignment and stakeholder consultation	Humber Estuary SMP and Paull Holme Strays managed realignment scheme (within Humber Estuary)
2	Identifying and developing sustainable solutions – use of sustainability appraisal	Moray flood alleviation scheme, Morayshire, Scotland
3	Accounting for social and environmental "intangibles" in decision making – use of multi-criteria analyses	Humber Estuary SMP and River Chet flood alleviation scheme
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5	Managing the conflicts between development and natural processes – Use of SMPs and associated consultation	North Norfolk SMP and associated strategies
6	Sustainable procurement and re-use of materials and waste minimisation	Brighton to Ovingdean coast protection scheme

Figure 1.1 below shows the geographical spread of the case study sites across the UK.

Figure 1.1 Location of case study sites

1.3.2 Case Study Characteristics

As described in Appendix 1, a number of considerations were made in deciding on the choice of case studies. These included relevance to identified sustainability issues, spread of location, time-frame, physical characteristics, type and level of management activity. Table 1.2 below illustrates how this has been achieved.

Table 1.2 Characteristics of selected case studies

Case Study No.	Physical characterisation	Management Type	Management Hierarchy	Time-frame
1	Estuarine	Local & community	Policy / Strategy	Ongoing / Recently completed
2	Fluvial	Regional & strategic	Strategy / Delivery	Ongoing
3	Estuarine	Regional & strategic	Policy / Strategy	MCA development ongoing; schemes completed
4a	Fluvial	Local & community	Delivery / O&M	Recently completed
4b	Fluvial	Regional & strategic; Local & community	Delivery	Ongoing
5	Coastal	Regional & strategic; Local & community	Policy / Strategy	SMP1 completed pre 2000; strategies recently completed; SMP2 ongoing
6	Coastal	Local & community	Delivery	Ongoing

1.3.3 Case Study Types and Objectives

Based on the timings of the projects in relation to the case study process and the sustainability issues associated with them, objectives were developed for each case study in line with the particular aspects where better understanding and guidance is required. The methodology of approach for each one then followed the process outlined within Appendix 1, depending on the case study type. Table 1.3 below describes the objectives for each case study and the type of case study.

Table 1.3 Case Study Objectives

Case Study No.	Case Study Type (as described in 2.2)	Case study Objective(s)
1	Type 1	To review the Humber Estuary SMP in order to identify factors (tools) that facilitate or constrain the development of shoreline management plans To review the implementation of Paull Holme Strays managed realignment scheme in an area of potential flood defence and nature conservation conflicts To examine the role of stakeholder participation in the development of sustainable outcomes
2	Type 1	To review the use and influence of sustainability indicators within the development of Moray FAS To identify guidance for the development of sustainability appraisal as tools for achieving sustainable outcomes
3	Type 2	To review the ongoing development of MCA methods within Defra's ongoing MCA R&D, and in particular the River Chet and Humber SMP case studies with regards to delivering sustainable outcomes
4a	Type 1	To review the potential of temporary and demountable flood protection as a tool for providing more sustainable flood management To assess their operational requirements and reliability, and the effect of these on their potential

Case Study No.	Case Study Type (as described in 2.2)	Case study Objective(s)
4b	Type 1	To review the ongoing Cambridgeshire FLOWS project with regards to the potential of SuDS for integrating land and flood risk management and achieving sustainable management of run-off and flood risk
5	Type 1	To review the North Norfolk SMP and associated strategies with regard to the effect of the SMP2 in the development of sustainable coastal management To assess the process of stakeholder engagement in the achievement of a sustainable coastal management in an area where potential conflicts of continued protection of communities and natural processes exist
6	Types 1 and 3	To use the Brighton to Ovingdean coast protection scheme to review the opportunities and barriers for sustainable use of materials within the design, procurement and construction of flood management and coast protection schemes To assess the use of the eco-point estimator as a tool for estimating indicators of environmental performance of various options of material use and management

1.4 Layout of the Report

The development and results of the case studies are provided within the case study reports. This consists of the main report (this report) and seven Annexes. The main report provides information about the objectives of case studies in relation to the overall project, the choice of case studies, their development and key outputs. The details of the individual case studies are provided separately as Annexes to the main report.

This section outlines the objectives of the case studies and puts it in the context of the overall R&D project. Section 2 provides a description of the overall methodology of approach. It describes the case study selection procedure, highlighting the key factors considered in choosing the case study topics and associated sites.

Section 3 provides information about the chosen case study sites, the approaches, tools and techniques of relevance to sustainability within them and the particular objectives and issues addressed by each case study.

Section 4 provides a summary discussion of the key outcomes of the case studies, in particular common issues in the management or delivery of the tools that can affect their potential impacts on sustainability.

The Annexes have all been developed to consistent formats. Each one has an introductory and objective setting section, followed by a section on case study information and assessment. An assessment of the benefits or otherwise of the tools/approaches, barriers, limitations and issues of wider applicability of the assessments to other sites then follows, concluding with a summary discussion or statement on the findings.

2 Case Study No. 1 Managed Realignment and Stakeholder Consultation – Humber Estuary

2.1 Introduction

2.1.1 Background Information

The Humber Estuary Coastal Authorities Group (HECAG) Shoreline Management Plan (Posford Duvivier, 1998) was prepared for the area between Flamborough Head and Donna Nook, and covers the Humber Estuary downstream of a line drawn between Hawkin's Point and Immingham Docks. Following this publication, a further SMP (The Humber Estuary Shoreline Management Plan, HESMP Phase 1) was prepared in 2000 (Environment Agency, 2000), which covers the whole of the tidal estuary. Running concurrently with the preparation of the HESMP Phase 1 were a series of Humber Estuary Geomorphology Studies Phase 2 (the results of which were integrated into the HESMP). The Environment Agency has since completed further assessments, and is currently preparing the final flood defence strategy.

Challenges for the Humber Estuary SMP include sustainable management of a number of stakeholder issues such as coastal flooding and protection of internationally designated sites. In these respects, the HESMP concluded that in places it may be appropriate to realign flood defences rather than repair or improve them on the existing line. However, managed realignment has major impacts on the owners of the land and on those who earn their living there, raising issues about the need for compensation. Nevertheless, there are potential flood defence or nature conservation benefits that could make it worthwhile at selected sites in the estuary. The HESMP recommended that opportunities for realigning the defences be sought wherever this might:

- reduce the threat of erosion affecting their stability
- lower extreme high water levels
- create habitat to offset losses resulting from schemes or rising sea levels
- deliver better value for money.

One realignment scheme has been implemented as 'urgent work', at Paull Holme Strays, 10 km to the south-east of Kingston-upon-Hull. This managed realignment site was identified as an 'urgent work' because the existing flood defence did not provide an adequate level of protection, with overtopping likely, and the possibility of defence failure resulting from repeated storm events. These factors were significant as a number of communities live within the local flood risk zone, including Thorngumbald and Paull Holme villages and a number of scattered houses and farms. In addition, the intertidal area in front of the site falls within the Humber Flats, Marshes and Coast Special Protection Area (SPA), is part of a Ramsar site and a candidate Special Area of Conservation (cSAC). Once fully established, the site is expected to provide compensation for losses due to flood defence works elsewhere in the estuary, and for possible losses due to sea-level rise.

Breaching of the existing bank took place in 2003. Over the next 5 years 80 ha of mudflat, saltmarsh and wet grassland should develop. In support of the proposals for the managed realignment works at Paull Holme Strays an Environmental Statement was published (Halcrow Group, 2000), covering a variety of sustainability issues.
A further potential scheme to eliminate the need for future maintenance of flood defences and to provide intertidal habitat is under consideration at Alkborough. This scheme would create 440 ha of intertidal and freshwater wetland habitats at the River Ouse/River Trent confluence and reduce water levels in the upper estuary to address impacts of sea-level rise.

2.1.2 Objective of Case Study

This case study is one of the seven carried out as part of the Defra funded R&D project Sustainability of Flood and Coastal Defence. The objective is to review the Humber Estuary SMP and identify factors (tools) that facilitate or constrain the implementation of managed realignment and to examine their applicability to other sites. Specifically, the Paull Holme Strays managed realignment scheme was chosen as part of this case study because it highlights potential sustainability issues/conflicts relating to flood defence and nature conservation that management should address. It is also useful as an example because the processes adopted have the potential to help develop strategies for sustainable managed realignment elsewhere, both in the Humber Estuary and further afield.

2.1.3 Sustainability Issues

Strategies for managed realignment in the Humber Estuary can be discussed with respect to implementation upstream and downstream of the Humber Bridge. Downstream of the bridge, 'strategic' realignment is needed to create habitat to offset expected coastal squeeze losses. In addition, some local realignment of the defences may reduce future maintenance costs and provide nature conservation benefits without having major economic or social impacts. This includes the Paull Holme Strays site. Upstream of the bridge, coastal squeeze becomes less of an issue, but there are opportunities to counter some of the effects of sea-level rise by realigning to create tidal washlands.

Sustainable Productive Agriculture
Much of the low-lying land surrounding the Humber Estuary is farmed and amongst the most fertile in the country. Taking large areas of it permanently out of production is unlikely to be acceptable nationally. The ability to sustain productive agriculture along the estuary depends on having an adequate standard of protection. The loss of small areas of land, either by realigning the defences or lowering the standard of protection, may be acceptable although removing part of a holding could be difficult if it involves reorganising a well balanced farming operation.

Financial Compensation
The Environment Agency is aiming to buy land currently in agricultural use where long-term intertidal habitat is created following managed realignment of the defences. Alternatively, payments may be available through the Intertidal

Options in the Countryside Stewardship Scheme. The habitat creation proposals must meet the criteria for acceptance into the Countryside Stewardship Scheme to be eligible for funding, and be compatible with the conservation objectives of the SPA where applicable.

Sustainable Flood Defence
According to the HESMP, about 70% of the land beside the Humber Estuary is currently provided with a standard of protection equal to or greater than the indicative standard. Assuming a 6 $mmyr^{-1}$ rise in sea level over the next 50 years, less than 40% of the land will be provided with the indicative standard unless the defences are raised. The overall cost of continuing to provide acceptable standards of defence is likely to be of the order of £400-500 million over the next 50 years. This is major investment that needs proper justification.

Loss of Intertidal Areas
The Environment Agency estimates that a sea level rise of 6 $mmyr^{-1}$ would lead to a decrease in the intertidal area in front of the flood defences. Modelling of the estuary suggests that it could lead to the total intertidal area in the estuary being reduced by 300-600 ha over the next 50 years. This has been used as a guide as to how much realignment is needed. The local biodiversity action plan for the Humber Estuary sets preliminary conservation targets recommending that any losses of intertidal habitats anticipated over the next 15 years should be replaced within the next 10 years to allow time for the habitats to develop.

Sustainable Habitat Creation
The configuration of the estuary is such that intertidal habitats are tightly constrained by existing flood defences and can only be created by realigning the defence line. In general, ground levels around much of the estuary are considered too low for saltmarsh to develop naturally if managed realignment takes place. In most areas mudflats or sandflats will develop, at least initially, although saltmarsh may be expected to develop as sediment accretes. It will therefore be necessary to take a long-term view when attempting to replace or recreate some of the habitats round the estuary. However, current evidence arising from realignment at Paull Holme Strays and previous small-scale realignments suggests that such measures are likely to meet with a high rate of success.

Change in Water Levels
According to the HESMP, realigning flood defences seaward of Kingston-upon-Hull will have little effect on water levels, locally or elsewhere in the system. Realigning between Kingston-upon-Hull and Humber Bridge could raise water levels further inland. Realigning upstream of Humber Bridge to Trent Falls could lower water levels there without affecting them significantly elsewhere. This effect is enhanced if the realignment takes place in the rivers feeding the Humber Estuary. The scale of the effect depends on the size, level and location of the realignment.

2.1.4 Summary of Available Information and Consultations

In order to compile this study the following publications, web sites and stakeholders have been consulted.

Publications

Binnie, Black and Veatch. 1999a. Estuary-wide impacts of the Urgent Works Programme.

Binnie, Black and Veatch. 1999b. Thorngumbald Urgent Works Geomorphological Study, Interim Report.

Black and Veatch. 2004. Humber Draft CHaMP. Report to the Environment Agency, February 2004.

Environment Agency. 2000. The Humber Estuary Shoreline Management Plan.

Environment Agency. 2001. Humber Tides News, December 2001.

Environment Agency. 2002a. The Humber Estuary. Consultation on managed realignment: information for landowners and tenants.

Environment Agency. 2002b. Humber Tides News, December 2002.

Environment Agency. 2004. Management of The Humber Estuary. Flyer.

Halcrow Group. 2000. Humber Estuary Tidal Defences Urgent Works. Environmental Statement Thorngumbald Clough to Little Humber. Report to the Environment Agency, June 2000.

Hanslip, V. 2002. The application of a conceptual model, decision tree and a logical framework approach to managed realignment schemes: a case study in the Humber Estuary, UK. Report of the Institute of Estuarine and Coastal Studies, University of Hull.

Manning, C.J. 2004 (compiler). Humber Management Scheme, October 2004.

Posford Duvivier. 1998. Humber Estuary Coastal Authorities Group (HECAG) Shoreline Management Plan.

Risk and Policy Analysts. 2003. Annex 5 Case Study No 5: Assessment of the Humber Estuary Shoreline Management Plan.

Web site

www.humberems.co.uk

Consultees

Consultation about this case study took place with Philip Winn (Environment Agency) and Roger Morris (English Nature).

2.2 Case study assessment

2.2.1 Objectives of HESMP

The Humber Estuary SMP is intended to be sustainable in the sense that it takes into account future changes in the environment (human, built or natural), in sea level and in the climate that will meet today's needs without compromising the needs of future generations. The overall objectives of the HESMP are:

- to develop a coherent and realistic plan for the estuary's flood defences that is
  - compatible with natural estuary processes
  - compatible with adjacent developments, including preferred options for adjoining lengths of the frontage
  - sustainable, as above.

- to ensure that all proposals are
  - technically feasible
  - economically viable
  - environmentally appropriate
  - socially acceptable.

The detailed objectives of the HESMP are summarised in Table 2.1.

Table 2.1 HESMP detailed objectives

Coastal Processes
• To build an understanding of the natural processes taking place within the estuary and work with these processes • To respond to future climate change and sea-level rise
Natural Environment
• To comply with all statutory obligations arising from national and international designations and related legislation • To encourage habitat development that contributes to the United Kingdom Biodiversity Action Plan • To create areas of new habitat in compensation for any habitat lost
Human and Built Environment
• To reduce the risk to people and property from flooding and erosion • To provide appropriate protection for industry and commerce and encourage future industrial and commercial development in suitable locations • To avoid adversely affecting navigation in the estuary or opportunities for its development • To avoid adversely affecting fisheries (inland or in the estuary) or the fishing industry • To protect, where appropriate, high quality agricultural land by the estuary • To minimise the impact of natural processes on land drainage to the estuary • To protect the overall interests of people living near the estuary

- To maintain and, where possible, improve the provision of sporting and recreational facilities by the estuary
- To allow for the importance of tourism to the local economy
- To avoid actions that adversely affect the estuary's heritage and cultural resources
- To comply with all statutory obligations arising from national and local designations and related legislation
- To protect, where necessary, the estuary's heritage and cultural resources against erosion
- To protect and, where possible, enhance the estuary's existing landscape character
- To complement the objectives of the Heritage Coast Management Strategies

Planning

- To provide standards of protection that are consistent with existing land use while permitting future development where appropriate
- To encourage the recognition of flood risk as an issue in regional planning guidance and in structure and local plans

In order for sustainability issues to be fully considered, a process of consultations with stakeholders was carried out prior to publication of the final SMP and post the SMP to assess the feasibility and potential delivery of sustainable managed realignment in the Humber Estuary.

SMP Consultation

The recommendations of the final HESMP relied to a large extent on the participation at the inception stages of local communities and landowners in the development of the Plan. Consultation during the development of the SMP took place in three stages. In October 1997, the plan was described and consultees were asked to provide relevant information. In April 1999, the issues were discussed and consultees were able to express their concerns and aspirations. This stage involved the distribution for comment of the 'A Strategy for Flood Defence' document. The draft plan was published in November 1999 as the 'Options Consultation Document'. This document was circulated widely and a large number of meetings were held to describe the issues, set out how the Environment Agency is responding to them and give those affected an opportunity to voice their concerns. The responses to this consultation were taken into account when revising the draft Plan to produce the final Plan.

Geomorphology Studies Phase 2

During consultation, concern was expressed that the Plan might not meet its basic objectives of being feasible and sustainable, environmentally and socially acceptable. Some early work was done on sustainability during the Geomorphology Studies Phase 2 of the HESMP, but not completed. A more comprehensive approach to assessing sustainability is currently under way and will be completed in 2005.

Realignment Consultation

Consultees views on the potential Paull Holme Strays managed realignment was carried out in two stages. Initial views were sought by issuing a number of documents including the Initial Scoping Report (June 1996), the Options

Development Report (May 1997) and the Consultation on Preferred Options Report (September 1997). The Initial Scoping Report described the project, the environmental and engineering work, and the perceived environmental issues. Consultees were asked to comment on the issues raised, the intended approach to the work, and any other points of concern. The Options Development Report presented feasible and non-feasible options and indicated their potential impacts on the environment. The consultees were asked to indicate their preferred options giving their reasons. This report received a favourable response from the consultees, providing a clear picture of the problems and potential solutions. The Consultation on Preferred Options Report provided details of the method of initial option selection, summarising and presenting the consultees comments in response to the Options Development Report. Based on economic, technical and environmental criteria the Environment Agency's preferred options were indicated.

After the written phase of consultation, a series of meetings took place with parties most interested in, and with key roles in delivering the scheme. These included English Nature, Wildlife Trusts, RSPB, the Planning Authority, Thorngumbald Internal Drainage Board, Defra (then MAFF) and relevant landowners.

Further Technical Studies
Following the Geomorphology Studies Phase 2, the next stage in the process was to study these realignment sites in more detail, to assess the benefits and costs of realigning and to draw up a programme for implementing the schemes. The studies included ecology, nature conservation and land use but draw most heavily on geomorphology to ensure that any perceived benefits are sustainable in the long term.

Flood Defence Strategy
The HESMP (2000) sets out the framework for managing the Humber Estuary's defences. However, the process by which this management could be implemented is a continuing process. Recently, the Environment Agency has delivered a detailed flood defence strategy and programme of works, for which approvals are currently being sought. As part of this, the Environment Agency has identified further realignment sites to provide new habitat to meet future expected coastal squeeze losses.

2.2.2 Analysis of Sustainability

HESMP Selected Strategies
The main aim of the HESMP process is to propose a sustainable strategic level approach to coastal defence. The objectives have a bias towards sustainability and as such the resulting end product should deliver a sustainable policy. The selected strategy for each Management Unit in the HESMP is summarised in Table 2.2. This demonstrates that strategic options considered to be sustainable in the long-term will be adopted. In a number of cases 'Hold the Line' is only preferred in the short term whilst they remain economically viable. For these Management Units, managed realignment is considered to be the sustainable policy in the long term.

Table 2.2 Selected strategies for Humber Estuary Management Units as outlined in the HESMP (Environment Agency, 2000)

Management Unit	Selected Strategy
1. Spurn Head to Paull	Consider local realignment to reduce maintenance costs or provide nature conservation benefits including compensation for habitat loss due to 'coastal squeeze'
2. Paull to North Ferriby	Continue to hold defences on their present line, repairing and raising as necessary
3. North Ferriby to Trent Falls	Consider local realignment to reduce water levels as well as provide potential nature conservation benefits including compensation for habitat loss due to 'coastal squeeze'
4A&B. Trent Falls to Boothferry Bridge	Consider local realignment to reduce water levels as well as provide potential nature conservation benefits including compensation for habitat loss due to 'coastal squeeze'
4C&D. Trent Falls to Keadby Bridge	Consider local realignment to reduce water levels as well as provide potential nature conservation benefits including compensation for habitat loss due to 'coastal squeeze'
5. Whitton to South Ferriby Cliff	Consider local realignment to reduce water levels as well as provide potential nature conservation benefits including compensation for habitat loss due to 'coastal squeeze'
6. South Ferriby Cliff to North Killingholme	Consider local realignment to reduce maintenance costs or provide nature conservation benefits including compensation for habitat loss due to 'coastal squeeze'
7. North Killingholme to Cleethorpes	In the north - Continue to hold the defences on their present line now but plan for a time in the future when this may no longer be sustainable. In the south - Continue to hold defences on their present line, repairing and raising as necessary
8. Cleethorpes to Donna Nook	Consider local realignment to reduce maintenance costs or provide nature conservation benefits including compensation for habitat loss due to 'coastal squeeze'

As far as possible, each of the strategies was selected to work with natural processes in the estuary and was arrived at following critical assessment of these processes. Two of the critical factors along four of the management units (3, 4A&B, 4C&D and 5) are the opportunity to reduce local water levels whilst simultaneously compensating for habitat losses elsewhere, taking into account economic, social and environmental aspects. Along three of the units (1, 6 and 8) the key issues were reduction of maintenance costs or provision of nature conservation benefits.

Perceived Objectives of Managed Realignment

As part of the selection of managed realignment sites for the Humber Estuary, stakeholders were asked to rank the scheme objectives in terms of which they considered to be the most important and which least. Only twelve responses were received, which were used to identify which objectives were most/least important to facilitate comparison of qualitative impacts. Risk and Policy Analysts (2003) used these data to assign weights to impact types, broken down into economic, environmental, social and cross-cutting impacts. Risk and Policy Analysts (2003) point out that the intention of the initial ranking exercise

was not to produce weightings and that the weighting data presented do not reflect actual weights for the Humber Estuary strategy and are likely to include a considerable degree of uncertainty. The results were:

- economic impacts: 20%
- environmental impacts: 17%
- social impacts: 8%
- cross-cutting impacts: 55%

The results probably reflect the particular interests of the respondents (where most were national organisations represented on the stakeholder group by a local representative). The weight for social impacts is low but there were no responses from local stakeholders (other than local councils). If the people living in and around the Humber Estuary had been involved in the ranking exercise, the weight for social impacts may have been different.

2.2.3 Overcoming Barriers at Paull Holme Strays

All possible barriers were highlighted at an early stage of the strategy to implement the managed realignment process at Paull Holme Strays (Table 2.3).

Table 2.3 Barriers, successes and failures related to sustainability of the Paull Holme Strays managed realignment.

Barriers
• Loss of agricultural land and financial compensation • Integrity of designated sites • Environment impacts • Loss of heritage interest • Protection of gas and sewerage pipelines
Successes
• Negotiation of an acceptable compensation package • Creation of 80 ha of new intertidal habitat • Improved standard of flood protection • No significant environmental impacts so approval of scheme was given both locally and regionally • Protection of heritage site. New footpaths, bird hide and visitor information • Monitoring and research programme will help plan future Humber Estuary projects • Pipelines protected
Failures
• None as yet

During initial consultation four main issues were raised; consideration of landowners concerns, maintaining the integrity of designated sites adjacent to the works, dealing with the pipelines crossing under the new flood embankment

and crossing the realignment site, and the potential adverse impact on heritage (archaeological) interest. Further meetings with consultees highlighted a number of requirements for initiation of construction. These included evidence that the works would be economically justifiable, that the land could be acquired within a reasonable time frame, and acknowledgement of any significant environmental impacts of the work. Because all of these requirements were met, detailed design of the scheme began with implementation in 2003.

Loss of Agricultural Land and Financial Compensation
A potential barrier to implementation was the loss of around 80 ha of agricultural land and the need to provide adequate compensation to landowners, in particular agreement over the level of fees that should be paid out. If the compensation is unacceptable to the landowner, then compulsory purchase is an option, but this tends to be avoided if at all possible. In the Paull Holme Strays case, landowners were consulted following the recognition of the site for managed realignment, and have been compensated accordingly for land lost due to the development. In this case, the early and sustained engagement with stakeholders led to achieving a satisfactory settlement.

Integrity of Designated Sites
The Humber Estuary, and some adjacent freshwater habitats, is a proposed Special Area of Conservation (pSAC) under the EC Habitats Directive, and is a mixture of proposed and classified Special Protection Area and Ramsar sites under the EC Birds Directive and the Ramsar Convention. These designations mean that there is an onus on the United Kingdom to maintain the nature conservation interest in favourable condition in the context of the Natura 2000 network of European sites. The Conservation (Natural Habitats &c.) Regulations, 1994, provide a clear framework for deciding on the implications of proposals such as managed realignment and upgrading flood management options. In this instance, the proposed realignment was implemented to compensate for losses elsewhere on the estuary, especially those relating to urgent works on the Pyewipe frontage (near Grimsby on the south side of the Humber Estuary). It was agreed only after the rigorous application of the tests of the Habitats Regulations, ensuring that the design of the breach was refined to minimise impacts on intertidal habitats within the estuary.

Environmental Impacts
If the scheme was predicted to create adverse environment impacts either locally or regionally then this could prove to be a barrier to its implementation. The proposed scheme had the potential for significant effects on the SPA, with respect to disturbance of birds on the foreshore and potential loss/change in intertidal habitat. To overcome this the Environment Agency had to prove that the scheme was not environmentally damaging, for approval internally and externally. Internal approval was sought from two groups; the National Review Group and the Project Appraisal Group. External approval was gained from Defra who provide grant aid. Defra gave the scheme ‘approval in principle’, which meant the environmental impacts predicted were acceptable provided the activities conformed to Defra guidelines.

Following approval, technical studies were initiated to further highlight the potential impacts as part of the Environmental Impact Assessment (Halcrow Group, 2000). These studies established the extent of species variation resulting from realignment and determined the extent to which the site will contribute to a 'no net habitat loss' approach, and to the overall value of the estuary's wetland resource. The technical studies included geomorphology, archaeology, ecology, nature conservation and land use. The scheme was approved relatively quickly as it provided compensatory habitat, for that lost at the urgent works scheme at Pyewipe.

Loss of Heritage Interest
The site also has heritage interest (Scheduled Monuments at Paull Holme manor house, World War II decoys and listed lighthouses) and is part of the 'Humber Estuary Landscape Character Site'. Loss of these sites or a need to record them could lead to delays in the implementation process. The lighthouses are operational and the maintenance of access to them, and their position, visibility and stability, is of paramount importance to safe navigation in the Humber Estuary. After long debate (the Environment Agency wanted to move them, but this was unacceptable to English Heritage), they were left in their original position and have been carefully protected with rock armour revetments.

Protection of Gas and Sewerage Pipelines
A gas distribution compound (Transco) is situated 500 m behind the defence and pipelines run under the existing defence and across the Humber Estuary. These are the main gas supply pipelines for Lincolnshire, and the compound is of strategic importance to Transco as it supplies gas to some of the major cities in the north of England. Transco initially refused to approve the works because of concerns over protection of the pipelines. A sewerage pipeline (Yorkshire Water) also runs through the proposed site. To protect all exposed gas and sewerage pipelines seaward of the proposed embankments, they were surrounded in 0.3 m of concrete.

2.2.4 Assessment of Benefits of Techniques

Two main techniques were used to ensure that the Paull Holme Strays managed realignment site in the Humber Estuary is sustainable in the long term; extensive consultation and suites of technical studies.

Consultation
Consultation with statutory and non-statutory consultees played a crucial role in impact assessment, mitigation and development of scheme proposals. Consultations with interested parties led to identification of a series of key concerns regarding the potential adverse impacts of the scheme on the SPA, and subsequently determination of the requirements for demonstrating that the Environment Agency could deliver the scheme. These requirements were:

- Assessment of the cumulative impacts of all flood defence works being carried out in the estuary and demonstration that these impacts would not threaten the integrity of the SPA/Ramsar site

- Investigation of the geomorphological impacts of the proposed realignment on both the local environment (potential for loss of existing mudflat at Thorngumbald) and the wider estuary
- Demonstration that the scheme could be justified economically (either in isolation, or linked to other schemes as compensation) and that it would fulfil the necessary MAFF (Defra) requirements for grant aid
- Demonstration that the Environment Agency could acquire the land for the managed realignment to allow its progression within a reasonable time scale.

Technical Studies

In seeking the long-term sustainability of the estuary, it was necessary to ensure that there would be no adverse affects on the overall functioning of the estuary, both locally and regionally, and in line with the consultation requirements above.

A variety of geomorphological studies were undertaken as part of HESMP Phase 2 to help to explain and quantify the likely evolution of the estuary over the next 50 years. These studies indicate that maintaining defences approximately along the existing line will lead to loss of intertidal habitats as a result of coastal squeeze arising from sea-level rise in an estuary constrained by extensive flood banks. They also show the relative sensitivity of the various parts of the estuary, showing where the greatest benefits to flood risk management can be achieved, and where the estuary is least likely to respond to realignment. These studies were essential to the process, especially as they provided the necessary reassurance that a programme of measures could be introduced to manage and respond to the impact of sea-level rise and associated flood risk and nature conservation impacts.

For Paull Holme Strays, a number of technical studies were undertaken to aid impact assessment (Halcrow Group, 2000). These were:

- Archaeology and heritage
- Ecology, nature conservation and land use
- Geomorphological investigations

It was considered that the scheme could have significant impacts on the local and wider geomorphological regimes and specific investigations and modelling studies were undertaken to address this concern. The initial geomorphological studies indicated that there would be negligible effects on the wider estuary (Binnie, Black and Veatch, 1999a), but doubts remained as to the level of local impact, particularly on the extensive mudflat seaward of the existing defence. The concerns centred on the requirement for two breaches to facilitate drainage of the realignment area, and the potential for this to cause scour and fragmentation of the mudflat. Subsequent model predictions (Binnie, Black and Veatch, 1999b) indicated that the realignment scheme would have minor impact on the SPA in terms of the creation of scour inside the breaches. However, the scheme would be unlikely to result in any fragmentation or significant foreshore loss and there would be gradual formation of creeks at the breach locations. Indeed, the modelling suggested that the scheme would reduce the rate of

foreshore loss predicted to occur in its absence. Overall, the scheme was predicted to have no adverse impact on the integrity of the Humber Flats, Marshes and Coast SPA.

Benefits of Techniques
Consultation was an important and fundamental aspect of appraising the potential impacts of the Paull Holme Strays realignment. The wide-ranging and conflicting stakeholder objectives and development of suitable solutions could not have been satisfactorily resolved without the early and continued engagement with stakeholders. The assessment of the effects of the strategic options on the long-term physical processes and realisation of objectives to obtain a sustainable and acceptable solution would not have been possible without the technical studies. Although consultation and technical studies are widely-used techniques in coastal management, their successful application to implement a sustainable scheme at Paull Holme Strays re-enforces their benefits. Indeed, it is possible that a sustainable scheme is unlikely to have been achieved without these techniques

2.2.5 Review of Opportunities and Wider Applicability

Working with Partners
There are many public, business and voluntary organisations with an interest in the Humber Estuary. Sustainable management needs organisations to work together and this is the case in the Humber Estuary. The Habitats Regulations, 1994, provide the focus for the 38 'Relevant Authorities', including local councils, drainage boards and the Environment Agency to produce a management scheme for the estuary (under Regulation 34). This was published in 2004 (Manning, 2004) and is concerned with how the authorities undertake their operational and regulatory activities so that the conservation status of the estuary is not jeopardised and, where possible, is enhanced.

A good example of working with partners is the Paull Village Restoration Scheme. The village of Paull is to the north-west of the realignment site. The Environment Agency recognised the potential for disruption to the village as a result of the implementation of the realignment project, but also the opportunities for local betterment. They therefore approached Paull Parish Council with a view to working with them and incorporating, where possible, the views of Parish Council members. The Parish Council clearly believed the realignment offered a unique opportunity to improve access to Paull foreshore and develop a combined Country Park and Nature Reserve for a growing number of visitors. Paull Parish Council therefore developed ideas for the enhancement of the foreshore area, to the benefit of both the village and visitors alike. A proportion of these have been delivered, though it will probably take many years for the true aspirations of the Council to be realised.

Optimising the Range of Uses of Realignment Sites
The Environment Agency highlight that they are keen to ensure that the selected managed realignment sites are designed and developed in a way that maximises the opportunity for a wide range of uses. Design and implementation work is increasingly involving the local community and partner organisations in

an effort to incorporate as wide a range of opportunities as possible. Recently this has included the inclusion of the Alkborough project as one of five demonstration sites in an EU funded project involving partners in the United Kingdom, Belgium and the Netherlands. Promoting new land uses alongside flood risk management is the main theme of this project. Alongside the main objectives of providing sustainable flood defences and creating new habitats the sites could also support continued and diversified agricultural uses such as grazing.

Recreation, access and education projects are increasingly being developed as an integral part of the realignment sites. There are a wide range of agri-environmental and other grants available to promote these projects that can provide a focus for maintaining jobs and new business development as well as community based projects. A good example is the hope that the forthcoming Alkborough managed realignment scheme will have far-reaching implications, providing a focus for wider economic regeneration, green tourism and farm diversification initiatives. Central to these ideas is the formation of a Steering Group with representatives from more than 40 organisations and interests. This group is responsible for ensuring the delivery of the work identifies all the potential opportunities and takes account of local concerns, and demonstrates best practice in consultation, design and management of the site. The local community identified more than 20 potential business opportunities arising from the proposal to realign the defences at Alkborough. More than £2 million has been secured so far to deliver these additional activities based on the core project.

Wider Application

The Humber Estuary is large funnel-shaped estuary with a large tidal prism, fed with waters from a large catchment. The analysis techniques employed in the estuary have worked to provide sustainable strategies for management units. These techniques have wider applicability to estuaries with different physical regimes. First, the process of consultation is important wherever a strategy for managed realignment is being devised. The necessity to consider the arguments of conflicting stakeholder interest equally applies in large estuary systems (Humber) as they do to smaller systems. The number of stakeholders and their interests may be different but the process of consultation is the same. Second, a suite of technical studies have been employed in the Humber Estuary providing a wide-ranging insight into its form and function, which have been applied to understand the potential impacts of different options. Again, technical studies are an important component of any option development regardless of the scale of the estuary in which the strategy is being developed. The final suite and scope of the studies may be different, but the process of deciding which ones are appropriate is the same. Overall, a combination of consultation and appropriate technical studies are critical to any potential scheme and should be implemented as standard practice.

2.3 Summary of findings

- The objective is to review the Humber Estuary SMP and identify factors (tools) that facilitate or constrain the implementation of managed realignment and to examine their applicability to other sites.

- The main aim of the HESMP process is a sustainable strategic approach to coastal defence. The objectives of the HESMP demonstrate that strategic options considered to be sustainable in the long-term will be adopted.

- Six main sustainability issues have been identified. These are:
  - Sustainable productive agriculture
  - Financial compensation
  - Sustainable flood defence
  - Loss of intertidal areas
  - Sustainable habitat creation
  - Change in water levels

- In order to assess the feasibility and potential delivery of sustainable managed realignment in the Humber Estuary, two approaches were initiated:
  - consultations with stakeholders
  - a series of technical studies to ensure long-term sustainability

Five main barriers to the implementation of managed realignment have been identified. These are:

- Loss of agricultural land and financial compensation
- Integrity of designated sites
- Environment impacts
- Loss of heritage interest
- Protection of gas and sewerage pipelines

All of these barriers were overcome through the process of early and sustained consultation, particularly with respect to financial compensation, and technical studies, to provide an understanding of the processes and effects of options (short and long-term).

It was important to consult early with those affected by the potential realignment schemes, particularly those who own land or property that will be affected. The issue of financial compensation was particularly relevant here.

It was beneficial to involve stakeholders in the decision making process for two main reasons. These are:

- Support from the stakeholders for the development and implementation was essential for project success
- The uses of the site and adjacent areas can provide a valuable insight regarding the sustainability issues that management should address

A variety of geomorphological studies were undertaken as part of HESMP Phase 2 to understand and quantify the likely evolution of the estuary over the next 50 years and highlight any potential long-term sustainability issues with respect to managed realignments.

Two main opportunities and wider applications of managed realignment in the Humber Estuary have been identified. These are:

- Potential for partnerships
- Optimisation of a range of uses of the realignment sites

Sustainable management in the Humber Estuary works because organisations work together to achieve it. A management scheme for the estuary has been published by co-operation of local councils, drainage boards and the Environment Agency. The scheme is concerned with how the authorities undertake their operational and regulatory activities so that the conservation status of the estuary is not jeopardised and, where possible, is enhanced.

The Environment Agency highlight that they are keen to ensure that selected managed realignment sites are designed and developed in a way that maximises the opportunity for a wide range of uses, such as diverse agricultural practices such as grazing, recreation and access.

A good example of wide ranging use is the potential of the Alkborough managed realignment scheme, which is hoped, will provide a focus for wider economic regeneration, green tourism and farm diversification initiatives. The local community has identified more than twenty potential business opportunities arising from the proposal to realign the defences at Alkborough.

3 Case Study No. 2: Sustainability Appraisal – Moray Flood Alleviation Scheme

3.1 Introduction

3.1.1 Background Information

In July 1997 Moray was severely affected by floods. Following heavy rainfall in June, an occluded front rotated over the Moray Firth area for over 48 hours and deposited extreme rainfall totals of up to 150mm. Severe flooding affected the communities of Lhanbryde, Forres and Elgin and more than 1200 people were evacuated from over 400 homes and agricultural land was extensively inundated. Disruption to business and transport was widespread with main road and rail links cut for extended periods. The damage caused in Elgin alone is estimated to have exceeded £6 million.

Following the 1997 floods the Moray Council commissioned a series of flood studies for each of the affected areas. These flood studies highlighted to the Moray Council the extent of the flooding problem and proposed some short to medium term solutions. Following a further minor flood in Elgin in April 2000, in which approximately 10 properties were inundated, and in light of the Egan Report, the Moray Council decided to take a partnering approach to solving their flood problems. Following a tender process, the Moray Council formed the Moray Flood Alleviation Group, a partnership between the Council and Posford Haskoning Consultant Engineers. Morrisons has subsequently joined the partnership in 2003 as the main contractor.

In November 2002, a further major flood event affected Moray, with 170mm of rainfall in 48 hours causing widespread inundation in Elgin and Rothes. Over 650 properties were affected in Elgin and 150 in Rothes. This event added further political pressure to resolving the flooding issues and Rothes was added to the projects being undertaken by the Flood Alleviation Group.

The main schemes relate to Lhanbryde, Elgin, Forres and Rothes, although the agreement is not limited to these sites. Since 2000, one scheme (Lhanbryde) has commenced construction and a further five schemes are at various stages of development.

3.1.2 Particular Sustainability Issues

The devolved Scottish government has a binding legal duty to pursue sustainable development in all it does. This aim drives the development and delivery of more sustainable approaches to flood management. In response to this and other drivers, Moray Council required that sustainability form an integral part of the work and a sustainability assessment tool was developed at an early stage of the process.

In terms of sustainability, the schemes aim to “deliver works to alleviate the long term flood risk to property and lives in a demonstrably sustainable manner that meets policy, legislative and community requirements”.

The particular sustainability issue which the sustainability appraisal system aims to deal with is the systematic maximisation of sustainability within the schemes through a transparent process. The coverage of key sustainability issues are detailed below in Table 3.1.

Table 3.1 Sustainability Issues

Climate Change and Energy
• Effect of climate change on flood risk (for example, increased rainfall intensity / flood frequency)
Sustainable Consumption, Production and the Use of Natural Resources
• Effect on economic interests • Effect of future changes in land management • Understanding of existing landforms and impacts upon flood frequency etc.
Environment and Social Justice
• Effect on environmental interests • Preservation of and enhancement, where appropriate, of cultural and recreation assets • Ensure that defence works are sympathetic to the overall landscape and local building styles • Potential impacts of the future implementation of the EU Water Framework Directive • Council’s own commitment to sustainability
Helping Communities Help Themselves
• Effect on long-term survival of community • Engagement of stakeholders in the development and planning decision process • Restrict the development of property assets likely to be vulnerable to flooding or erosion

3.1.3 Objective of Case Study

This is the only known formal use of sustainability assessment within flood and coastal erosion risk management in the UK. Following the development of the tool, it is now being applied to all the flood alleviation schemes, developed within Moray, from the option development stage onwards.

This case study provides an opportunity to consider the drivers that led to the implementation of a sustainability assessment tool, the development of the tool itself, and the successes and failures of using the tool to date.

The objective of this case study is to review the use of sustainability appraisal as applied within the Moray Flood Alleviation Scheme, and to assess its applicability and usefulness as a tool for improving the sustainability of flood and coastal erosion risk management.

3.1.4 Summary of Available Information and Consultations

The following data sources were reviewed:

- Rethinking Sustainability: Design Guidance and Procedures (Moray Flood Alleviation Group (MFAG), 2002);
- Waste Minimisation and Re-use: Design Guidance Sheet (MFAG, 2002);
- Use of Recycled Materials: Design Guidance Sheet (MFAG, 2002);
- Amenity and Recreation: Design Guidance Sheet (MFAG, 2002);
- Consultation and Awareness: Design Guidance Sheet (MFAG, 2002);
- Habitat Development: Design Guidance Sheet (MFAG, 2002);
- Landscaping: Design Guidance Sheet (MFAG, 2002);
- Site Management Practices: Design Guidance Sheet (MFAG, 2002);
- Sustainability Workshop Minutes – Elgin Flood Alleviation Scheme (FAS) (Option Appraisal);
- Sustainability Workshop Minutes – Forres FAS (Option Appraisal); and
- Sustainability Workshop Minutes – Forres FAS (Design Stage 1).

Consultations were also held with the following key members of the Moray Group, who were involved with the development of and application of sustainability assessment:

Steve Trewhella (Project Manager, Posford Haskoning);
Carina Oliver (Environmental Scientist, Posford Haskoning);
Daniel Moysey (Flood Defence Engineer, Forres Scheme: Design Stage 1);
Paul Hart (Hydrologist, Forres Scheme: Option Appraisal); and
Dave Gowans (Project Director, Moray Council).

3.2 Case study assessment

3.2.1 Objectives of Scheme Being Assessed

In 2000, Moray Council created the Moray Flood Alleviation Group (the Group) to address flooding issues in a number of communities in Morayshire. The mission statement of the Group is "*to alleviate flooding for the communities of Lhanbryde, Elgin, Forres and Rothes*".

The specific objectives of the schemes are summarised in Table 3.2 below (taken from http://www.morayflooding.org).

Table 3.2 Objectives of the Moray Flood Alleviation Schemes

Local Community and Stakeholders
• To increase the flood defence standard to cope with at least a 1 in 100 year event for the communities of Lhanbryde, Elgin, Forres and Rothes. • To make the community value central to the project. • To provide value for money. • To recognise and respect the views of all stakeholders. • To maintain, within the study area, the overall stock of tourism and recreation assets.

• To promote a culture of open government.
Natural Environment
• To protect critical natural habitats in their present state. • To maintain the landscape character, including both natural and human influences. • To create sustainable development that recognises the importance of the environment.
Working Culture
• To set an example for others to aspire to. • To create a working culture that is enjoyable, and where the project belongs to the participants.

At the beginning of this partnership process, a workshop was held which developed a number of objectives/drivers for the Group's work. Two important drivers underpinned the Group's approach to this project:

"*to create sustainable development that recognises the importance of the environment*". Thus any flood alleviation solutions developed by the Group must be demonstrably sustainable in terms of the environment, communities and economies; and the initiative '*Rethinking Construction*', a report produced by the Department of the Environment, Transport and the Regions (DETR) in 1998. This report aims at delivering a number of benefits to the UK construction industry through radically changing the traditional process that clients, contractors and suppliers together use to develop and deliver construction projects. These benefits include *inter alia*, no less than key gains in performance, efficiency, quality and customer-focused value, and reduced waste.

As detailed previously, any flood alleviation solutions developed by the Group must be demonstrably sustainable in terms of environment, communities and economies. As a result, a sustainability assessment procedure was developed, which uses the assessment and scoring of a range of sustainability indicators during the development and appraisal of flood alleviation options.

Moray sustainability assessment tool
In developing sustainability indicators, the Group reviewed indicator sets that had been developed at both national and regional levels, these included:

- Department of Environment, Transport and the Regions (DETR)
- Indicators of Sustainable Development for the UK (1997)
- Quality of Life Counts (1999)
- Scottish Executive
- Meeting the Needs…Priorities, Actions and Targets for Sustainable Development in Scotland (2002)
- Scottish Environment Protection Agency
- Sustainable objectives within the Corporate Plan 2002/3
- Environment Agency
- State of the Environment Reports (using nine sustainability themes)
- Welsh Assembly Government Indicators
- Developed its own indicators based on the DETR Quality of Life Counts

- Movement for Innovation Sustainable Construction Indicators
- Moray Council Indicators
- Kent County Council Indicators
- From Sustainability of Kent Coasts and Seas (2001)

The review found no examples of project-specific indicator sets that could be directly applied to the Group's work on flood alleviation. With this review in mind and combined with stakeholder workshops, the Group developed four sustainability objectives/themes:

PROJECT DEVELOPMENT: Design and construction of sustainable solutions;
ENVIRONMENT: Effective and long term protection of a healthy environment;
ECONOMY: Maintenance of a prosperous economy; and
COMMUNITY: An inclusive society which recognises the needs of everyone.

Within these themes project-specific sustainability indicators were developed. These are included within Appendix 2. Common factors/criteria for selecting sustainability indicators included:

- Address all sustainability issues at appropriate spatial and temporal scales;
- Limited in number, simple, interesting and understandable;
- Relevant to assessing progress towards sustainable development;
- Developed by an open, participatory and iterative process;
- Capable of being updated at appropriate intervals;
- SMART: Specific, Measurable, Appropriate, Realistic and Time-bound; and
- Analytical soundness supported by available data of an appropriate quality.

3.2.2 Assessment Process

Sustainability assessment is applied at several stages during the development of an individual scheme to ensure that its sustainability is maximised. These stages are: feasibility, design stage 1, design stage 2, construction and post-construction. The sustainability assessment process is shown in Figure 3.1.

The specific methodology described herein is generic and is intended to be applied to other engineering projects, using project specific indicators, whether or not the project is concerned with flood alleviation.

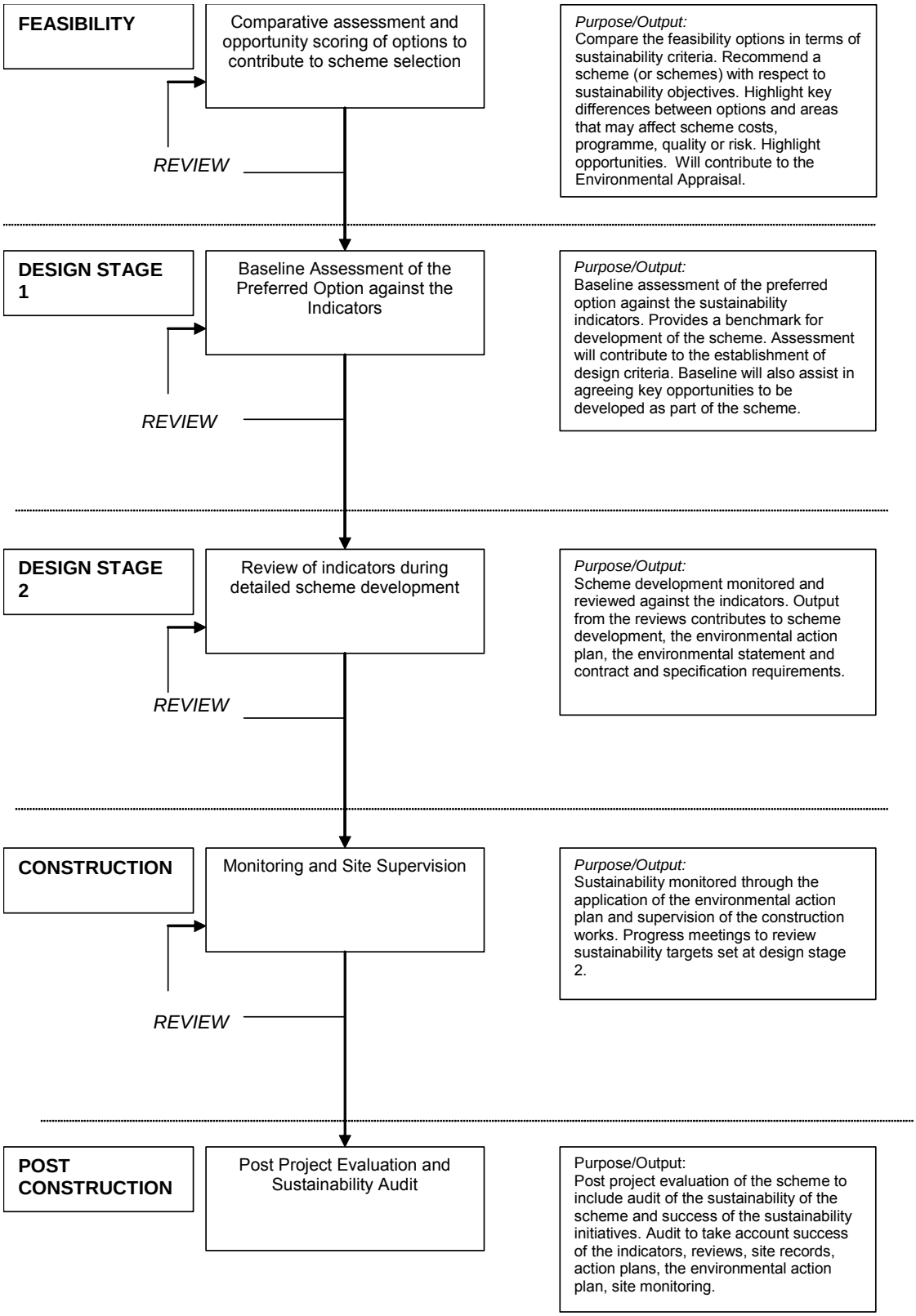

Figure 3.1 Sustainability Assessment Process

3.2.3 Assessment Procedure

Feasibility assessment
Purpose:

To carry out a comparative assessment of the options being considered at feasibility stage and provide an opportunity score for each option in terms of sustainability criteria. The assessment is applied at the feasibility stage where there are a range of alternative design options (maximum of 6) being considered. The assessment will also highlight key differences between options and areas that may affect scheme costs, programme, quality or risk and flag up opportunities for improving the sustainability of the preferred option. This method is used in conjunction with the technical, environmental and economic appraisal studies carried out at feasibility.

Input:

Feasibility – Sustainability Assessment sheets.
Details of the proposed options.
Guidance Sheets.

Work:

Three or four people from different disciplines (Project Management, Environment, Design, Construction) should carry out the feasibility assessment. Each option should be discussed and an opportunity score for each option against each indicator agreed. The proforma scores give each indicator set an equal weighting.

Output:

A comparative assessment and opportunity scoring of options to contribute to scheme selection and feasibility with respect to sustainability criteria. The findings and recommendations should be documented using the proforma.

Design Stage 1 assessment
Purpose:

To provide a baseline assessment of the preferred option against the sustainability indicators. The assessment will provide a benchmark opportunity score for the development of the scheme and contribute to the design criteria. This assessment will also assist in agreeing key opportunities that could be developed as part of the scheme and guide the identification of cost effective opportunities to deliver sustainability. This facilitates the integration of technical, environmental, community and economic issues in order to work towards achieving sustainable development.

Input:

Design Stage - Sustainability Review sheets.

Details of the scheme.
Guidance sheets.

Work:

Carry out the preliminary design stage assessment at the beginning of design stage one, in the same way as the feasibility assessment. In addition to the preliminary design stage one assessment, a minimum of one further review will be carried out during design stage one.

Output:

The information recorded at the preliminary assessment and following reviews will be used in comparison with subsequent reviews made during the design stages of the project to determine the progress made on maximising scheme sustainability. Inserting scores on the 'Sustainability Design Summary' proforma allows a visual confirmation of progress in improving sustainability.

Design Stage 2 assessment
Purpose:

To review achievement against the opportunities identified at design stage 1 and evaluate specific ideas and new opportunities as the detailed design progresses. This will ensure that the indicators and guidance sheets are used to drive design development with respect to sustainability.

Input:

Design Stage – Sustainability Review sheets.
Details of the scheme.
Guidance sheets.

Work:

To reapply the indicators to the scheme during design stage two. It is proposed that up to three reviews are carried out during design stage two.

Output:

The output at this stage will be the 'Sustainability Design Summary' proforma. Output at this stage will also contribute to the Environmental Impact Statement, Environmental Action Plan and the contract and specification requirements. The findings and recommendations at this stage should be documented using the proforma. Inserting scores on the 'Sustainability Design Summary' proforma allows a visual confirmation of progress in improving sustainability.

Construction
Purpose:

The sustainability assessment at this stage is essentially to check that all is going as planned at the construction stage.

Input:

Environmental Action Plan.
Site records.

Work:

At this stage, the sustainability of the scheme will be monitored through the application of the Environmental Action Plan and supervision of the construction works. Progress meetings will be held in order to review the sustainability targets set at the design stage of the project.

Output:

Output at this stage will include site records and progress reports, and any deliverables, undertakings, and actions identified in the Environmental Action Plan.

Post construction
Purpose:

To provide a post-project evaluation and sustainability audit to compare the initial opportunity score (in line with consideration of the sustainability indicators at the feasibility stage) with what has actually been achieved.

Input:

Sustainability assessment results.
Environmental Action Plan.
Site records.

Work:

Carry out evaluation of the project once it has been completed to determine how sustainable its development and construction has been. The evaluation of the scheme will include an audit of the sustainability of the scheme and the success or otherwise of the sustainability initiatives.

Output:

The audit will take into account the success of the indicators, reviews, action plans, site records, the Environmental Action Plan and site monitoring. The audit will highlight areas of poor and high performance, lessons learnt for future project management and recommendations for future monitoring for the 'whole life' of the scheme.

3.2.4 Assessment of Overall Sustainability

MORAY SCHEMES

Lhanbryde Scheme
The sustainability indicators were not prepared in time to be used at the early stages of the Lhanbryde scheme. The indicators could have been applied retrospectively, although this was deemed to simply represent a sustainability audit and was not carried out.

Forres Scheme
Forres suffered severe flooding in 1997 with smaller events occurring in 2000 and 2002. During the 1997 event, approximately 430 residential and 27 commercial properties were inundated. In addition, there was loss of rail services, infrastructure damage and loss of services.

Consultation with individuals affected by the flooding was undertaken in November 2001 and provided the Group with valuable local knowledge on flood mechanisms and flood risk areas, and in addition with further investigations and surveys, a baseline for the option development was established. From the wide range of options considered, three options were taken forward and appraised in detail. These were:

- Diversion of flood flows;
- Flood walls and embankments; and
- Flood storage and embankments.

To date, the sustainability tool has been applied to feasibility, option appraisal and Design Stage 1. The scores and ranking of the three options are shown in Table 3.3.

Table 3.3 Sustainability Scoring at Option Appraisal and For Option 3 at Design Stage 1 (for a description of the indicators refer to Appendix 1)

Ref.	Option 1 (Channel Diversion)	Option 2 (Walls and Embankments)	Option 3 (Flood storage)	Preliminary Design Stage 1 Option 3
	Score	Score	Score	Benchmark
A	**Project development – Design and construction of sustainable solutions**			
A1	3	2	3	4
A2	2	2	3	4
A3	1	2	2	3
A4	2	1	3	5
A5	2	1	3	5
Sub Total	**10**	**8**	**14**	**21**
Weighted Sub Total (sub total)*(25/25)	**10**	**8**	**14**	**21**
B	**Environment – Effective and long term protection of a healthy environment**			
B1	2	2	4	4
B2	2	1	3	4
B3	1	2	2	4
B4	2	1	3	3
B5	2	1	3	4
B6	1	1	4	4
B7	1	1	3	3
B8	2	2	4	5
B9	1	1	4	5
B10	2	2	2	4
B11	1	2	2	4
B12	1	2	3	5
B13	3	2	4	5
Sub Total	**21**	**20**	**41**	**54**
Weighted Sub Total (sub total)*(25/65)	**8**	**8**	**16**	**21**
C	**Economy – Maintenance of a prosperous economy**			
C1	3	3	4	4
C2	2	1	4	4
C3	2	1	4	3
C4	2	3	2	5
C5	3	3	3	3
C6	2	2	5	5
Sub Total	**14**	**13**	**22**	**24**
Weighted Sub Total (sub total)*(25/30)	**12**	**11**	**18**	**20**
D	**Community – An inclusive society which recognises the needs of everyone**			
D1	2	3	3	5
D2	2	2	3	4
D3	3	3	3	5
D4	2	2	5	5
D5	3	3	4	5
Sub Total	**12**	**13**	**18**	**24**
Weighted Sub Total (sub total)*(25/25)	**12**	**13**	**18**	**24**
Total Opportunity Rating (sum of sub totals) (max 100)	**42**	**40**	**66**	**86**

Table 3.3 indicates that Option 3, flood storage, performed best against the indicators and represented the most sustainable of the three options. Factors and opportunities that reflect this conclusion were:

- The storage option was comparatively insensitive to hydrological changes;
- The impact of residual flooding was less than the other options;
- There was good opportunity for sourcing construction material on site;
- No visual impact on the centre of Forres; and
- Significant environmental opportunities could be realised relatively easily.

Options 1 and 2 scored comparably. The key factors for these options scoring lower than Option 3 was their impact on the landscape and character of Forres.

The sustainability assessment was undertaken in parallel with several other performance indicator assessments that all fed into the selection process. These included:

- Environmental impact;
- Operation and maintenance;
- Health and safety; and
- Cost risk evaluation.

Table 3.4 below ranks the options against each of the performance criteria and shows that Option 3 was also the highest ranked for Health and Safety and Cost / Risk Evaluation, although it ranked the lowest for operational and maintenance aspects. Option 3 proved to be the preferred option.

Table 3.4 Performance Criteria Ranking for Forres Flood Alleviation Scheme

Description	Option 1 Channel Diversion	Option 2 Walls and Embankments	Option 3 Flood Storage
Appraisal Ranking			
Environmental ranking	3	2	1
Sustainability ranking	2	3	1
Operation Ranking	2	1	3
Maintenance Ranking	2	1	3
H & S Ranking	2	3	1
Cost / risk evaluation	2	3	1

A further sustainability assessment was undertaken at the preliminary design stage (refer to final column within Table 3.3). This assessment identified a significant number of opportunities that were not identified during the Option Appraisal Stage. These additional opportunities, as well as progress in incorporating earlier identified ones into the scheme development resulted in a higher score than achieved during the previous assessment. These opportunities then provided a benchmark score to compare future sustainability assessments against.

Elgin Scheme
Severe flooding in Elgin occurred in both 1997 and 2002. These events resulted in approximately 600 residential properties and 170 commercial properties being inundated during 1997, and 650 residential and 180 commercial properties being inundated during 2002.

In developing a flood defence scheme, a range of options were considered that included both hard and soft approaches to flood risk management. Criteria, considered to be important to ensure the success of the scheme, were also identified through discussion with stakeholders. Through investigations, further research and surveys, the wide range of options were narrowed down to three strategies: flood diversion, flood defences and widening, and flood storage combined with works in Elgin.

These options were compared against a range of performance criteria, including:

- Performance Matrix Evaluation – a range of non-monetary benefits identified by the Council, including:
  - Technical performance;
  - Environment;
  - Economy;
  - Programme; and
  - Community.

- Sustainability assessment.
- Environmental Impact, including:
  - Hydrology and water quality;
  - Geology and soils;
  - Ecology and nature conservation;
  - Landscape and visual impact; and
  - Air quality.

- Scheme operation.
- Scheme maintenance.
- Health and safety
  - Construction risk; and
  - Maintenance risk.

- Cost-risk evaluation.

The sustainability assessment was undertaken using the scoring system identified within Table 3.3 and the final scoring of the options are shown in Table 3.5.

Table 3.5 Sustainability Scoring For Elgin Options

Description	Option 1 – Flood Diversion	Option 2 – Flood Defences and Widening	Option 3 – Flood Storage and Works
Sustainability Assessment			
Sustainability Assessment Rating	100	70	73
Ranking	1	3	2

The most sustainable option at both Feasibility and Option Appraisal was the diversion channel. Factors and opportunities that reflect this conclusion include the fact that the diversion scheme is relatively insensitive to external man-made environment changes, makes good use of landform to manage flood risk, and provides a good opportunity to minimise waste and recycle tunnel arising within the embankment wall. Options 2 and 3 score comparably. The key factors for these options scoring lower than Option 1 are the impact on the landscape and existing assets within Elgin and water related issues.

Rankings from all the performance criteria were tabulated to compare the performances of each scheme. These are shown in Table 3.6.

Table 3.6 Ranking of All Performance Criteria

Assessments Undertaken	Option 1 – Flood Diversion	Option 2 – Flood Defences and Widening	Option 3 – Flood Storage and Works
	Ranking		
Performance Matrix Evaluation	1	2	3
Sustainability Assessment	1	3	2
Environmental Impact	1	2	3
Scheme Operation	2	1	3
Scheme Maintenance	2	1	3
Health and Safety	2	1	3
Cost Evaluation	2	1	3

No single option performed best on all the assessment criteria. In cost terms, Option 2, flood walls and embankments, clearly represents the most affordable and cost effective solution to flooding. Option 2 also represents a good investment in terms of operation and maintenance, and in terms of minimising health and safety risks over the operational life of the scheme.

Option 3 represents a poor investment as it is the most expensive scheme and is ranked third place in nearly all of the evaluation criteria.

Option 1 scores well in terms of the Council's performance evaluation, environmental impact and the sustainability assessment. However, the minimum scheme cost estimate for Option 1 exceeded the best estimate of Option 2 by approximately 20% and the extra cost could not be justified in appraisal terms. Therefore, Option 2 was taken forward as the preferred option.

Had the cost differences been closer between Options 1 and 2 it may have been justifiable to undertake more detailed Multi-Criteria Analysis (MCA) on the economics at the Option Appraisal Stage, to determine if there was additional 'hidden' value in going with the more sustainable option, i.e. cost benefits of job creation, avoiding rail / road closures, avoiding agricultural land flooding etc.

To keep the task of sustainability assessment cost effective at the Option Appraisal Stage, only 'tangible' economics were used, i.e. projected flood damage costs to residential and commercial properties. As the cost difference was simply too great between two schemes there was no benefit in attempting to identify added value through the further use of MCA.

On a large scheme it would typically be a requirement that more a detailed economic assessment (MCA or similar) of the preferred scheme be undertaken, however, it is simply not usually cost effective to undertake this exercise at the multiple scheme options stage.

Assessment of indicator tool

The assessment process brings together people from different disciplines and in itself helps to generate ideas towards sustainable development. The sustainability assessment tool therefore works well as a forum for sustainability opportunities to be identified and considered for a scheme at an early enough stage for them to be successfully implemented.

The tool is most successful when comparing a number of schemes against one another in a ranking system. In this way, it is able to identify from a number of schemes which one has the most opportunity for sustainable development.

The process, however, becomes more subjective following the Option Appraisal Stage and there is no built in system to fully assess whether the scheme with the most potential for sustainable development is in fact truly sustainable, i.e. the tool is able to distinguish between three or four options, identifying the scheme with the most opportunity for sustainable development, but not necessarily whether that scheme is truly sustainable.

The aim for sustainable development is to deliver 'win-win-win' situations, i.e. improvements to the environment, society and economies *at the same time*. This assessment tool allows for comparable ranking of schemes, however, tends to put an 'environmental' option up against an 'economical' option or 'operational' option, whereby for example an environmental option will only be taken forward if it can find the added value to 'compete' with the economical option. This contradicts the "Taking it on" principle of "*looking at the whole picture and linking social, environmental and economic concerns, not putting one in competition with the other*", despite the recognition that "*in some cases trade-offs have to be made*" (Consultation paper (Defra, 2004)). Table 3.7 below provides a summary critique of the tool.

Table 3.7 Assessment of Sustainability Indicator Tool

Sustainability
• Questions pre-conceived ideas about what is deemed to be sustainable, i.e. for Elgin the diversion channel proved to be most sustainable whereas previous thinking had assumed that flood storage would be. • Emphasises sustainable development that recognises the importance of the environment. • Drives sustainability and does not simply act as an audit tool. • No mechanism to determine if the highest ranked scheme is truly sustainable.
Assessment Process
• Ideal for assessing a number of schemes against one another to determine which has the most potential for sustainable development. • Subjective assessment (post option appraisal) that is not immediately transparent. • The assessment process may not be consistent during later assessments of the same project, due to the subjective nature of the assessment, if the team alters during the life of the project. • Can lead to a trade-off between environment, society and economical issues. • It is only one part of the option appraisal process within Moray FAS; therefore, the most sustainable scheme will not necessarily imply the preferred scheme.
Scheme Design
• Sustainability opportunities are used to drive sustainability improvements into scheme design. • Ensures that sustainability is considered at every stage of the scheme. • Provides a systematic approach to the assessment of a scheme's sustainability that can feed into scheme design. • Acts as a forum for developing ideas and maximising sustainability potential.

3.2.5 Review of Barriers, Successes and Failures

Table 3.8 Review of barriers, successes and failures

Barriers
• Although there are only 29 questions within the assessment, this can result in a long drawn out exercise if a lot of options are being considered. • There is considered to be some overlap of questions, which can lead to certain elements scoring highly or lowly twice for the same elements. • It is recognised that the assessment is only undertaken to its full potential once everyone has been involved in previous assessments, i.e. the process is not immediately transparent. This could lead to harsher or more lenient scoring later in the process, once people are more fully aware of the process. • The sustainability tool is used in conjunction with several other key performance indicator tools, such as environmental impact and cost evaluation. However, there are currently overlaps with elements of these other assessments and hence, double counting is taking place at a higher level as well as within the sustainability tool itself.
Successes
• The assessment process is designed to continually identify opportunities. Therefore, the assessments following Option Appraisal will not simply act as an audit for the preferred option. Since elements of each scheme may evolve through detailed design and consultation, the sustainability assessment will take on board these changes and re-assess

opportunities within the scheme. • For the Elgin scheme, the assessment changed pre-conceived ideas that a flood storage option would be the most sustainable (channel diversion proved the most sustainable). • Sceptics were surprised at the number of sustainable opportunities that could be generated and how much these could impact upon the final outcome. However, it is essential that a mix of disciplines undertake the assessment. • Identifying opportunities early gives a project the impetus to achieve these goals.
Failures
• The assessment tool essentially ranks a number of options against one another in terms of sustainability. There is no quantitative way to determine whether the highest ranking option is truly sustainable, i.e. the tool only assesses relative sustainability.

3.2.6 Assessment of Benefits of Techniques / Tools

To date, the sustainability assessment tool has had the following impacts upon the decision making processes of the flood alleviation schemes within Moray:

The tool proved successful for identifying option specific opportunities, which significantly improved the sustainability of the Preferred Option, but did not affect the Strategic Option selection process.

Within Design Stage 1 of the Forres scheme, the tool identified additional sustainable opportunities, which were not immediately considered during the Option Appraisal Stage.

In terms of Forres, the most sustainable option *was* the preferred option. This was, however, primarily due to economics (i.e. least cost), although sustainability opportunities were realised following Option Appraisal. However, if the tool had not been used the overall choice of scheme would not have altered.

For Elgin, the least sustainable option was taken forward as the preferred scheme. This related to economics rather than overall sustainability.

Sustainability is effectively 'diluted' in some instances as double-counting takes place, both within the sustainability assessment itself and across the higher level assessments, i.e. comparing schemes for environmental impact, sustainability, economics etc.

Currently, the tool is unlikely to affect scheme choice where the economics are significantly different, i.e. economic aspects have a 'controlling influence'.

3.2.7 Review of Opportunities, Lessons Learnt, Limitations and Wider Applicability

The sustainability tool should not be viewed as an 'audit' of sustainability. Rather it should be seen as a 'quality' driver that is applied throughout the development of the scheme, which may have financial, social and environmental implications.

Lessons learnt

The need for wider dissemination/training early on

Following the development of the sustainability indicators and subsequent sustainability assessment procedures, a series of guidance sheets were developed covering aspects of sustainability. These sheets collectively provide a broad summary of topics relating to the Group's sustainability indicators. The sheets assist with highlighting potential opportunities and benefits and provide practical measures to facilitate implementation. These guidance sheets were also intended as a training tool, for people to better use the sustainability assessment process.

Within the Group it was intended that there would be wide dissemination of the sustainability assessment tool through the training of all the members involved in the design and assessment of the schemes in order to maximise sustainability opportunities. Unfortunately, the Group rapidly expanded in size shortly after the development of the tools, as the number of schemes increased, and the opportunity to train people became restricted. As a result, the number of people undertaking sustainability assessment is limited within the Group and opportunities may be missed early on in schemes if there is not wider use of the tool.

Strong chairing of the assessment process

In order to ensure that realistic sustainability scores are determined during each review it is essential that three to four people from different disciplines (Project Management, Environment, Design, Construction etc.) meet and undertake the assessment together. However, to ensure that the focus of the assessment process is retained, i.e. to identify opportunities for sustainability, it is essential that these meetings are strongly chaired to prevent any bias from stronger 'personalities' within the Group.

Keep the process short and dynamic

The assessment process should not be a protracted affair. The process should not be viewed as a consultation exercise within the team where responses to ideas / opportunities may take several days or weeks. Instead, only four or five team members who are very familiar with the scheme should undertake the assessment and the whole assessment should not last longer than a single day, preferably half a day.

Timing of the assessment itself

Although the timings of assessments seem prescriptive, i.e. at Feasibility, Option Appraisal, Design Stage 1 etc., the actual timing of the assessment within each of these stages should be carefully considered. There needs to be enough information available for each scheme to fully assess the sustainability issues/opportunities, however, the results need to feed into the decision-making process early enough to be implemented.

Assign responsibility

The assessment process works well at identifying opportunities, however, unless someone is assigned to drive/progress opportunities then they are simply lost in the minutes of the meeting.

Limitations

Confidence in scheme sustainability

The assessment process instils confidence that the scheme selected has the greatest opportunity for sustainability relative to those it is being assessed against. However, this does not result in a scheme that is necessarily sustainable in real terms (i.e. 'win-win-win'), only in relative terms. Subsequent assessments, following Option Appraisal, are limited to the sustainable opportunities within that scheme alone, i.e. it is not truly a test of sustainability but of relative sustainability.

Full adoption of "Taking it on" principles

Further refinement of the tool is necessary to fully reflect the "Taking it on" principle of "looking at the whole picture and linking social, environmental and economic concerns, not putting one in competition with the other", despite the recognition that "in some cases trade-offs have to be made" (Consultation paper (Defra, 2004)).

Wider applicability

Flexible selection of indicators

Not withstanding the above comments, the indicators that are used are project specific and can be adapted to meet the needs of almost any project. In this sense, the tool is not limited in its application, but will require an element of time to tailor the indicators or devise new ones. While it had been developed with improvement schemes in mind, its generic nature makes it easily useable at strategic, scheme or operational management levels. At the national level scale however, the subjectivity at this scale may limit the usefulness of its outputs.

3.3 Summary of findings

The sustainability assessment tool, used within the decision making process of the Moray flood alleviation schemes, is the only known formal use of sustainability assessment within flood and coastal erosion risk management in the UK. Following the development of the tool, it is now being applied to all the flood alleviation schemes, developed within Moray, from the option development stage onwards.

The sustainability assessment procedure involves scoring the scheme against a range of sustainability indicators (refer to Appendix 1). The assessment is applied at several stages during the development of an individual scheme to ensure that its sustainability is maximised. These stages are: Feasibility / Option Appraisal, Design Stage 1, Design Stage 2, Construction and Post-construction. The sustainability assessment process is shown in Figure 3.1.

The assessment process brings together people from different disciplines and in itself helps to generate ideas towards sustainable development. The sustainability assessment tool therefore works well as a forum for sustainability opportunities to be identified and considered for a scheme at an early enough stage for them to be successfully implemented.

A full assessment of the use of the tool is included within Section 3.2, however, in summary:

- The tool ensures that sustainability is considered at every stage of a scheme.
- The tool drives sustainability rather than simply functioning as an audit tool.
- The tool is most successful when comparing a number of schemes relative to one another, in a ranking system.
- The tool is able to identify the scheme with the most opportunity for sustainable development, but does not necessarily identify whether that scheme is truly sustainable, i.e. win-win-win (see below).

The sustainability assessment is only one part of the Option Appraisal process within the Moray schemes; therefore, the most sustainable scheme will not necessarily imply the preferred scheme, and can result in a trade-off between environment, society and economical issues.

To maximise the potential for improving sustainability of flood and coastal defence management, all appraisal considerations such as economics, project risks and whole life management issues should be considered within the sustainability assessment. The preferred scheme from this process should then be taken forward, and not further compared with other factors.

To date, within the Moray schemes, the results of the sustainability assessment have not directly affected the choice of the Strategic Option; however, the process of identifying opportunities significantly increased the sustainability of the Preferred Option.

To date, there is some overlap of questions both within the sustainability assessment itself and across the wider selection process. This can, therefore, result in double-counting for some elements.
Further refinement of the tool is necessary to fully reflect the “Taking it on” principle of “looking at the whole picture and linking social, environmental and economic concerns, not putting one in competition with the other” (Consultation paper (Defra, 2004)).

Not withstanding the above comment, the indicators themselves can be tailored to be project specific, allowing the tool to be flexible enough to be applied to other schemes and projects.

4 Case Study No 3: Multi-criteria Analysis – Humber Estuary SMP and River Chet Flood Alleviation Scheme

4.1 Introduction

4.1.1 Background

The aim of Multi Criteria Analysis (MCA) is to provide a structured approach to capture a wide range of impacts that may not be readily valued in monetary terms, within the Flood and Coastal Defence decision making process. This approach aims to complement the strictly monetary and familiar Cost-Benefit Analysis (CBA), currently forming the basis for project and strategic appraisal.

The case study is, in some respects, different from the other case studies included in the Sustainability project, in that it examines, quite specifically, a technique currently being developed as part of the Flood and Coastal Defence R&D programme, rather than strictly the application of a technique to specific projects. This research is "Evaluating a Multi-Criteria Analysis Methodology for Application to Flood Management and Coastal Defence Appraisals" (FD2013). Within this however, two case studies are taken up from the development of the MCA approach; these being an area of the Humber Estuary SMP and the River Chet flood alleviation scheme. Details of these projects are taken from the original MCA approach case studies report and are used to examine how MCA, as applied, may contribute to sustainability. The aim is to examine the approach rather than the specific case study projects.

It is explicit within the FD 2013 reports that their research focuses on evaluating and developing a specific MCA-based methodology, rather than a full consideration of all MCA approaches. Their report does, however, review a variety of MCA approaches, the benefits and disadvantages of which are considered. In part, therefore, this current case study is able to assess other aspects of MCA in relation to sustainability.

In developing, an approach to appraisal, the research into MCA techniques aims to provide a tool which has to sit within the current economic approach, set out in the FCDPAG series, extending it to allow better inclusion of intangible benefits and costs.

4.1.2 Particular sustainability issues

Sustainability is defined in terms of taking an integrated view of flood and coastal erosion risk management, selecting an appropriate topography formed on the pillars of environment, society and economy.

There has been a growing concern that the established approach to CBA fails to take full account of social and environmental factors. This is reinforced in the disadvantages in the sole use of CBA, as it can only address a single objective; that of economic efficiency as judged in terms of monetary objectives. As a

consequence it ignores two main reasons why we have to make choices: that none of the options under consideration is superior to all others, when judged against all the objectives which we recognise should be brought to the process of making a choice, and that we do not agree what weight should be given to these different objectives.

MCA has the potential to address and consider all these aspects. As such multi-criteria analysis must constitute a fundamental tool in accessing success. In assessing the benefits, therefore, of the MCA-based approach, all aspects of sustainability need to be reflected.

4.1.3 Objective of the case study

Taking the above broad assessment remit through this case study, necessarily goes beyond that of the FD 2013 research. The objective of the case study is to examine to what degree the MCA-based approach has the potential for delivering more sustainable outcomes to decision making, where benefits are apparent and where barriers may be presented in any failure to deliver such an outcome.

The principal difference lies in the recognition that there are two aspects in the process of decision making.

- To enable the stakeholders to make better, better-informed choice between options (and ultimately to arrive at the preferred option) for management; drawing in the aspects of, or principles underlying sustainability.
- To provide accountability when the nation's resources are being spent. In particular, to demonstrate that the benefits of spending a sum on flood risk management in one area are comparable to those from spending that sum in other areas, and also comparable to benefits to the nation of spending that sum in other ways.

The focus of the MCA-based approach (as opposed to MCA in general) is on the latter, as part of the current appraisal process.

The objective of the case study has to be in assessing to what degree the first is inherent in the second and, therefore, how MCA may deliver its potential as a technique for sustainable flood and coastal management. In essence, does MCA deliver a real difference in choice?

4.1.4 Summary of available information

The FD2013 study has produced two principal reports:

- Case Studies Draft Final Report (November 2004)
- Guidance for the MCA-Based Element of the Current Approach to Appraisal (Draft November 2004)

In addition specific reports have been prepared as part of the FD2013 study;

- Assessment of the River Chet Flood Alleviation Scheme (Case Study 4, Annex 4)
- Assessment of the Humber Estuary shoreline Management Plan (Case Study 5, Annex 5).

Further reports reviewed in terms of background to the MCA approach and the case studies include:

- Taking it on; developing UK sustainable development strategy together. (Consulation document DEFRA 2004)
- Integrated Appraisal Methods (R&D Technical Report E2-044, January 2003)
- Planning for the Rising Tides, Humber Estuary Shoreline Management Plan (September 2000). This case study was also used as the principal breakout session example in the MCA Workshop (1st October 2004).

4.2 Case study assessment

4.2.1 Description of the Case Study

Objectives of MCA
The MCA-based approach aims to complement and enhance the Government's FCDPAG on Economic Appraisal (FCDPAG 3). It aims to allow the capture of a wider range of impacts that may not be readily valued in monetary terms. MCA further aims to establish preferences between options by reference to an explicit set of specific objectives and associated criteria, and assessing the extent to which these objectives have been achieved.

Further objectives:

- are to allow greater stakeholder involvement
- provide greater transparency

Furthermore the objectives in developing the approach have been:

- to ensure applicability at a number of decision levels
- high level (SMP and CFMPs)
- strategy level
- project level
- simplicity in use.

Derivation of the MCA- Based Approach
Various MCA approaches were considered and these are presented in the following table and text abstracted from FD2013.

Table 4.1 Characteristics of different multi-criteria methods

Method	Information	Result	Transparency	Computation	Costs
Weighted summation	Quantitative	Performance scores/ranking	High	Simple	Low
Ideal point method	Quantitative	Distance to target/ranking	Medium	Simple	Low
Evaluation by graphics	Qualitative, Quantitative and mixed	Visual presentation	High	Simple	Low
Outranking methods	Quantitative	Ranking/ incomplete ranking	Low	Very complex	Medium
Analytical hierarchy process (AHP)	Quantitative	Performance scores/ranking	Low	Complex	Medium
Regime method	Qualitative, Quantitative and mixed	Ranking/ probability	Low	Very complex	Low
Permutation method	Quantitative	Ranking	Low	Very complex	Medium
Evamix method	Mixed	Ranking	Low	Simple	Low

Note Adopted from FHRC/RPA (2002)

"It was concluded that:

- *in order to deal with quantitative information, the weighted summation methodology seems to be the most appropriate; it retains a high level of transparency, it is simple to apply and has a low cost; and*
- *in order to deal with qualitative information, all methods seem to provide only a low level of transparency. The AHP method seems to be the most appropriate since it is the only one that, using qualitative information, provides both performance scores and ranking. However, it is considered to be more complex in application, reducing its usefulness in a flood and coastal defence context.*

Furthermore, as the initial selection of the preferred option in flood and coastal defence appraisals is based on benefit-cost ratios and incremental benefit-cost assessments between options, the decision context is of a comparative nature. Use of comparative scoring methods ensures simplicity and ease of application, and in this sense may be preferred. At the same time, though, funding decisions are based on the relative performance of options on the basis of benefits and costs. This requires that some account is taken of how to convert the scored (intangible) costs/benefits of one scheme relative to another when the nature of these intangible benefits varies in geographic scale, type and severity."

It is worth noting in this, that the selection of the MCA technique seemed to have been steered very much by the need for compatibility with the existing CBA technique.

The MCA-based Methodology

The FD2013 findings are to be incorporated within FCDPAG3 which is currently being revised. The specific method for application of the MCA-based approach has been adapted from that reported in FD2013, and it is this new proposed method which has been used in the description below. The method is set out in the following figure (Figure 4.1).

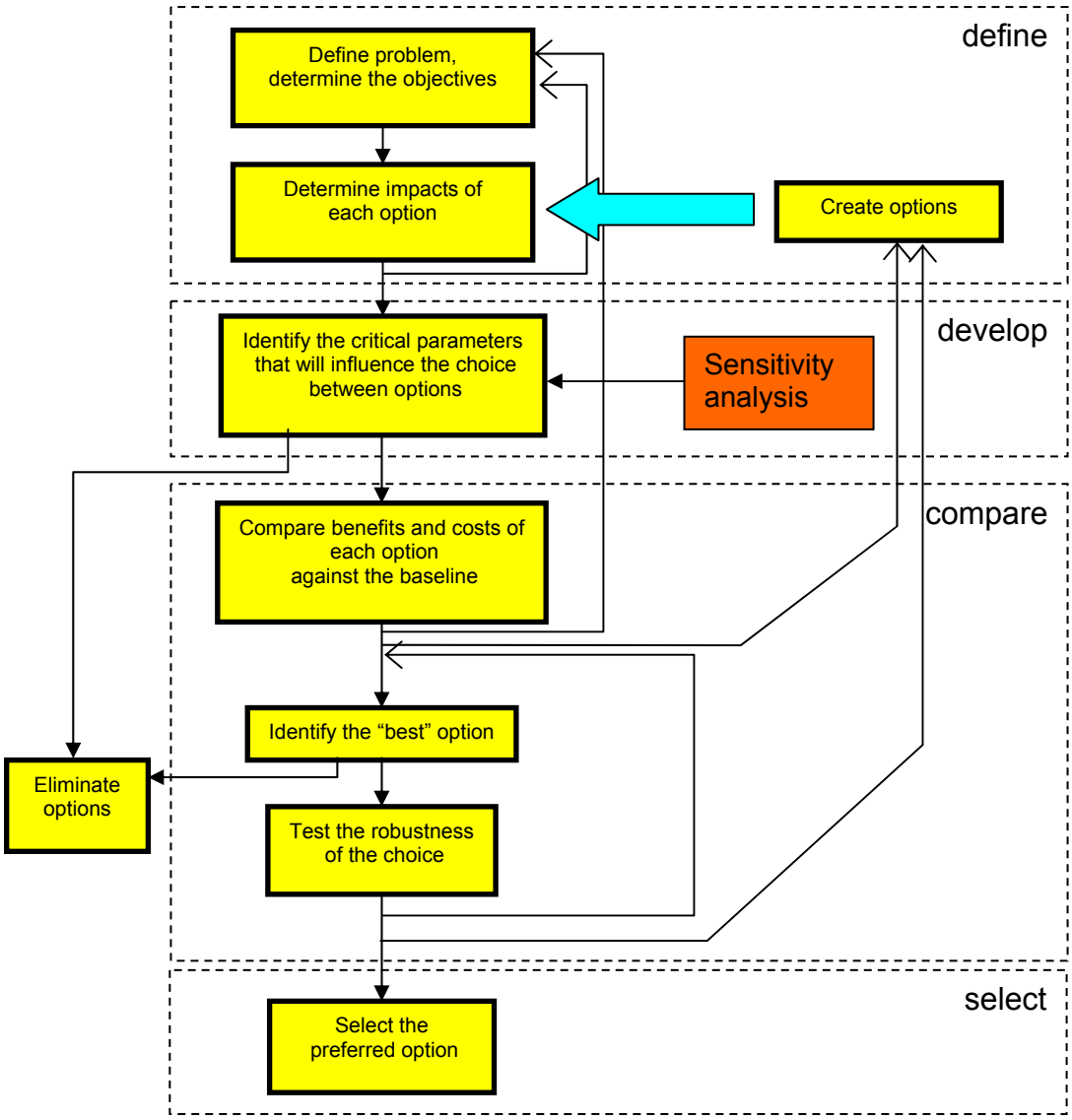

Figure 4.1 Proposed Appraisal Process

As identified in the FCDPAG 3, the project appraisal process involves four discrete stages – define, develop, compare and select – within which are included various procedural steps. The current approach to appraisal including the MCA-based methodology comprises the following steps:

- definition of problem, the objectives
- identification of options;

- identification of the critical aspects influencing choice, and within this assessing the sensitivities in the decision making process and between options. Part of this would involve a qualitative assessment of impacts, using the Appraisal Summary Table for Main Assessment (MA-AST) and the quantitative assessment of impacts, using the MA-AST;
- determination of the tangible benefits and costs of options; scoring impacts; weight elicitation, as appropriate (with the use of a weight generation analysis as optional to determine the necessity for weight elicitation) and from this, comparison of options using expanded decision rules;
- testing the robustness of the choice; and
- selecting the preferred option.

The key changes in this process from the current FCDPAG3 lie in:

- Sensitivity analysis being one of the first things done: finding out what are the critical parameters. These determine the choice between options as these are the ones to focus attention upon. Doing sensitivity analysis at the end of the process tells one what should already be known. Sensitivity is introduced at a time when it is still possible to influence decisions.
- Elimination of unreasonable options becoming part of the process rather than a distinct step. The intent is to improve refinement of options. As such it is always the consequence of an option which is considered unreasonable. Consideration of even unreasonable options gives further insight into the behaviour of the system.
- Allowing the process of option selection to evolve. How good the outcome is depends upon how good the options are. Part of the process must be to try to invent some better options (e.g. MCA should allow consideration of how combining elements of different options may refine delivery of a preferred option).

Details of the Two Specific FD2013 Case Studies

"The intention of the case studies was to test the methodology to answer two different questions:

• does the methodology provide information in a format that can be used to inform a range of different decisions? And

• does the methodology have added value over current approaches, i.e. would it help ensure that decisions are more robust and sustainable and/or can it help to take the views of all stakeholders into account such that conflicts that have arisen can be addressed specifically in the assessment?"

RIVER CHET FLOOD ALLEVIATION SCHEME

The River Chet runs for approximately 3.5 miles, from the town of Loddon until it joins the River Yare, between Cantley and Reedham. The river is narrow in places, wooded at first, as it nears Hardley Cross it becomes more canal like, with extensive grazing marshes.

The River Chet case study comprises the south bank of the River Chet from Pyes Mill to Nogdam End which is part of Compartment 22 - Burgh Norton - of the Broadland Flood Alleviation Strategy. Also part of this compartment is the right hand bank of the River Yare from the Chet to Haddiscoe Cut, Haddiscoe Cut south bank, and the River Waveney left bank from Haddiscoe Cut to Burgh St Peter - Broadland Flood Alleviation Strategy Study (EA, 1996). The flood and coastal defence management in the Broadland is covered under the Broadland Flood Alleviation Strategy (BFAS).

Compartment 22 is typical of Broadland, land use is almost 100% agriculture and the land is very low lying. The area is particularly susceptible to flooding, either from high freshwater river flows or more frequently high sea levels (EA, 1996).

The two main natural features to be highlighted and that would be threatened by flooding in the south bank of the River Chet are:

- the fresh water soke dykes which support a varied marginal and aquatic flora, including reed sweet grass, common reed, common duckweed and ivy-leave duckweed; and
- wet woodland which occurs along the Chet Valley

Ronds (area between channel and the floodbank) are a local feature and provide a vital flood defence function in that they minimise erosion of the floodbank and provide additional water holding capacity during the high flows.

The River Chet, as part of Broadland, is one of the few remaining areas of lowland river valley grassland in Britain and considered to be ecologically unique in Europe. Characteristic species in the floodbank include common reed, common couch, creeping thistle, spear thistle, cleavers, nettle and bramble. Furthermore, the vegetation along the landward berm of the floodbank (i.e. the folding) is typically dominated by common reed along with creeping thistle, hemlock, nettle, false oat grass and couch grass. Notable species include marsh sow thistle and stands of marsh mallow. Notable habitats along the folding include occasional wet hallows, with areas of turf and saltmarsh in some sections. There are no nature conservation sites within the study area and the area has been designated an ESA by MAFF (now DEFRA). However, Species Actions Plans exist for species present in the soke dykes, such as the water vole and floating water-plantain. It is unclear at this point whether these species are present in the soke dykes of the River Chet.

Finally, it is worth noting that there are no Schedule Ancient Monuments in the study area and there are no archaeological sites of interest.

Five options were defined for the purpose of the MCA-based approach case study:

- **do nothing:** where there is no investment in flood defence assets or activities;

- **maintain:** maintenance of the existing flood defences at the current standard (assumed to be 1 in 5 return period), involving reactive repairs to the flood defences as necessary. This option would involve some strengthening of flood banks and setting back the soke dyke where necessary, including clearing the banks of excess vegetation and re-shaping the crest of the banks, (equivalent to Broadland Environmental Services Limited's do something option);
- **improve (sustain):** the existing flood standards would be increased to 1 in 20 return period (the indicative standard of protection) through strengthening of the flood banks, restoring them to their earlier levels where excessive settlement has occurred, accounting for sea level rise, and replacing or providing new erosion protection where the integrity of the flood banks is threatened;
- **flooding to high ground:** existing hard defences would be removed strategically, the bank in this area would be re-profiled and the river would be allowed to erode and accrete naturally until it met higher ground. However, flood defences would be provided to properties (in particular their gardens) to achieve a 1 in 20 standard; and
- **maintain, then flood to high ground**: a combination of the two options (set out above) but with a limited period of maintenance due to the very poor ground conditions and deterioration of the peaty material that form the embankments. This also gives time for discussions with landowners and the Agency to find a way to flood to high ground as an option (in line with Defra's guidance on exit strategies).

Under existing CBA, based purely on the monetary evaluation conducted in the case study, Do Nothing would be the preferred option. This would run counter to the conclusions of high level Broadlands Flood Alleviation Strategy (BFAS). The argument therefore put forward, is that based on the high level strategy options should be compared solely on the damages avoided by different do something options. Do Nothing is eliminated on the basis of the high level strategy. While valid, this approach is still considered to ignore the majority of environmental and social benefits of options.

Discussion of the River Chet Case Study

The MCA-based approach, drawing in these other factors, would conclude that there are two or three competing options: Maintain (2), Flood to High Ground (4) and Maintain and Flood to High Ground (5).

The approach allows examination of the different attributes of different options. This is represented in the figure (Figure 4.2) below, based on the un-weighted score ascribed to the various key criteria used in the assessment. (The monetary criteria have been excluded.)

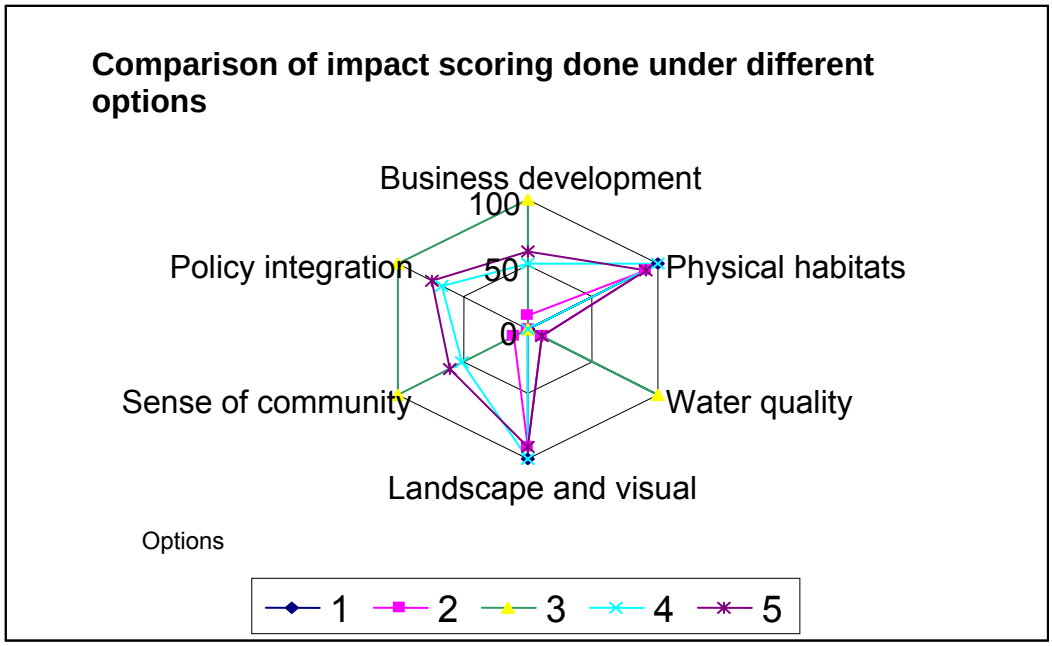

Figure 4.2 Comparison of River Chet Options

The MCA appraisal has identified Options 2, 4 or 5 as potential preferred solutions to the problem. The figure shows (as a result of the weighting regimes applied in the appraisal) the balance between potential impacts. By comparing Option 3 with Options 2, 4 and 5 (as a group), it may be seen that the process has highlighted two relative distinct outcomes. In the case of Option 3, the emphasis is on business, policy integration, sense of community and water quality. In the case of the potentially preferred options, the emphasis has shifted away from the above (most particularly in terms of water quality), towards physical habitats and landscape and visual amenity; Option 2, being the most extreme case of this. Further assessment should have to be undertaken to consider how the topography of sustainability is actually distorted by this shift in impact.

HUMBER ESTUARY SHORELINE MANAGEMENT PLAN

"The Humber case study is based on the economic appraisal undertaken for the Humber Estuary Shoreline Management Plan Stage 2 study. This appraisal was undertaken by RPA in association with Black & Veatch for the Environment Agency in 2003. This approach included the completion of Appraisal Summary Tables (ASTs) to ensure that the non-quantified impacts were fully identified and could influence decision-making. For this case study, Management Unit 6 is used to investigate how the inclusion of multi-criteria analysis may have affected the decision."

Management Unit 6 runs from South Ferriby Cliff to North Killingholme and is mainly comprised of medium grade agricultural land for up to three kilometres inland. The main settlement in the area is Barton-upon-Humber. Clay pits immediately behind the defences between Chowder Ness and New Holland are important environmental and recreation sites, with some designated for their environmental value. There are also a number of small industrial areas,

including New Holland Dock. The area is categorised as Land Use Band C, with an indicative standard of 1:10 to 1:100 (based on FCDPAG3).

The Humber Estuary Shoreline Management Plan (SMP) was published in September 2000 (Environment Agency, 2000). This sets out the Environment Agency's vision for managing the flood defences of the Humber Estuary. The SMP has since been further developed in a Stage 2 study, which attempts to provide fully justified decisions on the policy for each Management Unit. For Management Unit 6, the SMP identified that an appraisal is required to determine whether moving the line locally would be worthwhile. Elsewhere, the existing defences will generally be held on their present alignment until a length needs to be repaired or improved.

About half of the defences between South Ferriby and New Holland Dock provide protection against a 1 in 50 year event. Around Barton Creek, some lengths of the defences give significantly lower standards. East of New Holland Dock, around 70% of the defences protect against an event with a return period of 1 in 20 years. In 50 years, the standard of defence is expected to fall such that about 50% of the defence will no longer protect against a 1 in 10 year event. The overall condition of the defences is fair to good. There is concern that erosion of mudflats may threaten the stability of the defences. There are also some lengths where the crest level of the embankment is low (Environment Agency, 2000).

In the Humber Estuary SMP Stage 2, three options are assessed for Management Unit 6:

- Option 1: Do-Nothing;
- Option 2: Hold the Line (low standard of 1:10); and
- Option 3: Hold the Line (high standard of 1:100).

For the case study, the Humber Estuary is assessed at the strategy level, such that five options are assessed:

Do-Nothing;
Maintain: standard of defence decreases from current level of 1:20 to a maintainable level of 1:10. The standard of defence decreases to 1:10 by year 9, due to the condition of the defences, and to 1:5 by the end of the 100 year appraisal time horizon (due to sea level rise). (This option is assumed to be equivalent to the 'hold the line (low standard) option from the Humber Estuary SMP Stage 2);

Sustain: standard of defence is sustained at 1:20 throughout the 100 year time horizon;

Improve 1:50: standard of defence is improved to 1:100 throughout the 100 year time horizon; and

Improve 1:100: standard of defence is improved to 1:300 throughout the 100 year time horizon. (This assumed to be equivalent to the 'hold the line (high standard) option from the Humber Estuary SMP Stage 2).

Discussion of the Humber Estuary Case Study
The conclusions of the case study are based on the following table abstracted from the FD2013 report:

Table 4.2 Summary of costs and benefits for Management Unit 6

	Costs and Benefits				
	Option 1: Do Nothing	**Option 2: Maintain**	**Option 3: Sustain**	**Option 4: Improve 1:50**	**Option 5P: Improve 1:100**
PV costs from estimates (include optimism bias at 60%)	-	£26,744,000	£40,000,000	£48,000,000	£59,279,000
PV damage	£164,163,000	£20,881,000	£2,781,000	£556,000	£247,000
PV damage avoided	-	£143,282,000	£161,381,000	£163,607,000	£163,916,000
Total PV benefits	-	£143,282,000	£161,381,000	£163,607,000	£163,916,000
Net Present Value (NPV)	-	£115,653,800	£121,381,000	£115,604,000	£104,637,000
Average benefit/cost ratio	-	5.36	4.03	3.41	2.77
Incremental benefit/cost ratio	-	-	1.37	0.28	0.03
Weighted Score	4	83	94	95	96
Intangible-cost ratio	Not available	0.00031	0.0024	0.002	0.0016
Incremental intangible/cost ratio	Not available	Not available	0.0014	0.0002	0.0000
Required incremental benefit-cost ratio	-	-	1.5[2]	3.0	3.0
Benefits required to move to higher option	-	-	£163,166,000	£185,381,000	£197,444,00

It may be seen that the conclusion based solely on monetary appraisal would be in favour of Option 2 (maintain) with the potential incremental advantage in raising the defence standard with time to Option 3 (sustain).

The conclusion of the MCA-based approach, taking in to account intangible benefits and assessing the typical affordability of these, would be in favour of Option 3. In effect, on initial inspection, this merely provides a confirmation that the additional expenditure would be worthwhile.

The following table gives the unweighted scores attributed to each option.

Table 4.3 Chart scores for Humber case study (MU6)

Category	Do-Nothing	Maintain	Sustain	Improve 1:50	Improve 1:100
Land Use	0	80	96	99	100
Transport	0	70	96	99	100
Business Development	0	88	98	100	100
Physical habitats – freshwater	0	86	98	100	100
Physical habitats – intertidal	100	23	3	0	0
Water quality	0	76	96	99	100
Water quantity	0	89	99	100	100
Natural processes	0	87	99	100	100
Historical environment	0	87	99	100	100
Landscape and visual amenity	0	74	94	99	100
Recreation – terrestrial	0	86	98	100	100
Recreation – intertidal	100	20	3	0	0
Health and safety	0	81	97	99	100
Availability and accessibility of services	0	88	98	100	100
Equity	0	88	98	100	100
Sense of community	0	87	98	100	100
Policy Integration	0	89	100	100	100

In a similar manner to the River Chet appraisal, two distinct groups of option can be seen. Option 1 and 2; in particular 1, have an emphasis towards improvements in the Physical habitats- intertidal and the Recreation- intertidal, at the expense of detrimental impacts on the terrestrial criteria. All other options have a consistent increase in score with respect to the terrestrial criteria at the expense of the intertidal. This is not surprising in that the selection of options is purely an examination increased levels of terrestrial defence. Considering the results between do something options, the choice, between Options 2 and 3 comes down again to the importance of attached to the intertidal aspects versus anything else. This may be seen in a comparison of the two options based in the figure (Figure 4.3) below, based on the above table.

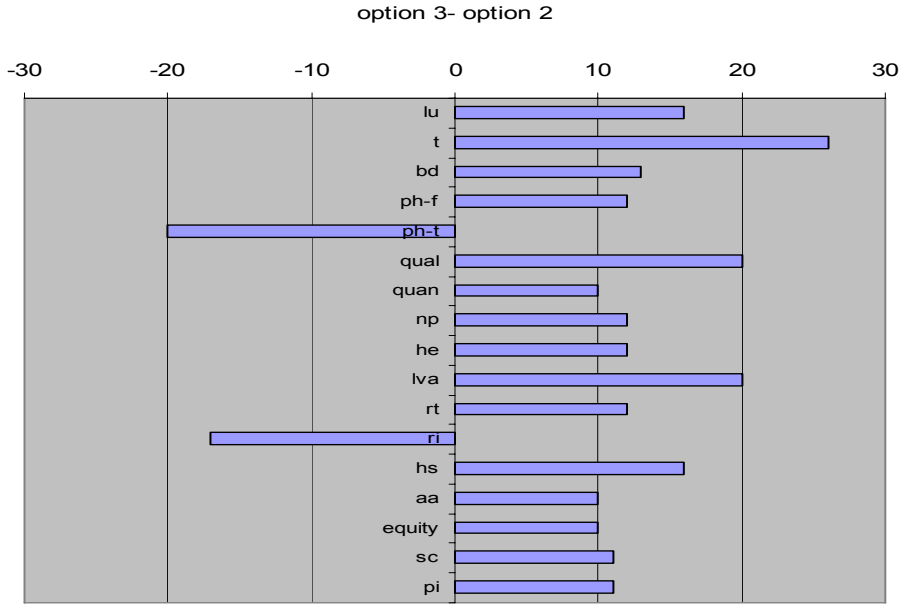

Figure 4.3 Comparison of Key Issues for Options 2 and 3

The question then is whether the additional value of the objectives met by Option 3 are worth the additional cost between options of £13 million.

Drawing an analogy with the sustainability topography structured on the three pillars, the Humber appraisal describes solely a slope based on two pillars of intertidal benefit and terrestrial benefit.

At a project level; having decided at the level of the SMP the significance of balancing these two pillars over the broader area of the estuary, the MCA-based appraisal could be then used to agree and add legitimacy to the decision as to the level of protection to be provided.

The starkness of the decision making process, in this case, is, therefore, between the option of defence and abandonment. As such the technique highlights where potentially conflict is being set up through the choice of options, which can potentially never then be resolved. To advance the cause of sustainability, having highlighted this problem, further techniques (possibly different forms of MCA) are needed to elicit in greater detail the underlying, and possibly truer criteria giving rise to peoples' opposition to choices and begs the question whether further consideration of alternative options is not warranted to attempt to ameliorate the distinction between defence or abandonment.

To a degree this process is hampered by the need to simplify, and the manner in which certain impact criteria are recorded. For example, in this case the score evaluation of roads (transport) is based on length. A more functional approach might better value such a feature by service (e.g. The ability to maintain a bus service to a community, or more fundamentally, merely the ability of people to move efficiently in and out of the area; thus solved by providing a alternative forms of transport.)
The process could then be taken forward through examination of other composite options to arrive at a more sustainable decision.

4.3 Summary of findings

4.3.1 Assessment of overall sustainability

Sustainability may be seen as defining criteria against which to judge the balance between effort, in terms of input (the need for continuing work, the increasing input to maintain a system), and the outputted benefits of that system or differing benefits (or damages) arising from that system. This may be appreciated most starkly in the axiom that a successful system requiring no input is sustainable, and is the principle underlying the use of the Do Nothing, base line option, in appraisal. The existing CBA based appraisal aims to minimise damage for limited on-going cost, evaluated solely in monetary terms and determined through comparison of a set of initial options.

The revised approach to appraisal, moving more towards a process of design; shown in Figure 1, highlights the potential to learn from assessment of initial options (even those rejected), to build towards an optimal preferred position. The review of the case study of techniques, and the example specific case

studies, demonstrate the ability of MCA to open an essential further dimension in this revised appraisal approach and potentially in providing more sustainable solutions. From this, the greatest strengths of the MCA technique is seen in providing:

- The ability to consider impacts and benefits over a broader scale than those reflected in monetary terms.
- An analytical tool for assessing the sensitivities of a system to differing options, which could be tuned, through the selection of categories, the scoring system and subsequent weighting, to promote decisions towards agreed sustainability targets.
- An analytical tool for reassessing the inherent conflicts produced through the selection of options and allowing development of subsequent, more sympathetic options within the appraisal process.

4.3.2 Review of barriers, successes and failures

The potential benefits of MCA and the success of the specific approach to use of MCA, as investigated through FD2013, is identified above. It is, however, felt that certain barriers still exist in developing this potential.

The main aspects of this may be highlighted in the acknowledged limitations of the specific case studies. In both cases, the approach was taken forward only to a point where the essential sensitivities of the situations were being examined. In the case of the Chet, a conflict was identified between existing business and community interest (these interests being championed by option 3) and the development of a more natural system and improved landscape (championed most exclusively by option 2). Options 4 and 5 start to explore more inclusive approaches and through them the potential of MCA can be seen in the iterative development of solutions.

In the case of the Humber, the key sensitivities to decision-making are clearly demonstrated between the wish to defend and the wish to abandon. This fundamental issue seems unlikely to be resolved purely in terms of flood defence risk (except in pure monetary terms, i.e. confirmation of the incremental benefit cost ratio determined by CBA). The MCA approach has highlighted the possible need to take the decision making process to a higher, or, at least, broader level and more detailed assessment of criteria. It is in incorporating this broader level that the real opportunity lies to bring in or strength the use of sustainability concepts in attempting to develop an acceptable solution.

In some ways the limitations of the case study (MCA based approach) have arisen, therefore, from the requirement (within FD 2013) to develop a methodology which is consistent and may incorporate the existing CBA procedures. This constraint, while understandable in the need to enlarge the scope of project appraisal, limits the broader potential of the technique. These limitations are considered to be:

- The focus on risk to assets (tangible and intangible) arising from flood and coastal erosion, in contrast to the need for sustainability to consider the

function and influence of coastal and flood defence in the broader spectrum of management of coasts and rivers.
- As a consequence of the above, the greater applicability of CBA, and hence MCA-based (CBA compatible) approach, to the scheme level. The case study of the Humber clearly demonstrates the single dimension of decision making at this level. Such a focus is quite acceptable; assuming that at a higher level of policy a broader consideration of issues and options has been undertaken.
- The need for national consistency for comparison, reduced ultimately to a monetary basis. The MCA-based approach attempts to pull away from a strictly monetary approach, developing usefully on an assessment of switching values. This does come down to an assessment of likely affordability of intangibles in terms of additional cost.
- The focus on justification of choice as opposed to the initial identification of options and hence establishing where real choice lies.
- The assumption that the different levels of decision making are primarily distinguished by the different levels of information or detail available. In reality the main difference can be seen in the breadth rather than the depth of issues.

To overcome these limitations there needs to be:

- Reconsideration of the different MCA approach at different levels of decision making and choice identification specifically with the focus on delivery of sustainability. Less quantifiable approaches may be more appropriate at policy level (as indicated by the FD2013 report). This has the potential to broaden the examination at a level where really different decisions may be made.
- Careful consideration of the categories used in the AST tables to reflect any or all of the key sustainability headlines. For example, using and appropriately weighting aspects of environmental issues could be developed from the objective of delivering a sustainable environmental feature. Similarly, in terms of “helping communities help themselves”, categories under which impacts (positive and negative are assessed) may provide the necessary inputs to highlight achievement of this specific aspect of sustainability.
- Further investigation of the important interaction of impacts, as distinct from the avoidance of double counting.

4.3.3 Assessment of benefits of techniques

MCA presents a strong potential for assessing and delivering sustainable solutions. The approach taken by FD2013 has taken significant strides in achieving this, potentially allowing better inclusion of the pillars of sustainability into the appraisal and decision making process. It is felt however, that there is further scope for development and focussing of this tool to improve its potential to deliver sustainable outcomes.

5 Case Study No 4a: River Severn Temporary and Demountable Systems

5.1 Introduction

5.1.1 Background Information

This case study is one of the seven carried out as part of the R&D project titled Sustainability of Flood and Coastal Erosion Risk Management. It is focused on temporary and demountable defences on the River Severn.

The River Severn is the longest river in Great Britain, being approximately 354km in length from its source in the Cambrian Mountains (Mid-Wales) to its outfall into the Bristol Channel. The River Severn Valley is lined by settled thriving communities, most of which have long histories of flooding. Some of them have been flooded up to 50 times in the last 100 years. As with many other locations in England and Wales, the River Severn catchment was very badly flooded in 1998 and 2000, causing extensive damage to many undefended communities along the valley.

This study covers four communities of Shrewsbury, Ironbridge, Bewdley and Worcester, all along the Upper Severn Area. The catchment area of the river at Shrewsbury, the most upstream of these communities, is approximately 2,500km^2. Each of these communities has had previous unsuccessful attempts to develop acceptable flood alleviation schemes. Particular challenges with previous failed attempts include the following:

- The communities are located within highly aesthetic natural, built and historic environments, including world heritage sites, and it had been difficult to develop a scheme without significant visual impact.
- The topography, existing developments adjacent to the river and associated engineering difficulties have made options for permanent protection very expensive and so far uneconomical.
- The sources of flooding consisted generally of a combination of direct river flooding and back-up/surcharge of the local drainage system, therefore requiring integrated solutions covering more than one organisation (Environment Agency, Sewerage undertaker, and local authorities).

Against this background, the last few years have seen the emergence of a number of temporary and demountable barrier systems, the development of the Environment Agency's guidance for their use and the development of a British Standard kite-mark scheme and publicly available specification for their use. These developments in the UK occurred against the backdrop of similar developments and successful use of these systems abroad.

Between 2002 and 2003, the first two major demountable flood alleviation schemes in the UK were constructed in Bewdley and Shrewsbury. In 2003, the Environment Agency obtained funding from Defra to facilitate trials of temporary flood barriers to evaluate their potential for reducing flood risk. The sites

chosen for the trials (within Shrewsbury, Ironbridge and Worcester), along with the recently completed demountable schemes provide the opportunity for a case study on these non permanent defences, particularly as they all had to be deployed during the very high flows that occurred in February 2002. Together about 100 properties would be protected at the three temporary defence trial sites.

Due to the high level of operational involvement, this case study will focus in particular on the temporary defence trials. The demountable systems would be reviewed to assess the implications of the outcome of the case study on them, drawing out the similarities, differences and particular issues as they affect each type.

These temporary and demountable schemes did not have the benefit of completed CFMPs or strategic studies, as these were only under development then, and are still yet to be completed at the time of preparation of this case study. All the sites however had benefited from previous modelling and pre-feasibility studies which provided information for their design and for the assessment of their impacts on surrounding land.

5.1.2 Particular Sustainability Issues

A number of issues relating to sustainability have been identified with regards to the provision of flood alleviation for the affected communities within Shrewsbury, Ironbridge, Bewdley and Worcester. These have been outlined in the table below according to the main sustainability themes within Defra's "Taking it on" report.

Table 5.1 Sustainability Issues

Climate Change and Energy
• Effect of climate change on rainfall patterns and flood risk • Long lead time between flood warning and onset of flooding (> 12 hours)
Sustainable Management and Use of Resources
• Current approach involves significant use of sandbags with associated demand for primary aggregates, clean-up and disposal of bags and contaminated soils. • Management of frequent flooding uses up manpower from emergency organisations and local population
Social and Environmental Justice
• Previous permanent scheme proposals had significant visual and aesthetic impacts • Previous permanent schemes were not economically justified • The communities are located in the midst of important natural, historical and built environmental features and landscapes • Current levels of flooding have significant long term cost, health and social impacts on the community. • Current levels of protection are generally below the government's indicative standard or typical protection applying to similar sized communities in England.
Helping Communities Help Themselves
• Flooding was a high priority issue in the communities and they all had local Flood Action Groups and involvement of local MPs

- The objective is to continue to alleviate the risk to people and property from flooding where economically, technically and environmentally feasible
- There are multiple sources of flooding which cross individual and organisational responsibility areas
- The long lead time between flood forecasting and onset of flooding allows communities and organisations time to carry out emergency action

5.1.3 Objective of Case Study

The objectives of this case study are as follows:

- to review the applicability of temporary and demountable flood protection systems as options for alleviating flooding in areas where traditional permanent defences are not feasible
- to assess their sustainability and associated whole life management, and
- to identify guidance for their use to improve sustainable flood risk management through the River Severn experience.

5.1.4 Summary of Available Information

Consultation in the form of meetings and telephone conversations were carried out with a number of key people involved with the relevant schemes. These consultations provided information about the development of the schemes, the organisations involved, working relationships, the February 2004 event and associated response, and the post event evaluations and feedback. The following Environment Agency personnel were consulted.

- Peter May (Upper Severn Area Flood Defence Manager)
- Anthony Crowther (Upper Severn Area Team Leader Strategic Planning)
- Roy Stokes (Midland Region Flood Defence Operations Engineer and Project Manager for the Temporary Flood Defence Trials)
- Roger Prestwood (Project Manager Bewdley Flood Alleviation Scheme)
- Tim Ive (Project Manager Shrewsbury Flood Alleviation Scheme)
- Loretta Adams (Project Manager River Severn CFMP and Strategy Study).

In addition to the direct consultations the following reports and brochures were reviewed to obtain further information about the schemes. These included the following:

- The Severn Valley: An Alternative Solution, Evaluation of temporary flood barriers during February 2004 flood, Roy Stokes and Peter May Environment Agency; May 2004
- The Severn Valley: A Temporary Solution - A review of temporary flood defences pilot. Environment Agency; January 2004
- Bewdley Flood Alleviation scheme – Your questions answered. Environment Agency; May 2001
- Shrewsbury Flood alleviation Scheme – Your questions answered. Environment Agency; March 2001
- Frankwell Flood Alleviation Scheme, Shrewsbury. Environment Agency, March 2004

- Severn Catchment Flood Management Plan and Fluvial strategy Update. Environment Agency; June 2003.

5.2 Case study assessment

5.2.1 Objectives of Scheme

The Environment Agency's objectives for carrying out the trials are outlined below:

- To assess the use of temporary flood barriers as realistic options for reducing the risk of flooding
- To assess the operational resource and requirements associated with the use of temporary flood barriers during real flood events
- To provide opportunities to assess the reliability of some of the available temporary flood barriers under real flood conditions
- To assess the ability of various government and local organisations to work together in the planning and emergency deployment of temporary flood barriers.
- To inform the overall policy on the use of temporary flood barriers.

5.2.2 Scheme Details

Overall Scheme Information
Temporary flood barriers are wholly installed away from individual properties, prior to a flood event and completely removed when flood levels have receded. They form a flood protection system with their bedding surface and their connections at either end to some structure or high ground.

By contrast, demountable flood protection systems are fully engineered systems that are partly or fully installed under normal conditions, requiring part erection or closure to form a defence against flooding. They are fully designed for particular locations and would include appropriate foundations and other considerations as required for permanent flood defences. Local flood protection on the other hand includes flood proofing at particular buildings or assets being protected, such as flood resistant construction, elevation, contouring and flood boards.

This case study looks in particular at the trials of temporary defences carried out during 2003/04. Following a process of site selection, three sites were chosen for the trials from about 35 originally considered. The chosen sites are located in Shrewsbury, Ironbridge and Worcester. Figure 5.1 below shows their locations in relation to each other and the Upper Severn.

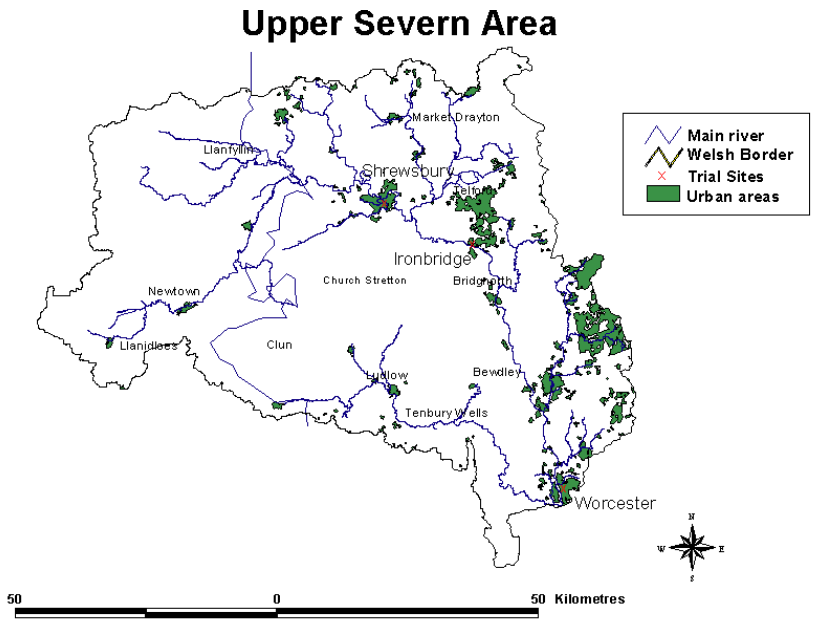

Figure 5.1 Location of the trial sites

Summary information on the sites and defences are provided below. Further detail about each site is provided in Appendix 3.

- Site 1: Coleham Head in Shrewsbury. Here, the barrier was a 100m long and 1.25m diameter Mobile Dam (a water filled tube temporary barrier) system. It consists of two reinforced polypropylene tubes, attached in parallel with stainless steel coupling units. The dam can be transported to site, rolled out in-situ and filled with water when in place. This barrier, along with associated drainage and pumping works, when fully deployed, provides flood protection to 42 properties up to a 1:10 year flood event. Figure 5.2 shows the line of the temporary barrier at Coleham Head.

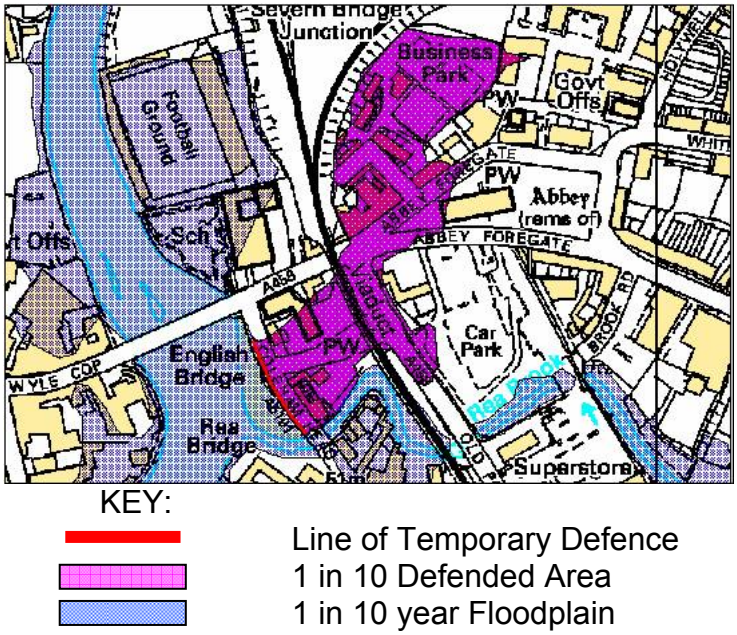

Figure 5.2 Line of Temporary Barrier at Coleham Head, Shrewsbury

- Site 2: The Wharfage in Ironbridge. Here the barrier was a 500m long and 1.25m high (1.8m for very low spots) Pallet Barrier system, a temporary flood barrier with frame. It consists of collapsible galvanised steel supports, to which aluminium sheets are fixed. These sheets are then covered with properly weighted and anchored waterproof membranes. This barrier, along with associated drainage and pumping works, when fully deployed, provides flood protection to 24 properties up to a 1:50 year flood event. Figure 5.3 shows the line of the temporary barrier at the Wharfage.

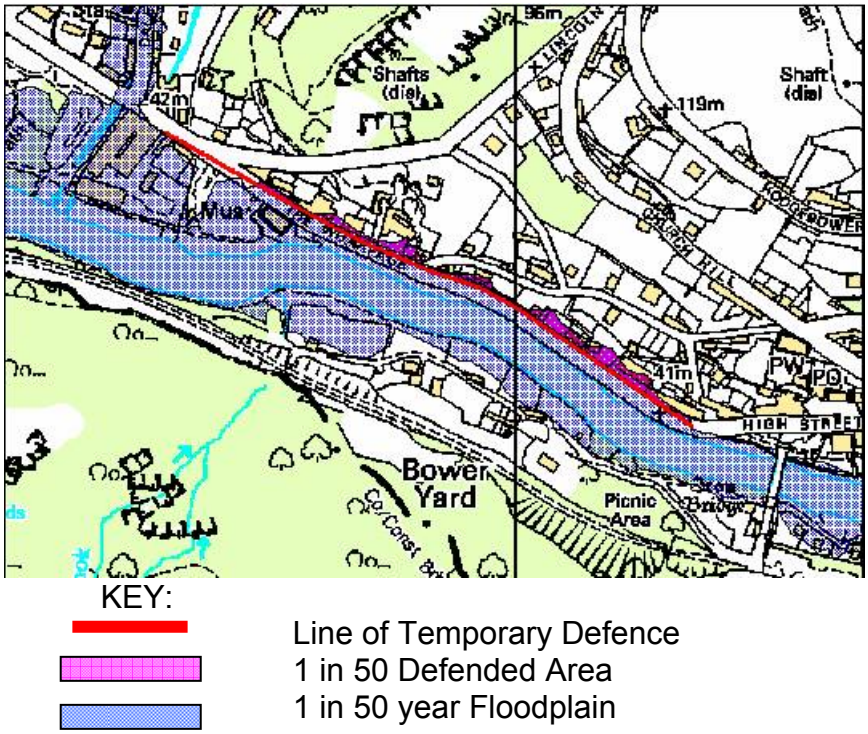

Figure 5.3 Line of Temporary Barrier at the Wharfage, Ironbridge

- Site 3: Hylton Road in Worcester. Again, the Pallet barrier system was used here. A 330m long and 1.25m high barrier system along with associated drainage and pumping works, when fully deployed, provides 24 properties with a 1:50 year standard of protection. Figure 5.4 shows the line of the temporary barrier at Hylton Road.

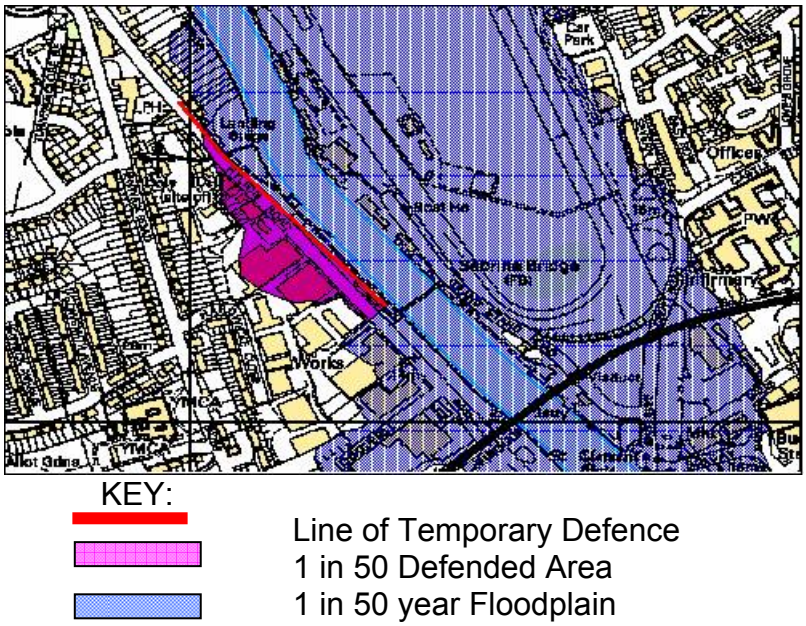

Figure 5.4 Line of the Temporary Barrier at Hylton Road Worcester

The mobile dam used in Shrewsbury in its deployed state is shown in Plate 5.1.

Plate 5.1 The Mobile Dam

Plate 5.2 shows an illustration of the Pallet Barrier, used in Ironbridge and Worcester (note steel sheets used in trials instead of wooden pallets).

Plate 5.2 The Pallet Barrier

The following characteristics were common to all three sites:

- Long history of frequent flooding
- Existing reliable flood forecasting and warning systems
- A minimum of 8 hours lead time between forecast and onset of flooding
- Previous feasibility studies confirming that permanent schemes were not feasible
- Existence of recent hydraulic models
- Modelling showed no adverse effect on adjacent properties expected
- Located along or adjacent to main roads
- Active Flood Action Groups and support of local MPs
- Flooding is caused by a combination of river flooding and inadequate drainage.

Partnerships

Due to the large number of responsibilities associated with flood event management, the need for joint operational action plans were identified at an early stage in the trials development. The development of the action plans and their delivery involved close working among a number of organisations. By February 2004, Operational Action Plans had been agreed for Shrewsbury and Ironbridge sites, but that for Worcester was still in development. The principal organisations involved are highlighted below:

- The Environment Agency, whose tasks include providing flood forecasting and warning, deployment and removal of the temporary barriers (except in Worcester) and monitoring of deployed barriers
- Severn Trent Water, whose tasks include installing and operating penstocks, valves and pumps to isolate sewers from river levels and keep them operational
- Shropshire County Council / Worcester City Council, whose tasks are to carry out the diversion and management of traffic and associated activities -

As a special case, Worcester City Council is responsible for barrier deployment in Worcester
- Shrewsbury and Atcham Borough Council / Borough of Telford and Wrekin, whose tasks will include managing pedestrian access and restrictions, removal of blockage from the line of barrier, assistance with monitoring of deployed barriers and post-event clean-up
- Local Flood Action Groups, whose tasks include raising awareness about flooding and associated plans among the local population
- Other organisations such as the emergency services and local parish councils would be involved in the development of the Flood Action Plans.

Preparation Works

As the temporary defence systems require a lot of operational activities and organisation to provide protection during flood events, a number of activities were carried out for all the sites to ensure readiness during an event. These included:

- Identification of operational requirements and establishment of clear areas of responsibilities for them
- Development of integrated flood action plans
- Preparation of traffic diversion plans
- Access plans for residents emergency services and businesses during events
- Detailed layout and drainage infrastructure survey
- Development of plan to isolate sewers from high river levels and pumping to keep them operational
- Installation of new penstocks and non-return valves on drainage systems
- Ongoing liaison with and education of the local residents and businesses through flood action and local consultative groups.
- Dry runs and desk-top exercises to test and refine procedures

February 2004 Flood Event

This flood event affected significant parts of Wales and the Midlands, and with regard to this case study, conveniently occurred during the period of the trials. Between 30th January and 7th February 2004, bands of heavy and prolonged rainfall totalling 236.5mm in places, with daily totals reaching 54.5mm, fell on the previously saturated catchment. The rainfall was highly concentrated on the Welsh Mountains, reducing downstream. The prolonged heavy rain pattern was concentrated in three main periods, a few days apart, resulting in multiple flood peaks. In particular, the heaviest rainfall on 3rd February saw the most rapid rise, leading to the issue of three increasingly severe warnings within a short space of time, and an acceleration of barrier deployment.

Each of the sites had about 24 hours of prior severe warning. The event was assessed as a 1:10 year return period at Shrewsbury, Bewdley and Ironbridge and a 1:5 year return period at Worcester, reducing as it travelled further downstream.

Operational Response
The response was carried out as outlined in the pre-established joint action plans for each site, with the exception of Worcester for which a final plan had not been agreed prior to the flood event. The plan was triggered off at each site by flood warnings by the Environment Agency. Preparation works were carried out as outlined above and the barriers were deployed and monitored throughout the period of high water. Following planned stand-down arrangements, the demobilisation and clean-up operations followed. All partners were actively involved with the operations which were co-ordinated from joint incident rooms. Some particular issues worthy of note during the response are outlined below:

- As a result of the complex nature of the storms and multiple flood peaks, forecasts of flood levels and rate of rise changed significantly during the event. This led to an acceleration of deployment plans.
- The operational plan had assumed that there will always be enough lead time to enable deployment during daylight hours. As a result of this, there was no preparation for night-time deployment.
- Due to difficulties in changing pre-agreed plans of daylight-only deployment and other related constraints including accelerated mobilisation of deployment staff, safety concerns and conflict with earlier press releases, the deployments at Worcester and Ironbridge were delayed until the morning. As a result this was carried out in shallow water, which was rising as deployment continued. The ability to erect the barriers in rising water was critical to the eventual deployment. All barriers were eventually deployed and associated works completed before flood waters reached the protected properties. This was achieved by ensuring the deployment progressed from the lowest points, working outwards.

5.2.3 Assessment of Sustainability

Table 5.2 assesses particular aspects of the case study according to the main sustainability themes within Defra's "Taking it on" report. The assessments below focus on the comparison of the relative sustainability of the current scenario i.e. permanent defences only and use of sand bags for emergency protection as compared to the types of systems used within the case study.

Table 5.2 Assessment of Sustainability

Climate Change and Energy
• The flexibility and versatility of these systems allow increased capability to provide more sustainable flood risk management in the light of uncertainties in the effects of climate change • Their moveable nature allows the flexibility to locate them to lines of defence which fits with the energy they are able to safely absorb.
Sustainable Management and Use of Resources
• Permanent systems to the same standard are more sustainable in terms of use of resources, as less are required during flood events. This however assumes that a permanent defence scheme is technically, environmentally and economically feasible • As compared to sand bags, the systems used in these trials, and in general most systems available, require less need for primary aggregates such as sand and associated clean-up

and post event disposal of contaminated materials and soils • An assessment of the man-hours deployed showed that this was significantly less than would have been the case if sand-bags (as is the norm) had been used to provide a similar level of protection; even though past experience showed that the sandbags nearly always failed anyway. • A number of relevant organisations and the public working together in a joined up way, each with clear responsibilities in line with their expertise is a more efficient way of utilising resources during an emergency, cutting down on confusion, omissions, redundancies and repetitions. This is therefore a more sustainable management of scarce resources • The barriers used within these trials as well as most of those available can be re-used many times over as compared to sand bags, which can only be used once.
Social and Environmental Justice
• These systems have provided a scheme to protect areas where permanent protection had not been feasible due to a combination of economic, technical and visual impact issues. They therefore provided the ability for the local inhabitants to enjoy improved protection in line with other parts of England and Wales. • The trial shows that temporary flood protection can provide a sustainable solution where the important heritage and environmental attributes of areas e.g. Iron Bridge Gorge World Heritage Site make traditional approaches unacceptable. • Temporary defences allow settlements to continue to enjoy the social, recreational and other benefits of retaining access and view of watercourses, while enjoying flood protection. • The additional opportunities offered by these forms of defences will reduce the significant long term cost, health and social impacts of flooding on the affected communities. • For the case study areas, the use of temporary protection allowed the development of sustainable solutions whereby flood protection was provided that recognised the visual and environmental characters of the locations, leading to a win-win for the environment, economy and social issues. • Current levels of protection afforded to the affected areas are now generally in line with the government's indicative standard or typical protection applying to similar sized communities in England. This provides the communities with a sense of fairness and justice.
Helping Communities Help Themselves
• There was very significant local community involvement which included local flood action groups, local consultation committees, local councillors, members of parliament, all of which helped to shape the outcome in line with local wishes. • The community, particularly the local flood action groups were directly involved in the education and dissemination of scheme objectives through direct contacts and organisation of flood fairs and exhibitions. • The shared understanding and partnership between various government, private and local organisations enables sustainable solutions to be achieved for flooding where the sources and associated responsibilities cut across their areas of responsibilities.

A review of the above table shows that the use of appropriate temporary flood protection has a potential to contribute to sustainable flood risk management. It can be seen clearly that the opportunities span all the key areas assessed.

It did show in particular that in terms of use of resources, it is not as sustainable as permanent flood protection, and as such where such systems are feasible, they should be provided. The potential for these systems to improve sustainability therefore comes from their use when permanent systems are not feasible. The review also showed that these forms of systems are significantly more sustainable than the traditional sand bags.

An assessment of the operational responses during the February 2004 flood event is given in the summary Tables 5.3 to 5.4 for the Shrewsbury, Ironbridge and Worcester trial sites respectively.

Table 5.3 Operational Summary for Trial Sites

	Shrewsbury	**Ironbridge**	**Worcester**
Prior alert time given (hours)	24	48	48
No. of operatives EA	3	15	10
No. of operatives Contractor	4	20	4
Man Hours EA	24	200	150
Man Hours Contractor	36	300	30
Operating Costs PLANT	£2000	£6000	£5000
LABOUR	£1000	£10000	£4000
MATERIALS	£2000	£7500	£2000
Total Operational Cost	**£5000**	**£23000**	**£11000**
Cost per Metre	**£50/metre**	**£43/metre**	**£33/metre**
Time to mobilise	2 hrs	10.5 hrs (delayed until morning)	10.5 hrs (delayed until morning)
Time Defence effective	2 hrs after arrival	5 hrs after arrival	5 hrs after arrival
Duration of defence in operation	48 hrs	48 hrs	48 hrs
Time to demobilise	4 hrs	6hrs	8hrs
Number of Sandbags alternative	1200 (260 tonnes)	62000 (1350 tonnes)	45000 (975 tonnes)
Lorry Movements	13	70	50
Cost of Sandbags (including disposal)	£9000	£47000	£34000
LABOUR	£2900	£15000	£11000
NO. OF OPERATIVES	11	55 for 2 days	40 for 2 days
Total Operational Cost	**£11900**	**£62000**	**£45000**
Cost per Metre	**£119/metre**	**£112/metre**	**£136/metre**
Cost of 1 tonne Sandbags (including disposal)	£2500	£32000	£23000
LABOUR	£1500	£5000	£4000
NO. OF OPERATIVES	4	10	7
Total Operational Cost	**£4000**	**£37000**	**£27000**
Cost per Metre	**£40/metre**	**£67/metre**	**£81/metre**

It can be seen from Table 5.3 that the operational cost of deploying the temporary defence systems were significantly less than that for equivalent sandbags for the same protection level. Previous events would suggest that sandbags would most likely have been overwhelmed or suffered from excessive leakage. It should be noted however that the cost of the temporary defence barriers have not been included in the above analyses, as they would have been purchased once and re-used over a period of time. The actual economic comparison would need to consider particular defences and their expected life and associated costs such as purchase, maintenance and storage.

5.2.4 Barriers, Successes and Failures

Table 5.4 below provides an analysis of the barriers encountered within the trials and how they were overcome (if applicable). It also provides information on particular successes or failures of note.

Table 5.4 Barriers, Successes and Failures

Barriers
• Lack of public confidence in the success of the scheme as previous permanent options had not been viable. Public education and engagement through all stages and the ongoing flooding problem improved their enthusiasm. • Long term commitment required from all participants (EA, Local Authorities, Severn Trent Water etc.). Some organisations could only commit for the trial period and are still trying to secure funds for ongoing requirements. • These systems are not as robust as the permanent systems, particularly due to the additional risk of operational failure. Their use is only recommended where permanent schemes are not feasible. • They require reliable forecasting and warning system, sufficient lead time for deployment and suitable organisational framework to be effective. This was available on the River Severn. • Complex multiple rainfall events, leading to rapid rise in forecast levels coupled with the plan only to deploy barriers in daylight hours led to acceleration or amendment of deployment plans • Engineers are less willing to consider these systems due to a lack of experience of their use in the UK and information about their performance • Some temporary barriers have non rigid parts or aspects that are susceptible to vandalism. Security patrols were carried out once the barriers were in place to avoid accidental or vandal damage. • Public interest is usually high during the use of such systems. Adequate public management, while ensuring effective access for operatives and emergency services was essential. • A lack of a consistent method of appraisal of these systems, which takes account of the reliability of each associated operational processes makes it difficult to carry out consistent assessments. This can affect approval of such schemes. • The successes of the barriers in protecting the designated areas have led to the call for similar systems for neighbouring areas. As these systems become more popular, organisational systems and resources would need to be re-assessed, as the statutory organisations only have finite resources. The inhabitants of unprotected areas adjacent to the River Severn temporary and demountable sites have already alleged that the presence of the barriers worsened their flooding, in an effort to support a case for providing similar protection for them.
Successes
• The partnerships worked and all deployment was completed before onset of property flooding • About 100 properties were protected from flooding and associated damage for the first time • The relationship between the Environment Agency and the local public improved significantly following the February 2004 event. • The operational cost for the February 2004 event was found to be significantly less than would have been if the usual less effective sandbagging was used. • Economic prosperity to the protected areas was immediate as property prices soared.

Failures
• The rapid rise in forecast caused by the complex multiple rainfall event of February 2004, led to deployment in wet/shallow water conditions as water had started to encroach on the proposed barrier line. However, no property flooding resulted. The decision to only carry out deployment during daylight hours contributed to this.

5.2.5 Assessment of Benefits of Techniques/Tools

Years of failed attempts at trying to find a feasible solution to the flooding problem at the three trial sites were resolved by the use of temporary flood protection, which has already been proven to work. It can therefore be concluded that there is significant benefits to sustainable flood risk management to be gained from the use of these systems. The case studies also highlight the peculiarities of the sites that made them suitable and the importance of the associated organisational processes and planning to their success. These issues and the extrapolation of the results of this case study to wider techniques and situations are considered in Section 2.6.

5.2.6 Review of Opportunities and Limitations, Lessons Learnt, Wider Applicability

Opportunities, Limitations and Wider Applicability
Temporary defence systems offer opportunities for provision of sustainable flood protection where permanent or more formal demountable systems are not feasible.

When permanent options for flood risk reduction are feasible, they would provide more sustainable solutions as the associated operational activities and the added risk of operational failure would be avoided.

Where permanent systems are not feasible, more formal demountable systems would offer the next best sustainable solution as they would be purpose built engineered systems. Such schemes would include all necessary work to form complete defences such as properly designed foundations, ties into adjacent high points and the blockage of all routes through which the barrier could be bypassed during barrier deployment.

Temporary systems on the other hand will usually be bedded on whatever surface was available. Pre-planned temporary systems such as provided for the trials provide added opportunities for improvement of their bedding onto the ground, as well as the identification of and development of contingency plans for blocking through drains or installation of valves as necessary.

Following from the above discussion, sustainable flood protection should be considered in the following order - Permanent flood defences → demountable flood protection → temporary flood protection.

As the use of temporary flood protection relies on completion of all necessary operational activities for deployment before the flood level is reached, the

following are some of the key requirements that would limit the use of these systems.

- A reliable flood forecasting and warning system is required.
- Enough lead time is required following receipt of warning, to allow mobilisation and complete deployment of the temporary defence system before the critical flood water level is reached. This will normally rule out developments in small or steep catchments and those close to the top of the catchment.
- Availability of adequate resources (trained manpower, plant and materials) would need to be guaranteed to ensure successful closure operation.
- A well rehearsed flood operational plan would be required to ensure all personnel and organisations involved have clear and co-ordinated responsibilities.
- There is a limit to the number of temporary protection systems that can be planned for an area as they may all need to be deployed during the same event. The ability to mobilise the required appropriately trained staff and resources within a short period of time would normally be the limiting factors.

In order to ensure that appropriate opportunities are taken where the use of temporary and demountable protection can provide the most sustainable option for flood management, while ensuring they are not used for inappropriate areas, their applicability should be considered as part of higher level catchment decisions. Within the current flood risk management framework, this would be within CFMPs and strategic studies. These higher level assessments will ensure appropriate consideration of locations within the catchment, minimum lead times, reliability of forecasting systems and availability of operational resources at catchment or organisational resource management scales. The considerations on a scheme by scheme basis will then be guided by more strategic higher level assessments.

Lessons Learnt

Some lessons were learnt from this case study which should be considered in any future development of flood protection through the use of these systems. These lessons were identified from positive actions that proved necessary or omissions which in hindsight would have improved effectiveness. Some of these are outlined below:

- Even if there is a very long lead time for deployment, the choice of temporary system and proper operational planning should ensure that deployment can be carried out safely during day or night time hours.
- Assessment of operational requirement and cost should be assessed properly. Experience to date, including the trials showed that more often than not, they are grossly under-estimated.
- Operational plans should allow for the possibility of freak and complex storm events, particularly multiple events.
- Where a number of separate organisations or groups are involved, a clear flood plan should be jointly developed, agreed, communicated and rehearsed to ensure reliability of response.

- Once barriers are erected, continuous monitoring should be carried out to ensure its continued integrity and identify early signs of fatigue or problems.
- Where the line of temporary barrier has been pre-agreed, consideration should be given to ensuring that the bedding area would provide an adequate seal and safe conditions and access for deployment and safe working (avoid soft areas)
- Adequate temporary pumping arrangements need to be in place to remove seepage under, around or through barriers.
- Keep the barriers in an easily accessible area, as close as possible to the deployment site.
- If possible opt for barriers that are easy to erect or raise within partially flooded areas if the need arises.
- Education of the public as part of scheme development is vital. All reasonable avenues should be used, including the relevant local groups. This also helps manage local expectations.
- Ensuring the health and safety of all during the periods of deployment is important. Safe public areas should be properly demarcated, while ensuring adequate operational and emergency access.
- As much as possible during the planning stages, extensive surveys should be carried out to identify all drainage and routes for flood water to bypass the barrier, and contingency plans made to prevent ingress of flood water when the barrier is in place.
- Measures to isolate sewers from the influence of high river levels should be planned. It is likely that over-pumping of sewer systems would also be required due to the surcharge effect of the flood water.

5.3 Summary of findings

In summary, the findings of this case study are that temporary and demountable defences have significant potential to provide sustainable flood management, where permanent flood defences are not feasible. Their use involves significant operational requirements, which need to be properly planned and executed to realise this potential.

The successful use of the temporary and demountable systems following their deployment in Shrewsbury, Ironbridge, Bewdley and Worcester during the February 2004 flood event can best be captured by the quote below from post event comments by the local press.

"The rule book has been changed for ever. The old consensus that nothing can be done has been replaced by a knowledge that something can be done. The barriers were a great success" - Shropshire Star, February 2004.

6 Case Study 4b: Cambridgeshire FLOWS Project on Sustainable Water Management Systems

6.1 Introduction

6.1.1 Background Information

This case study is one of the seven carried out as part of the R&D project titled Sustainability of Flood and Coastal Erosion Risk Management. It is focused on the ongoing EU funded project in Cambridgeshire to showcase the use of sustainable water management systems (SWMS).

The historical approach to flood risk reduction in the United Kingdom has been to allow run-off to flow relatively unimpeded to receiving watercourses, where flood alleviation measures are provided to protect particular areas of interest. These measures have tended to include measures such as upstream flood storage, watercourse capacity improvement, flood walls and flood diversion around the protected area.

Some form of drainage is required wherever building development exists to remove surface water. Traditionally this has been achieved by replacing the natural drainage processes by impermeable surfaces and piped drainage systems that are designed for quantity, to remove all runoff as quickly as practicable to receiving systems. This alteration of natural flow patterns often leads to local problems such as reduced infiltration, evapo-transpiration and surface water storage. Further down the catchment, this can also lead to an increase in flood risk and pollution. In the face of increasing development and the effects of climate change, it is becoming apparent that such traditional drainage systems are not sustainable. Experience of failed and unsustainable attempts over the years has gradually led to the evolution of smarter management approaches.

A systematic move from flood defence to flood risk management has been occurring in the UK over the last few years. One of the key parts of this culture change has been the move from concentrating solely on traditional flood alleviation techniques to a wider consideration and management of the probabilities and consequences of flooding. Such an array of approaches provides the ability to develop sustainable solutions which work better with natural processes and enhance the natural environment, habitat diversity and social well-being. Sustainable drainage systems (SuDS) are regarded as one of the measures that can assist in the achievement of these objectives.

The Foresight report (OST, 2004) provides an indication of future risks from flooding and the effectiveness of a wide range of measures for responding to the future challenges. It concluded among other things that “all SuDS are more effective to some degree than piped drainage at both controlling the quantity and quality of storm water drained”. It also recommended that “the awareness

and understanding of SuDS will need to be promoted to educate stakeholders to take more responsibility for local drainage".

The draft Defra strategy, "Making Space for Water", highlights the need for a holistic approach to the management of flood risk using a portfolio of measures. The document recognises the potential of SuDS "to reduce flood risk, while achieving multiple benefits in improving water quality, recharging ground water and enhancing the potential for biodiversity" (Defra, 2004).

As part of the delivery of the Water Framework Directive, River Basin Management Plans need to be completed by 2009. A particular challenge in meeting the directive's requirements is tackling diffuse pollution from urban and rural sources. SuDS techniques are likely to be one of the key techniques required to manage this problem.

As part of the measures to combat the current pressures on the availability and prices of houses, the UK government has identified four growth areas within which it plans to build 200,000 houses in addition to its existing housing programme by 2016. Cambridgeshire falls within the M11 corridor growth area, where the target for new houses by 2016 is currently 166,500 (ABI, 2005). About 47,500 of these are currently proposed within Cambridgeshire (FLOWS Newsletter Issue 1, 2005). The site considered for this case study is within the Cambourne development; a new town development in Cambridgeshire.

The need to promote the development of sustainable communities is a key priority for Cambridgeshire County Council. The commissioning of the sustainable water management project is a part of this overall plan to identify best practice and promote their uptake. The project is part of the FLOWS (Floodplain land-use optimising workable sustainability) programme funded within the European Union's Interreg IIIB programme, with partners from the Netherlands, Sweden, Germany and Norway. It focuses on the design and construction of sustainable water management systems within a new residential development. Two aspects of SWMS covered by this project are SuDS techniques and flood proofing of new residential developments; in particular it focuses on the available techniques, their practicality, applicability, limitations and whole life management issues. This case study is only concerned with the SuDS aspect of the project.

6.1.2 Particular Sustainability Issues

A number of issues relating to sustainability have been identified with regards to the use of SuDS. These are summarised below:

- Whole life management to ensure continued performance
- Effect of climate change on long term viability of measures
- Availability of space or ability to manage dual use of space with other functions
- Provision of solutions that meet the objectives of improved drainage/flood management, water quality and amenity, leading to win-wins for the environment, economy and social wellbeing.

- Use of rainwater and associated run-off as a resource as opposed to a threat
- Dealing with flood risk at source in line with the polluter pays principle
- Reducing the effect of development on flood risk and water quality downstream
- Creation of sustainable environmental habitats and improved amenity

These issues are discussed further within the case study assessment section.

6.1.3 Objective of Case Study

The objectives of this case study are as follows:

- to assess the effectiveness of SuDS for managing flood risk nearer to the source of flooding
- to assess their sustainability, benefits, concerns, applicability and limitations, and
- to identify guidance for their use to improve sustainable flood risk management through an assessment of the ongoing Cambridgeshire FLOWS project.

6.1.4 Summary of Available Information

Consultation in the form of meetings and telephone conversations were carried out with a number of key people involved with the project development. In addition, a number of publications and other supporting information relating to the project and associated wider issues were reviewed.

The following personnel involved with the project were consulted.

- Mark Vigor, Cambridgeshire County Council (Client Project Manager and Council's Strategic Planning Manager)
- Robert Bray, Robert Bray Associates (SuDS specialist within Project Team)
- Renuka Gunasekara, Royal Haskoning. (Scheme development Consultant Project Manager)
- David Rayner, Higgins Construction Plc. (Building Contractor).

In addition to the direct consultations, the following documents were also reviewed:

- Showcasing sustainable water management techniques for new residential developments – information pack, FLOWS, 2004.
- Showcasing sustainable water management Systems in Cambridgeshire – Developer brief, Royal Haskoning, April 2004.
- Living with flood risk in a changing climate, FLOWS Newsletter Issue 1, January 2005.
- East of England Plan: draft revision to the regional spatial strategy for the East of England, East of England Regional Assembly, Bury St Edmunds, December 2004.

- Making communities sustainable - managing flood risks in the government's growth areas, Summary Report, Association of British Insurers, London, February 2005.
- Sustainable urban drainage systems – best practice manual, CIRIA C523, London, 2001.
- Model agreements for sustainable water management systems – model agreements for SuDS, CIRIA C625, London, 2004.
- Sustainable drainage systems – Hydraulic, structural and water quality advice, CIRIA C609, London, 2004.
- Making space for water – Developing a new government strategy for flood and coastal erosion risk management in England, a consultation exercise, Defra, London, July 2004.
- Ogunyoye et al. Managing flood risk at source – showcasing best practice, International Flood Management Symposium, Nijmegen, 2005
- Patterson et al. Lessons from the application of sustainable floodplain, drainage and stream management in Australia, Third National Conference on Sustainable Drainage, Coventry, 2005.
- Foresight future flooding, volumes 1 and 2, Office of Science and Technology, London, 2004.

6.2 Case study assessment

6.2.1 Objectives of Scheme

The overarching objectives of the FLOWS team in carrying out this project are as follows:

- To design and construct a new residential development to showcase sustainable water management in residential developments that deliver practical and cost-effective solutions which can be readily adopted by the building industry;
- Produce best practice guidance on water management within residential developments and disseminate recommendations to stakeholders in the area, the rest of the UK and the wider EU;
- Help to demonstrate to the Local Authorities how they can continue to plan for development incorporating water efficiency measures;
- Highlight measures for adapting communities and homes to climate change;
- Provide a benchmark of best practice guidance that will positively influence developers, construction companies and local planning authorities.

The two main challenges that the project is focussing on in delivering the above objectives, are:

- The effect of development on flooding (how to reduce run-off from developments, which exacerbates flooding elsewhere);
- The effect of flooding on development (how dwellings can be flood proofed).

This case study is only concerned with the first Item. Also, grey and black-water recycling and re-use are outside the scope of this project.

6.2.2 Scheme Development and Details

Case study Site
This case study site is the GC16 site within the Cambourne development; a new town development in Cambridgeshire. The master plan for the Cambourne development allocates 69,675 m^2 of business floor-space within the business park and 3,300 residential dwelling. Figure 6.1 shows the location of the GC16 site within the context of the overall Cambourne development. GC16 is a 2.5 acre site proposed for 35 social residential dwellings that will be managed by Cambridgeshire Housing society. The site is not within the 1:100 year flood plain and the sub-soil is generally impervious.

The GC16 site was chosen for the Showcase site following a systematic site selection process. The process was designed to deliver a site which had the potential for demonstrating a wide range of practical and cost effective SuDS techniques among other sustainable development attributes. In addition to reducing the risk of planning objections, a site with a good chance of obtaining planning consent was identified. The downside of this was that the design was already advanced; however, the developers were flexible enough to accept significant changes to the design as long as the site layout was not fundamentally altered. All the key stakeholders such as the Environment Agency, sewerage authority, local planning authority and highway authority were part of the project stakeholder group; this assisted with identifying concerns early and obtaining appropriate steers.

Figure 6.1 Location of the case study site

The drainage design for the GC16 site had already been carried out before involvement of the FLOWS team in the project. The original design involved all site drainage from the development areas being piped and discharged into the storm water sewer that has been designed for the 1:30 year normal adoptable standard. The design did not include any source control measures at the development site. All flows entering the storm water sewer will freely discharge into a strategic storage scheme that already exists for the wider Cambourne development, which will attenuate all flows up to the 1:100 year storm event. The sustainable drainage measures were therefore designed retrospectively into the project.

The SuDS Design Principles

The design principles were developed in line with current UK guidance (CIRIA 2000), as well as other recent guidance and experience gained from previous SuDS designs. The currently available guidance was reviewed with particular emphasis on the use of appropriate SuDS techniques for new residential developments. The site as a whole slopes on a 1:50 gradient from west to east. In line with working with natural processes, the challenge was therefore to

design a series of integrated drainage measures to move excess water safely into the regional drainage system, in line with the natural gradient. The design followed three main principles, namely the "drainage triangle", the "SuDS management train" and best practice whole life management considerations. These three principles are described below:

1. The drainage triangle principle ensures that SuDS meets the three integrated objectives of dealing with run-off by controlling flow (quantity), preventing pollution (quality) and offering environmental benefits (amenity) in equal measure. The drainage triangle is illustrated in Figure 6.2 below.

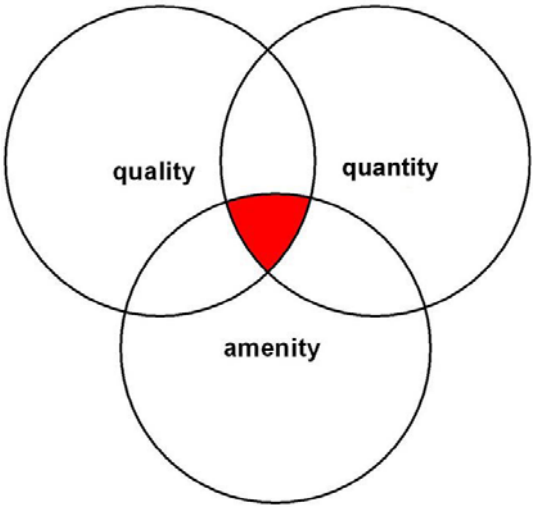

Figure 6.2 The drainage triangle

2. The SuDS management train is a hierarchical process whereby a suite of integrated SuDS techniques are applied in series, ensuring the management of run-off is targeted as close as possible to its source, progressing down catchment into the receiving system. This process is illustrated in following flow chart.

   Prevention → Source control → Site control → Regional control

3. The whole life management principles that guided the design are as follows:
   - simplicity of construction
   - visibility to aid understanding
   - robustness in use
   - easy and obvious maintenance
   - cost effectiveness
   - long design life.

Design Development

A number of issues encountered within the design are described here. In the early stages of design, it was shown that the full attenuation of additional runoff (based on existing green-field run-off of 5 litres/s) to a 1 in 100 year standard with allowance for climate change could be accommodated within the site boundary. However, this would have been very costly and would require the use of special below ground storage techniques, which may be a problem for

the long-term maintenance. It would also have defeated some of the objectives of the scheme, such as practicality, ease of maintenance and cost-effectiveness.

In order to provide a 1 in 100 year return period volume with an extra 20% allowance for probable climate change effects whilst limiting post development runoff to 'green-field' rate, it became apparent that the peripheral 'public open space' would be required to achieve a reasonable hierarchy of storage. Therefore the concept of managing day to day runoff within the development up to a 1 in 2 year storm return (apart from permeable pavement areas) was developed with additional storage up to the full requirement in recreational space. Some of this recreational space was available within the site where an area had been defined for Local Area of Play (LAP), while the remainder was found within the adjacent 'greenway' and golf course that would be managed by the local Wildlife Trust and the Camborne Developer Consortium. Although it would have been possible to discharge to the main storm water sewer just outside the eastern site boundary, it was recognised that a more natural pathway, meeting the current Building Regulation guidance, is to a local ditch. This preliminary exercise meets the key SuDS principle of mimicking natural drainage.

This practical solution to the management of different storage volumes highlighted the need for a radical review of current adoption procedures. In principle, the housing development deals with smaller frequent rainfall events using 'source control' measures within the development to clean and store runoff and larger infrequent storm events discharge to Public Open Space (POS), where the clean water contributes to wetland features, visual amenity and wildlife. The future management of the POS by the Local Authority (or whoever manages the POS) has been designed through a maintenance schedule to incorporate the multifunctional aspect of the green space and drainage.

The drainage strategy was derived from topography and the likely pre-development drainage pattern. Two clear drainage routes were identified on this impermeable clay site. The first discharges through the LAP area to the 'greenway' and the second, which provides a flood route for extreme storms, flows between adjacent housing blocks at the lowest part of the site, to the proposed drainage route at the western boundary of the proposed golf course. The site can be considered as two drainage sub-catchments, the first comprising a housing court, flowing to the LAP and the second including the remaining roadway and adjoining houses.

Revised Drainage Design

The GC16 site layout showing the drainage design is shown in Figure 6.3. The housing court provided a good opportunity to use permeable pavement as there was little space for open SuDS features. The regular maintenance required for permeable surfaces can be ensured by dedicated Housing Society management to increase its effectiveness and design life by minimising siltation and pollution of voided storage space within the pavement construction. The storage provided by permeable pavement also shows that SuDS can be used in

high density urban development. The small detention basin, collecting roof water, demonstrates the use of small landscape features to create amenity within housing even with high density. This part of the site demonstrates a practical SuDS solution for dense, well managed housing schemes.

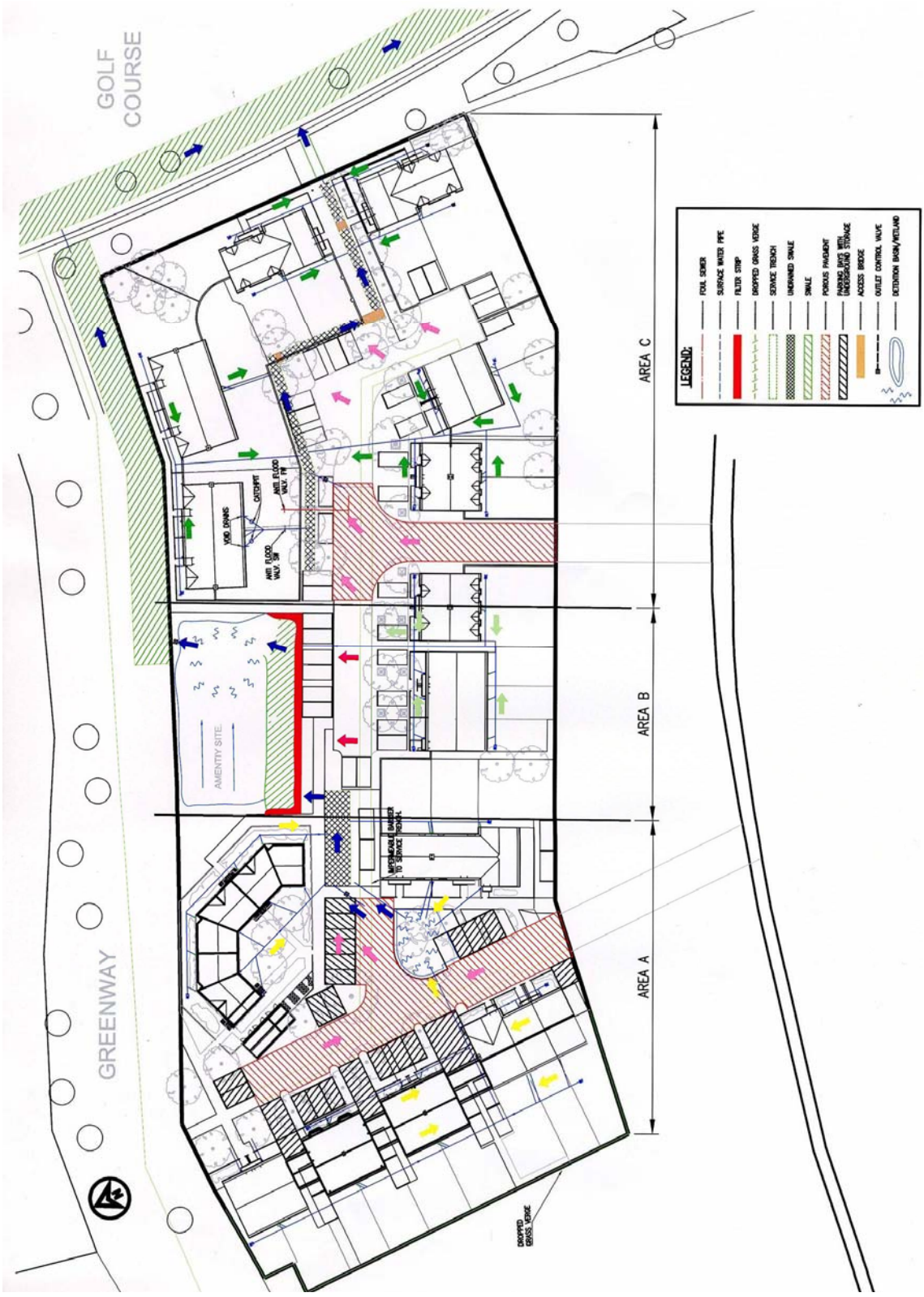

Figure 6.3 Revised drainage layout

A significant innovation for the project is the development of the under-drained swale as an appropriate SuDS technique for housing. This feature combines the benefit of the filter drain that collects and treats runoff before conveying it quickly to a convenient discharge point with the robust protection of the swale. The design is based on guidance from the USA and practical experience from housing in Dundee, Scotland. The overland flood route follows the under-drained swale into the green-space network of storage features. This arrangement protects both the properties within the development and the other areas downstream of the development. A series of small basins (beginning on site and leading to the greenway) linked by a low flow channel deal with rainfall in excess of the 1 in 2 year storm. During the development of this case study, it became apparent that the acceptable green field run-off would be 3 litres/s and not 5 litres/s as originally envisaged. Design changes to accommodate this are currently ongoing.

The revised drainage scheme is currently at the detailed design stage, with planning approvals and consents processes at advanced stages. The design objective is to aim to attenuate run-off, using SuDS, up to a 1:100 year event within the proposed scheme. The final design is still evolving, but it is not expected to alter significantly from the current one. Due to the late stage at which sustainable drainage design was introduced to GC16, there was some constraint on the degree to which an effective sustainable drainage solution could be achieved. Ideally SuDS should be an integral part of site layout and should therefore be considered at the beginning of the design process to gain maximum benefits.

Other design considerations

SuDS technique selection was reviewed to ensure ease of building, robust construction and maintenance and the other special requirements of the housing sector such as health and safety and the practical use of multifunctional land by local residents. The project has considered Health and Safety using recognised measures to reduce risk to the public and has been reviewed favourably by the Royal Society for the Prevention of Accidents (RoSPA). However it is recognised that the amenity and wildlife benefit of water features must be balanced with perceived safety risks. In order to ensure this, the adopted approach can be summarised as follows:

- SuDS open space was designed to be fully accessible both visually and physically to allow parents and residents to see what is happening at all times to provide informal policing and communal ownership.
- The wetland area including low flow channels and ‘rain garden’ are to be planted with attractive native water plants to provide a wildlife asset and naturally delineate wet areas without preventing access for maintenance, play and recreation.

The FLOWS project has provided guidance on planting of SuDS schemes and a checklist of maintenance tasks to allow developers, clients, and the statutory and private organisations to understand the simple management requirements of SuDS schemes that follow the design guidance developed through the FLOWS project.

6.2.3 Assessment of Sustainability

The underlying concept of SuDS is that solutions should meet the three integrated objectives of dealing with runoff by controlling flow (Quantity), preventing pollution (Quality) and offering environmental benefits (Amenity) in equal measure. This is in line with the three pillars of sustainability.
Table 6.1 assesses particular aspects of the case study according to the main sustainability themes within Defra's "Taking it on" report. The assessments below focus on the assessment of the sustainability of SuDS as used within the case study project, in line with established sustainability principles.

Table 6.1 Assessment of Sustainability

Climate Change and Energy
• SuDS attempt to mimic natural drainage as much as practicable, thereby reducing the energy of run-off onto receiving systems. • With climate change likely to increase storminess and flood peaks, SuDS improve the ability to maximise source, site and regional control techniques in reducing these effects of run-off and associated flood risk. • SuDS are not technically feasible within flood plains, particularly those which are permanently inundated, or with a high return period of flooding. Climate change is likely to lead to an increase in flood plains and frequency of flooding. Appropriate use is therefore necessary to ensure their sustainable application. • SuDS systems are at their most efficient for managing high frequency run-off. The limitations of space and local physical characteristics may imply that SuDS are unable to efficiently provide drainage to the desirable standard, in such circumstances further extreme event management is still required.
Sustainable Management and Use of Resources
• SuDS allow water to be managed as a local resource such as for ground water recharge, recreation, education, habitat improvement and amenity, as opposed to treating it as a threat that needs to be removed elsewhere as soon as it appears. • SuDS allow recycling/re-use of water all through its management train, maximising its use as a resource and reducing the quantity that is passed on as waste. • The collection and re-use of water leads to reduced demand for potable water, by allowing re-use of rain water for activities which do not require potable water quality. • Like all natural and engineered systems, SuDS rely on whole life management in order to remain effective. They normally require predominantly 'little and often' type maintenance. The extent of maintenance is determined by the simplicity of the design; making it a major consideration during design.
Social and Environmental Justice
• SuDS increase the scope for reducing flood risk from developments onto downstream communities. • SuDS allow flood management measures to be carried out, as much as practicable, higher up the drainage cycle where the developments and other interventions with natural processes are occurring; furthering the 'polluter pays' principle. • The inclusion of SuDS principles in new developments allows the opportunity for achievement of multiple objectives for the environment, the social wellbeing of the inhabitants and reduced pollution and quantity of run-off to receiving systems. • Visibility, which is one of the key attributes of SuDS measures, allows improved understanding of the drainage and water management cycle, with potential educational and

awareness benefits.
Helping Communities Help Themselves
• The hierarch of SuDS measures, which allows source, site and regional treatment of quality and quantity of run-off, allows participation of individuals and communities in drainage and flood management. • Experience of developments where SuDS systems have been applied as integral parts show that they have led to community pride, sought after areas and in some cases increased house prices. • The project development is being steered by a stakeholder group including wide local and national interests to ensure the project is in tune with local community needs and more strategic national strategies. • Partnering with the community has led to the project forming the basis of a thesis at a local University (Cranfield University), with further involvement with longer term monitoring currently being assessed.

A review of the above table shows that the use of SuDS has a significant potential to contribute greatly to more sustainable flood risk management. This relies on its appropriate use. Lessons learnt from the case study and guidance to ensure this potential is maximised are discussed in Section 2.6. It should be noted that not all techniques are applicable everywhere and as a tool it does have limitations. These are also discussed within the same section.

6.2.4 Barriers, Successes and Failures

Table 6.2 below provides an analysis of the barriers encountered so far within the project development trials and how they were overcome (if applicable). It also provides information on particular successes or failures of note.

Table 6.2 Barriers, Successes and Failures

Barriers
• Design of the SuDS measures were commenced late in the scheme development process. This limited their potential. The consideration of SuDS much earlier at the planning/layout stage of development sites would enable development of more integrated systems. • Organisations responsible for future maintenance of some of the systems, such as the permeable pavements were very conservative in their assessment of the whole life management requirements. Early engagement and involvement in regular stakeholder meetings assisted in achieving more realistic assessments. Improved use and performance monitoring should address this in the future. • There were significant concerns by the local planning authority regarding the dual use of the designated “Local Area of Play” (LAP) as flood storage during high storm events. Early consultation, further hydraulic analyses and continuous engagement allowed an agreement of the dual use to the satisfaction of all concerned. • There were safety concerns about the infrequent flooding of the LAP and the wetland/pond at one end of it. An agreed design was finally obtained following the involvement of ROSPA in the review of the scheme and the design of landscaping/vegetation as a dual safety and habitat enhancement feature. Measures such as safe access benches, gentle slopes, strategically placed dense vegetation zones, child-proof fencing and retained shallow depth of the pond helped address the issue, while ensuring amenity and environmental opportunities were not compromised.

- The movement of very heavy vehicles and soil during construction provided concerns for blockage of measures that relied on some form of permeability (e.g. permeable pavements). The sequencing of construction works is being planned to ensure such systems are built only after completion of heavy construction and soil movements. Appropriate inspection and maintenance schedules are also in place.
- The allowable parameter for acceptable green-field run-off for design was altered at a very late stage of the design, due to conflicting demands by different parts of the regulatory authority. The redesign to accommodate this more stringent condition is ongoing. Future works will need to ensure clear agreement and documentation of such key parameters by the appropriate sections of the Environment Agency or similar Authority, prior to commencement of design.
- Current rules of sewerage authorities do not allow adoption of drainage that has been routed through land. This complicates adoption for integrated whole site drainage including parking and similar areas to be incorporated. This is still a major issue and would require rethink if the benefits of SuDS are to be maximised. The new model agreements recently developed by CIRIA should help in this regard.
- The current rule that allows development of brown field sites as long as there is no more run-off than present does not provide the incentive for developers to utilise currently available techniques to provide cost-effective run-off reductions easily achievable within current capabilities. As the capabilities become more apparent, it is hoped that this approach will change.
- Guidance and intentions aimed at facilitating SuDS are increasingly being made available. They are however generally not mandatory and often rely on developer's goodwill. Clearer and unambiguous legislation may be required to drive required changes as have occurred in places such as Australia.
- The current scenario only provides an incentive for developers to embrace SuDS where they are so restricted by planning conditions and where they can see short term financial benefits. Other longer term financial, environmental and water quality benefits are therefore not being realised, as developers are often not involved for the long term. Further action from planning authorities would be required in this regard to maximise the potential of SuDS.
- While not an issue in this case study, experience from other sites show that potential for reduction in revenues for benefactors from traditional piped systems such as sewerage undertakers and pipe manufacturers can lead to some resistance to wide scale application.

Successes

- The results show that run-off from development sites (even those with relatively impervious soils) can be reduced through appropriate use of SuDS to a green-field run-off equivalent; generally up to at least 1 in 2 year event storm and in places up to a 1 in 100 year storm event, depending on local circumstances.
- The scheme was able to include a range of measures that demonstrate a train of integrated sustainable drainage measures for developments of varying densities.
- Compared to the previously piped surface run-off, the SuDS scheme provides regulation and treatment of the run-off through each stage, giving rise to improved water quality at the final point of discharge.
- The design enabled the collection and re-use of roof drainage for gardening and other appropriate household uses, reducing the demand on scarce potable water.
- The scheme successfully brought together a wide range of stakeholders including developers, local councils, the Environment Agency, highway authority, the local sewerage authority and the local wildlife trust, to develop a range of measures that achieved their multiple objectives.
- The scheme significantly increased the amenity and biodiversity of the development site and its surroundings.
- The scheme showed that there already exist a range of measures which can be used to

reduce run-off at or much closer to the source, reducing downstream flood risk.

- The showcase site when complete will provide an educational, learning and point of reference for good practice in sustainable drainage and flood management at source, potentially increasing the understanding and future uptake of such measures.
- The project showed the willingness of all stakeholders to work together to achieve more sustainable solutions.
- The project showed that with proper risk management and design, dual use of public open spaces can significantly improve storage of flood water without impacting on the health and safety and enjoyment of the primary use.
- The project showed that with simple designs, a SuDS system can be designed to ensure most of the future maintenance can be accommodated within normal landscape maintenance.
- The engagement of the wider stakeholder throughout the development ensured that the good practice and lessons learnt are being disseminated into the industry, even during the development.

Failures

- The lateness of consideration of SuDS measures meant the loss of significant opportunities for more integrated whole-site management, as the layout of the site and buildings were already in place.
- Despite early engagement of stakeholders, failure to ensure confirmation of agreed design parameters with appropriate parts of the consenting authorities led to a need to design for more stringent measures at a late stage. Early assessments indicate that this can be successfully accommodated within the overall design philosophy.

6.2.5 Assessment of Benefits of Techniques/Tools

The conversion of a previously designed traditional piped drainage system to a SuDS system provides a good measure for comparison of the value of the SuDS technique for the case study site. Particular benefits of reduced peak run-off and water demand, and improved water and environmental qualities are discussed below.

The SuDS techniques provide the opportunity to reduce peak flows from a development site and its associated sub-catchment area in a manner that enhances the environment and quality of life of the community. The case study showed that it is possible to limit peak flows from development sites to green field run-off rate to a minimum of 1 in 2 year storm event for high density development and up to 1 in 100 year event for lower density developments. It also showed that with the additional use of associated regional areas, a 1in 100 year standard can be achieved; even in regions incorporating high density development.

The technique allowed some reductions to be made on portable water demand, due to the collection, recycling/re-use of roof drainage. Studies carried out in Australia show that only about 1% of potable water is used for drinking, even though this precious commodity tends to be used for all household purposes. By comparison to standard methods therefore, it provides a direct benefit of reduced water demand, as well as potentially reduced cost to householders and reduced abstraction from surface and ground water. Rain water butts at each property as used in the development only has limited effect; more significant effect can be achieved with the use of rain water tanks and recycling of the

retained water for more household uses. Appropriate use of grey water recycling can also contribute to reduced potable water demand.

When compared to the traditional piped drainage to the sewer network, marked improvement in the discharge quality of the run-off reaching the regional system will be achieved compared to the traditional drainage approach through a progressive removal of pollutants as it passes through the series of natural detention areas, swales and filter systems.

The creation of swales, ponds and wetland areas which are all planted with a variety of attractive native aquatic plants will provide a wildlife asset and naturally delineate the wet areas, thereby improving the environmental quality and community recreational enjoyment within the area. Compared to the tradition drainage design, the benefit of increased opportunities for environmental and social benefits are therefore significant.

The current assessment of costs show that despite the late incorporation of the SuDS measured and associated extra re-design costs, the whole life cost is not expected to be higher than that for conventional systems, the environmental and social benefits are however significantly greater than that derivable from the more traditional design. If SuDS had been considered in a more effective manner from the planning / site layout stages, the reductions in cost due to avoided abortive and redesign costs as well as the possibility of reduced ongoing charges from the Sewerage Authority would have enabled even greater cost effectiveness.

6.2.6 Review of Opportunities, Limitations, Lessons Learnt and Wider Applicability

Opportunities

The case study shows that appropriate use of SuDS systems provide a number of opportunities for sustainable flood risk management. Some of these are outlined below:

- To manage run-off and flows as close as possible to their source, reducing the effect of developments and other human intervention on flooding; allowing better application of the polluter pays principle.
- To incorporate enhancements to water quality, environmental quality, landscape and amenity within drainage and flood management measures.
- To support catchment or region wide flood management and drainage considerations in the planning and layout of individual or strategic development plans, thereby allowing opportunities for maximum benefits to flood risk reduction.
- To target particular pollutants with treatment methods to suit their efficient removal, in tandem with attaining required drainage and flow attenuation objectives.
- To increase the visibility of drainage and flood management measures, leading to better education of the local communities about flood risk issues.

- To widen the suite of approaches available for managing run-off and their associated flood risk, particularly in light of the expected effects of climate change.
- To extend the concepts of the hierarchical management train to other activities that can increase run-off such as rural land and farm management, and other aspects of the built environment.

Limitations

The application of SuDS needs to be appropriate for the local conditions and the efficiency of particular measures given the local circumstances. In particular the following limitations apply:

- It is unlikely that typical SuDS features within the confines of development sites will be capable of attenuating peak run-off much greater than a 1 in 2 year return period standard without the use of open spaces such as parks and play areas, or relatively expensive large scale underground storage systems. Extension of SuDS systems from site onto integrated regional systems should improve their overall potential.
- SuDS systems are not effective in active flood plain areas
- SuDS systems are not effective for attenuating extreme or less frequent storm events. This could be due to exceedance of design capacities or some conflict of operational use. For example pond, tanks and other retention/detention areas may already be partially full from antecedent rainfall or retention for other purposes, also soil required for filtration may be saturated from antecedent rainfall or high ground water.
- Systems that depend on infiltration would be ineffective in soils with low permeability and are likely to worsen pollution problems in areas with saline soils.
- Measures such as rain-water tanks can not usually be depended on all year to provide all non potable water required. They should therefore be designed to supplement and not to replace water demand.
- Measures such as swales and on-line detention areas would not be very effective over steep gradients. Check dams or other intermittent retention structures could improve their efficiency.

Wider Applicability

While the case study was concerned with new development, the techniques are also applicable for In relation to re-development of brown-field sites or extensions to existing development.

The case study site contained areas of low and high densities, as well as sub-catchments that drain through a grassland play area and one that drains directly off the site. This allowed a wide range of techniques to be tested for a variety of scenarios, and their potential efficiencies assessed. The range of measures and opportunities should be easily transferable across sites; however, the particular measures that fit the local site conditions of each site such as topography, soil type or particular target pollutants will need to be taken into account in terms of appropriateness of individual measures. Some guidance on applicability to assist with wider use is given in Table 6.3 below.

Table 6.3 Applicability of Generic SuDS Techniques
(After Ogunyoye et al., 2005)

Technique	Description	Use
Filter Strips and Swales	Filter strips are gently sloping grass or other vegetated surfaces that drain water evenly from impermeable surfaces. Swales are shallow channels that are designed to convey, infiltrate, store and treat runoff.	Filter strips can be used wherever possible to collect water and protect infiltration devices such as filter drains, pervious surfaces and swales. Swales can be used in all but the densest urban situations.
Filter drains and permeable surfaces	Filter drains are trenches filled with permeable material into which runoff is collected, stored and conveyed. Permeable surfaces allow rainwater to infiltrate through them into an underlying storage layer. They have a volume of permeable material below ground to store and infiltrate surface water and include grass, reinforced grass, gravelled areas, permeable blocks and porous surfaces	Filter drains can be used in most low to medium density housing but care is required to anticipate the blocking by silt. They can be used to drain car parks, residential drives, paths, patios and roads. Permeable surfaces can be used in most sites but especially useful on urban sites where space is limited.
Infiltration devices	Infiltration devices drain water directly into the ground. They include soakaways, infiltration and basins as well as swales, bio-retention swales, filter drains and ponds. They work by enhancing the natural capacity of the ground to store and drain water.	Where sediment load is low and ground is permeable.
Basins, ponds and wetlands	These are devices for temporary storage of water. The main differences among them are the length of time water is held and the purpose of retention. Detention basins temporarily store water until the flood has passed. They are normally dry. Retention basins hold water back for treatment of pollution and are permanently wet ponds with rooted aquatic vegetation. Wetlands are shallow ponds and marshland areas which are covered almost entirely in aquatic vegetation.	Within sites where sufficient space is available and site topography is suitable for the use of basins and ponds. Public open spaces within housing offer opportunities to store run-off, collect silt and begin treatment of diffuse pollution.

Lessons Learnt

The FLOWS project is still ongoing; however the consultation, technique and adoption selection process to date has provided lessons for preliminary design, SuDS technique selection and future management of SuDS. It is expected that further lessons would become apparent as the project progresses to completion. Some of the lessons learnt so far are outlined below:

Design Brief

A set of basic design criteria should be developed as part of the planning brief to ensure the developer and drainage designers are aware of the requirements of SuDS for the site.

The design criteria that are developed in the early stages of the design or provided as part of the planning brief should include a requirement for a clear drainage route through the proposed development. This will demonstrate a flood route for design storm exceedance and an above ground flow route for

SuDS conveyance features, such as low flow channels and swales following natural topography.

The brief should provide clear guidance on regulatory requirements for the drainage proposals including design storms, attenuation and rates of discharge from the site.

The preferred discharge route as set out in the Building Regulations should be confirmed as: infiltrate if possible or discharge to a watercourse with the sewer as a last resort.

The planning brief should indicate adoption possibilities, particularly the opportunities to use Public Open Space (POS) and other Local Authority initiatives.

SuDS design and technique selection
Design and technique selection should recognise the limitations of the housing sector.

The design needs to be simple, easily understandable and capable of being constructed using existing skills and technology. Techniques that can be permanently damaged by siltation (e.g. filter strips, treatment trenches and permeable surfaces) should only be used after careful consideration. Where used, their sequencing within the construction programme and quality control should be properly managed.

SuDS design strategies and overland flood route for development sites need to be informed by the natural topography of the site to ensure the design works with natural processes

The design should be visible to allow inspection through the construction period and ensure effective maintenance following hand-over of the site. The drainage system should be understandable by the developer and occupiers.

The design should be robust and allow simple repair or replacement of any part of the system.

The SuDS should be designed with maintenance in mind. This will ensure the drainage system will function effectively with minimum landscape care.

The design should meet all agreed Health and Safety criteria set out in current guidance.

Management
SuDS should be designed with maintenance in mind using surface structures that are simple, visible and robust.

SuDS should be designed to be maintained as part of everyday site care by a landscape contractor or site staff.

Funding of SuDS maintenance should be agreed as part of design criteria discussions.

Management of SuDS features in POS or outside the development site boundaries may require different adoption or ownership arrangements than that undertaken within the site boundary.

6.3 Summary of findings

The case study has clearly shown that SuDS can provide solutions which satisfy the multiple benefits of improved drainage, amenity and habitat diversity for new developments. The techniques are also applicable to existing developments, but the scope for significant gains may be somewhat restricted. Whether used in new or existing developments, it has significant potential for increasing their overall sustainability. There are also significant benefits to be gained from the increased use of similar concepts in rural and agricultural land management.

The FLOWS project has demonstrated that the Sustainable Drainage (SuDS) approach to managing run-off from rainfall can be applied with modest revisions to current design practice.

Careful selection of SuDS techniques is necessary to meet the special needs of the housing sector to ensure buildability, long design life, ease of maintenance and multiple land use.

Current UK storage requirements for 1 in 100 year storm return periods cannot easily be accommodated in housing without permeable pavements or more expensive proprietary underground storage box systems. Public open space should therefore be considered as a logical drainage infrastructure for housing landscape, encouraging multiple land use. Appropriate source control measures should ensure silt and pollution is dealt with where it occurs, at source, preventing contamination of amenity space.

SuDS considered at an early stage in development plans should be cost effective to build and can provide an easily maintained sustainable drainage system for the future.

7 Case Study No 5: Stakeholder Engagement – North Norfolk SMP and Associated Strategies

7.1 Introduction

7.1.1 Background Information

General
A Shoreline Management Plan (SMP) by definition is "a document which sets out a strategy for coastal defence for a specified length of coast taking account of natural coastal processes and human and other environmental influences and needs" (MAFF Guidance Note 1995). An SMP provides a large-scale assessment of the risks associated with coastal evolution and presents a policy framework to address these risks in a sustainable manner.

The 66km of the North Norfolk coastline between Sheringham (Kelling) and Lowestoft is classified as sediment sub-cell 3(b). The original Shoreline Management Plan for this frontage was prepared in 1996. This has recently been updated, with the draft SMP2 currently issued for consultation.

Sheringham to Lowestoft Shoreline Management Plan (SMP1 3(b), 1996)
This SMP was prepared by Sir William Halcrow and Partners on behalf of North Norfolk District Council, Great Yarmouth Borough Council, Waveney District Council and the Environment Agency. The plan was prepared in accordance with the guidelines produced for coastal defence authorities by the Ministry of Agriculture, Fisheries and Food (MAFF, now Defra), published in 1995.

The SMP considers the management objectives applicable between Sheringham and Lowestoft as a whole and sub-divides the coastline into *Management Units*. The Management Units identified within the SMP were intended to cover lengths of the shoreline with coherent characteristics in terms of coastal processes and land assets.

Within the SMP, the open coast between Cromer and Walcott was divided into two Management Areas (TRI and BAC) and eight Management Units (TRI 1 – 6 and BAC 1 & 2). Each Management Unit was then assigned a preferred policy option, selected from one of the available options as identified by MAFF (1995).

SMP2 (2004)
A pilot SMP2 has recently been developed for sediment Sub-cell 3(b), in accordance with the current Defra Guidelines (Defra, 2003) and has been issued as a draft for consultation. This is the first revision to the original (1996) plan and has taken account changes in legislation and new information and knowledge gained in the interim. The development of the revision has been led by a group including technical officers and representatives from North Norfolk District Council, Great Yarmouth Borough Council, Waveney District Council, the Environment Agency, English Nature, Defra and Great Yarmouth Port Authority.

Overstrand to Mundesley and Mundesley to Walcott Strategy Studies
These Strategy Plans have been developed within the SMP area. Strategy Plans form one element within the hierarchy of plans that govern the way in which coastal zones are managed. Therefore, the Coastal Defence Strategy recognises these other plans and where appropriate incorporates their policy aims. The principal plans consulted during the development of the Coastal Defence Strategy Plan include the SMPs, Biodiversity Action Plans (BAPs), Local Environment Agency Plans (LEAPs), Local Authority Structure Plans, Coastal Habitat Management Plans (CHaMPs) and Area of Outstanding Natural Beauty (AONB) strategies.

7.1.2 Particular Sustainability Issues

A large number of issues relating to sustainability have been identified in the SMPs and strategy plans for North Norfolk and these are summarised below. More specific issues were also identified for particular sections of the coast, which fall within the more general issues given below. The specific issues are discussed in more detail in Section 7.3 of this report.

- Ensure continued protection of major population centres, tourist areas and associated infrastructure and recreation facilities against erosion and flooding
- Allow natural geomorphological and other physical processes to continue, including continued supply of sediment from eroding cliffs
- Maintain sites of conservation, habitat and heritage importance
- Avoid detrimental impacts on the local economy
- Maintain landscape quality
- Maintain status of tourist beaches
- Protect land suitable for future development
- Attempt to reconcile conflicting needs so that the SMP consists of a set of shared objectives
- Develop a heightened public awareness of the overall behaviour of the coast and the influences they and others have over it.

The majority of these issues relate to the sustainability theme “social and environmental justice”, as identified in the Stage 1 report. However, some of the most important key issues for the development of an appropriate Shoreline Management Plan for this area are the continued supply of sediment from the eroding cliffs and the continuation of the natural geomorphological processes. These are “sustainable management and use of resources” issues. Whilst these issues relate directly to certain of the ‘social’ issues given above (e.g. status of tourist beaches), there is potentially significant conflict with some of the other important issues, in particular the continued protection of population centres and tourist areas against erosion and flooding. As identified above, an overarching objective of the SMPs was to attempt to reconcile these conflicting needs so that the SMP consists of a set of shared objectives.

7.1.3 Objective of Case Study

On the North Norfolk coast, the consequences of decisions relating to all of the issues identified above are far reaching. Therefore, the main objective of this case study is to review the methodology used to assess these conflicting aspects of sustainability, and in particular the involvement of the various stakeholders in the SMP process. The long term sustainability and the potential impact on the wider coastal zone of the proposed solutions are also assessed. The benefits and constraints of any changes made to the SMP process between SMP1 and SMP2 will be taken into account in the case study assessment.

7.1.4 Summary of Available Information

The following data sources were reviewed:

- Sheringham to Lowestoft Shoreline Management Plan; May 1996
- Kelling to Lowestoft Ness Shoreline Management Plan (Draft for Consultation), November 2004
- Overstrand to Mundesley Coastal Defence Strategy Study, HR Wallingford, 2004
- Mundesley to Walcott Coastal Defence Strategy Study, HR Wallingford 2004
- Flood and Coastal Defence Project Appraisal Guidance (FCDPAG 1-6), MAFF 2001
- Shoreline Management Plans – A Guide for Coastal Defence Authorities, Defra 2001
- Interim Procedural Guidance for Shoreline Management Plans, Defra 2003
- The United Kingdom Parliament, House of Commons Debates for 8 March 2005, Shoreline Management (Norfolk).

Consultations were held with the following key members of the SMP2 project group:

- Gary Watson (Project Manager, North Norfolk District Council)
- Terry Oakes (Stakeholder Engagement Consultant, Terry Oakes Associates)

A record of the discussions with these key members is provided in Appendix 4.

7.1.5 The SMP Process

General
The intention of the SMP process is to establish a Coastal Defence Policy that is technically, environmentally, and economically sustainable, at a Cell or Sub-Cell scale. This requires consideration of the wide area coastal process regime, natural environment, and the interactions that exist between areas. However, due to their broad-brush nature, SMPs do not seek to set out definitive coastal defence options; instead, they aim to define smaller scale Management Units and Policy Objectives for those units.

The aim of a SMP, as set out by the original DEFRA guidelines (Defra, 2001), is 'to provide the basis for sustainable coastal defence policies within a sediment cell and to set objectives for the future management of the shoreline'. The guidelines go on to define sustainable schemes as those 'which take account of the inter-relationships with other defences, developments and processes within a catchment or coastal cell or sub-cell, and which avoid as far as possible, tying future generations into inflexible and expensive options for defence'. This definition of sustainability is open to differing interpretation depending on the perceptions of different interest groups. These different perceptions are at the root of many of the conflicts over preferred strategic defence options.

It should be noted, however, that neither SMPs, Strategy Plans or Scheme Appraisals intend to set out strategies for the broader coastal issues addressed by Coastal Zone Management or Local Development Plans. As such, management issues surrounding tourism, recreation, natural habitats or commercial resources feature within these plans and appraisals only in the context of how they relate to coastal defence management.

A Shoreline Management Plan contains the coastal defence strategy to be adopted at that time. However, it is a 'live' working document, intended to be capable of change to allow new information to be incorporated, for example due to new planning requirements, a change in environmental factors or improved understanding of natural processes.

SMP1

The original SMP for sub-cell 3b was undertaken in two phases. The first phase of the SMP development was the collation of existing information and the undertaking of studies to produce an assessment of the present situation, identifying the various needs and conflicts of interest.

Two stages of consultation were undertaken during Phase 1 of the SMP development. An initial consultation document (including a brief outline of the study objectives, the data being collected and the work being performed) was sent to parties with an interest in this length of coastline. This enabled organisations and individuals to comment on issues they wished to see addressed and to provide information. The responses provided were given close consideration in developing policies for the SMP.

The findings in the first phase of the plan preparation were summarised to allow comment by individuals and organisations prior to the development of management strategies for the shoreline. Consultation meetings were also held. The views arising from this stage of consultation fed into the development of the final (Phase 2) SMP document, which was developed from the Phase 1 studies, formalising the division of the shoreline in to appropriate Management units and establishing strategies for each.

The four generic strategic coastal defence options identified by MAFF (now Defra) were considered for each management unit. These strategic options were defined as follows:

- Do-nothing – “carry out no coastal defence activity except for safety measures”
- Hold the existing line – “by intervention, hold the existing defence where it is”
- Advance the existing line – “by intervention to move the existing defence seaward”
- Retreat the existing line – “by intervention to move the existing defence landward”, also referred to as Managed Retreat

On completion of the draft SMP1, this was disseminated more widely to the public for comment. On the basis of this further phase of consultation the draft proposed policy was revised in order for the document to be finalised and adopted.

SMP2
Since the original SMPs were prepared, of which the Plan for Sub-cell 3b was one of the first, a number of lessons have been learnt; the strengths and weaknesses of various plans have been examined and revised guidance has been issued by Defra (2003).

The more fundamental issues that have been addressed by this revised guidance include: the inappropriateness of certain policies, which may be found to be incompatible and impossible to justify when assessed in more detail with a view to implementation and the flexibility of the plans to adapt to changes in legislation, politics and social attitudes.

The preparation of the SMP2 for sub-cell 3b followed this revised guidance. The 28 *Management Units* determined in SMP1 were reassessed and redefined into 24 *Policy Units* in SMP2.

To ensure that all the relevant and potentially conflicting issues were considered and addressed appropriately, the involvement of stakeholders in the appraisal process was extended through the formation of an Extended Steering Group (ESG) and through the involvement of stakeholders throughout the development of the plan. The public was also given the opportunity to comment on the choice and appraisal of options.

The ESG was intended to be a focal point for discussion and consultation, throughout the development of the SMP. Members of the ESG were involved in a series of workshops and also consulted through written correspondence. Additional stakeholders were consulted at the start of the SMP to gather information and views on the issues along the SMP coast. The various stages of stakeholder involvement in the SMP process are summarised in Table 7.1 below, which demonstrates that the stakeholder and public consultation and dissemination process followed for SMP2 was much more extensive and focussed than that for SMP1.

The generic shoreline management policies considered for the SMP2 are those defined by the current Defra Guidelines, as follows:

- Hold the line – maintain or upgrade the level of protection provided by the existing defences
- Advance the line – build new defences seaward of the existing defence line.
- Managed realignment – allow retreat of the shoreline with monitoring and, if appropriate, management to limit or control movement
- No active intervention – a decision not to invest in providing or maintaining defences.

These policies are broadly similar to those proposed by the original SMP and previous guidelines, however, the wording has been changed to better clarify the management approach taken.

Table 7.1 Stakeholder Involvement Strategy

Stage of SMP	**Stakeholder Involvement**	
	Activity	*Purpose*
Stage 1 – SMP Scope	• Initial stakeholder contact • Initial ESG meeting	• Inform that SMP being prepared, request information, gather views on issues, invitations to join ESG • Involve members at early stage, explain involvement
Stage 2 – Assessments to support policy	• Draft Issues & Objectives Table	• ESG members review features identified, check all relevant issues included, check that correct benefits identified, check objectives set and ranking
Stage 3 – Policy Development	• ESG Workshop 1 • ESG/Members meetings	• Establish: - stakeholders vision for SMP shoreline over each epoch - drivers for directing future policy - specific policy options for testing - areas of agreement and conflict - scope for compromise/acceptance • Present members with policy options, invite to take a role in steering policy decisions
Stage 4 – Public Examination	• Public consultation	• Make general public aware of draft plan, provide opportunities for support and objection and move towards resolving differences
Stage 5 – Finalise SMP	-	-
Stage 6 – Dissemination	-	-

Strategy Studies

All of the policy options assigned to the management units within sediment sub-cell 3b were reviewed as part of the strategy studies for Overstrand to Mundesley and Mundesley to Walcott; a summary of the preferred generic options was tabulated as outlined in the SMP along with a brief commentary.

The option identification, evaluation and selection process is a cyclic, iterative process of exploring the problem, generating viable options and selecting the preferred approach. The first stage of this process was completed for the

strategy areas as part of the Shoreline Management Plan (SMP1). Within the SMP the various Policy options of *Do Nothing, Retreat the Line, Hold the Line* and *Advance the Line* were assessed and *The Preferred Policy* was identified.

Within the Strategy Studies, these Policy choices are reviewed. To evaluate *The Preferred Policy,* the Benefit Cost Ratios for the least cost options that will achieve the preferred policy in each area have been evaluated. Where the SMP requires "Hold the Line", active intervention is required. In the remaining areas active intervention to maintain the existing coastline would provide very little benefit and could possibly have a detrimental effect on adjoining defence lengths due to interrupting coastal processes. Therefore in these areas no active intervention has been considered other than annual monitoring to ensure public safety.

The development of an appropriate strategic approach to coastal management demands an appreciation of the available engineering options and their likely performance. The appraisal of engineering performance therefore aims to:

- Establish a list of possible solutions based on the generic policies of Maintain, Sustain and Improve.
- Present an engineering overview of these options.
- Establish a broad brush, but strategically reliable cost of the options.
- Highlight CDM issues related to construction of the options.
- Review the likely performance of the options in terms of overtopping, breaching and erosion as well as the options overall practical sustainability (i.e. recycling with time may alter the performance of a beach and reduce its ability to perform as required in the future).

Environmental Performance

To ensure due recognition of environmental concerns (both human and natural) within the option selection process, and promote environmental enhancement, each generic option was assessed based on its impact on four key areas:

- Built environment (Property/Commercial)
- Nature conservation and geological designations (Environment)
- Tourism and leisure (Amenity)
- Archaeology and cultural heritage (Heritage)

The overview of human and natural environmental assets, including nature conservation, landscape and archaeological interests, needs to put in context the environmental objectives of interested parties and to judge the environmental acceptability of the management options. The purpose is therefore, to provide an overview of the likely impacts of the various coastal defence options on the different aspects of the natural, human and built environment. Based on this assessment of impacts the performance of each generic option has then been determined as either beneficial, likely to be acceptable, no impact, likely to be unacceptable and unacceptable.

Economic Performance
The appraisal of economic performance is a key stage in the development of the preferred strategic approach. The aims and objectives of the strategic economic appraisal may be summarised as follows:

- To ensure best use of public money
  Demands for public funding always exceed the money available. It is therefore necessary to aim for economic efficiency in the investments that are made, by maximising benefit relative to the resource used to achieve that benefit. Using DEFRA guidance (FCDPAG3), the economic worthiness of any particular intervention is established, by assessing the flood or erosion damage that may be expected once the scheme is implemented and comparing this to the damage that maybe accepted assuming the adoption of a *do nothing* approach. The damage avoided by the scheme is the 'scheme benefit', which is then compared with the cost of implementation enabling the evaluation of the 'Benefit Cost Ratio' (BCR).
- To ensure economic sustainability
  The decision making process must be mindful of the needs of future generations and should not commit them to unnecessarily expensive solutions or tie in excessive maintenance requirements.
- To demonstrate accountability
  A formal process of project appraisal (engineering, environmental and economic) can demonstrate that a wide range of different alternatives has been considered. Economic appraisal is the most auditable of these appraisals and provides the most effective audit trail of the decision making process.

- Appraisal period and accounting for inflation
  Options are assessed over a time span of 100 years (based on current Defra and Treasury guidance), with option costs discounted to a common date using discount rates set by the Treasury. The discount rate represents the assumed difference between inflation and the likely returns from an investment on the open market and therefore inflation is implicitly included within the discounting process. Once scheme benefits and costs have been discounted to the common base date they are then referred to as Present Values (PVs).

Consultation
The MAFF Interim Guidance for the Strategic Planning and Appraisal of Flood and Coastal Defence Schemes (MAFF 1997) recognises the essential nature of consultation in strategy development. In accordance with this guidance, the two key principles underlying the consultation exercise for the Overstrand to Mundesley Coastal Defence Strategy Study were openness and access. Thus, the project was undertaken in a transparent manner, with all relevant information available to interested parties. Furthermore, throughout the duration of the project, efforts were made to ensure that interested parties were able to contact members of the client or project team as necessary.

The two main objectives in undertaking the consultation exercise were:

1. To ensure that all people or organisations with an interest in the long-term development strategy for the study area have the opportunity to express their views and aspirations for consideration during the development process.
2. To collect relevant and up to date information relating to processes and practices within the study area.

However, the approach also recognised the context within which the study was undertaken, in particular the extensive consultation carried out during the preparation of the Shoreline Management Plan (Halcrow 1996) and that associated with the various coastal defence and other types of planning and development initiatives.

There are very many diverse human and natural environment interests within the study area and the consultation process aimed to consult and involve representatives of as many interest groups as possible. Those parties with potential interests were identified through a range of investigations including the following:

- National, regional, and local organisations such as the Environment Agency, English Nature, and North Norfolk District Council.
- Organisations identified during the preparation of the SMP.
- Other organisations known to members of the consultant's team.

In addition to statutory consultees, those representing the following types of organisations were invited to participate in the consultation process:

- Adjacent local authorities
- Town, parish and district councils
- Councillors and elected representatives
- Conservation organisations
- Landowners
- Commercial interests
- Fisheries and angling
- Recreation, leisure and tourism.

The Norfolk Coast Partnership (NCP) was set up in December 1991 to address the visitor pressures experienced at that time within the area. The Partnership has since evolved to have the following objective:

> 'To seek to ensure that the use of the area is sustainable that the use of it does not destroy its natural beauty and that future generations have the same opportunity to enjoy and benefit from it.'

Within this overall objective, other objectives of the NCP are:

- to conserve and enhance the natural beauty of the Norfolk Coast
- to facilitate and enhance the publics enjoyment, understanding and appreciation of the area, and
- to promote sustainable forms of social and economic development that in themselves conserve and enhance the areas natural beauty.

Based at Wells-next-the-Sea, the Partnership is funded by the Countryside Agency, Norfolk County Council (NCC), North Norfolk District Council (NNDC),

and Kings Lynn and West Norfolk Borough Council (KLWNBC). The full Partnership meets up to three times per year and comprises representatives from the following organisations:

- Countryside Agency
- Norfolk County Council
- North Norfolk District Council
- Kings Lynn & West Norfolk Borough Council
- Norfolk Wildlife Trust
- National Trust
- Royal Society for the Protection of Birds
- English Nature
- Environment Agency
- Country Landowners Association
- National Farmers Union
- East of England Tourist Board
- Ministry of Agriculture, Fisheries & Food
- Local representative for Sports & Recreation
- East of England Development Agency
- Five elected representatives from the 69 parish councils within the AONB
- An officer from Great Yarmouth Borough Council
- Any other funding partner or group considered appropriate

Alliances such as this aim to establish integrated regional coastal defence strategies within a strategic framework that accommodates the varying spatial and temporal scales within which a coastline develops and coastal defence options perform. To facilitate this process, DEFRA provided guidance (FCDPAG, 2001) that outlines the approach to developing such a strategy that is consistent with their stated Policy objective of reducing risks to people and the developed and natural environment from flooding and coastal erosion.

7.2 Case study assessment

7.2.1 Objectives of Scheme

Shoreline Management Plans (General)
The main objectives of Shoreline Management Plans, as defined by the original MAFF guidelines (1995), were to:

- Assess a range of strategic coastal defence options and agree a preferred approach
- Outline future requirements for monitoring, management of data and research related to the shoreline
- Inform the statutory planning process and related coastal zone planning
- Identify opportunities for maintaining and enhancing the natural coastal environment, taking account of any specific targets set by legislation or by locally set targets
- Set out arrangements for continued consultation with interested parties.

The revised objectives, set out in the Defra guidance (2001), are as follows:

- To define, in general terms, the risks to people and the developed, historic and natural environment within the SMP area

- To identify the preferred policies for managing these risks over the next 50 years
- To identify the consequences of implementing the preferred policies
- To set out procedures for monitoring the effectiveness of the SMP policies
- To ensure that future land use and development of the shoreline takes due account of the risks and the preferred SMP policies
- To comply with international and national nature conservation legislation and biodiversity obligations.

More recent procedural guidance (Defra, 2003) did not change the general principles behind these objectives, but clarified that the appraisal of SMP policies should consider a 100 year timeframe, in line with changes to Treasury guidance.

North Norfolk SMPs
The more specific objectives set for the North Norfolk SMPs are set out for comparison in Table 7.2 below:

Table 7.2 Sheringham to Lowestoft SMP Objectives

SMP1, 1996	***SMP2, 2004***
Coastal Processes	
• Develop a heightened public awareness of the overall behaviour of the coast and the influences they and others have over it • Maintain supply of sediment to beaches from cliff erosion • Allow natural geomorphological processes to continue	• Maintain supply of sediment to beaches from cliff erosion • Allow natural geomorphological processes to continue • Reduce pressure on shingle ridges, allowing them to roll back
Natural Environment	
• Maintain conservation sites designated for geological exposures • Maintain sites of environmental importance (e.g. dune systems, cliff face habitats) • Prevent loss of heritage/ archaeological sites • Maintain status of tourist beaches • Maintain landscape quality	• Maintain designated conservation sites (e.g. geological exposures) • Maintain sites of environmental importance (e.g. dune systems, cliff face habitat sites) • Prevent loss of heritage/ archaeological sites • Maintain status of tourist beaches • Maintain landscape quality
Human and Built Environment	
• Ensure continued protection of population centres against erosion and flooding • Maintain tourism and recreational facilities • Stabilise those sections of coastline historically prone to major failures • Ensure continued provision of port facilities at Great Yarmouth • Avoid detrimental impacts on the local economy • Preserve Bacton natural gas terminal • Maintain the Norfolk Coastal Path • Prevent loss of Grade 2/3 agricultural land	• Ensure continued protection of population centres against erosion and flooding • Maintain tourism and recreational facilities • Ensure continued provision of port facilities at Great Yarmouth • Prevent loss of historical pier • Maintain Lifeboat Stations • Prevent loss of historical seawall • Prevent loss of Grade 2/3 agricultural land • Prevent loss of public open space and recreation facilities • Avoid detrimental impacts on the local economy • Preserve Bacton natural gas terminal

Planning	
	• Prevent loss of land potentially suitable for future development
General	
• Attempt to reconcile conflicting needs so that the SMP consists of a set of shared objectives	

Four over-arching objectives were also set as part of the SMP2:

Framework Objective	Shoreline management policies should comply with the current flood and coastal defence management framework where public funding would be required for their implementation.
Technical Objective	Shoreline management policies should seek to have no adverse effect on any physical processes that benefits rely upon.
Environmental Objective	Shoreline management policies should take due consideration of biodiversity targets and the need to maintain, restore or where possible enhance the total stock of natural and historical assets.
Socio-Economic Objective	Shoreline management policies should consider current regional development agency objectives and statutory planning policies.

Overstrand to Mundesley and Mundesley to Walcott Strategy Studies
The principal aims and objectives of these Strategy Studies are detailed below with those related directly to sustainability shown in bold type.

- To prepare a Coastal Defence Strategy Plan for the frontage from Overstrand to Mundesley and Mundesley to Walcott.
- To develop a scheme strategy plan in accordance with DEFRA guidelines, reconciling with the coastal policies established through the SMP and taking due account of all existing information.
- To ensure effective consultation and reflect the views expressed through sensitive development of options.
- **To develop a phased programme of sustainable works and maintenance for the shoreline.**
- To develop an appropriate understanding of the likely extent of erosion in the future.
- To develop an appropriate understanding of the environmental sensitivities.
- **To enhance the environment where possible and to propose effective mitigation measures against environmental degradation where necessary.**
- **To prepare a list of real alternative designs for the future management of the coastal defences within the study area; ranging from 'do nothing' through 'do minimum' to management approaches and more capital intensive scheme options.**
- To develop a robust and defensible estimate of the likely benefits that includes an appropriate understanding of the interaction between linked benefit areas.
- To develop an appropriate costing of the management option(s) proposed for the study frontage.

- **To identify an optimal approach to coastal management based on a synthesis of economic constraints, engineering and environmental issues.**
- To provide robustly argued economic justification for all management options proposed.
- To establish a programme of monitoring and a method of review for the adopted strategy.

Within the Overstrand to Mundesley and Mundesley to Walcott Strategy Plans, the following general principles have been applied to assist in the interpretation of sustainability:

- The Strategy Plan is assumed to apply over a period of 50 years, although uncertainty over future coastal processes may result in revision of policies within a shorter period.
- The Strategy Plan is based on present day economic, social, and political values. However, it recognises that these values may evolve as they have in recent decades with respect to issues such as the natural environment, farmland, public access, and shorefront residential property.
- Existing residential areas will be retained.
- It is assumed that existing planning policies, restricting development in Coastal Zones, will be retained and that there will be no further development in areas identified as at risk.
- Existing commercial and private holiday property within areas at risk will not necessarily be retained
- Agricultural or recreational land will not necessarily be retained.
- If a preferred strategic defence option cannot be agreed at present, then any works required retaining the existing situation should be flexible.

7.2.2 Assessment of Sustainability

General Assessment of Sustainability

Shoreline Management Plans

The main aim of the SMP process is to determine a sustainable strategic level approach to coastal defence. The SMP objectives have a bias towards sustainability and as such the resulting end product should deliver sustainable policy if the objectives are met.

The preferred coastal defence policy for each Management Unit is summarised in Table 3.2 below, for both the SMP1 and SMP2. For SMP2, the preferred policy varies during the epochs for certain policy units (where it is difficult to define the expected timing of a change in policy). In these cases, the general policy is stated. For a number of policy units the unit boundary has changed so that units are split or combined. Where there are only slight variations in the cell boundary location these are not shown for ease of comparison of policy. Where the policy has changed between SMP1 and SMP2, this has been highlighted in the table.

It should be noted that the SMP2 is currently only published in draft for consultation and revisions to the proposed policies might be expected in the

final version. The SMP1 policies stated are those given in the final SMP document. Changes were made to the proposed SMP1 policy between the draft and final versions.

This table shows that for SMP1, Hold the Line was the preferred policy for all parts of the coast with residential or commercial interests. Elsewhere, the policy was to allow retreat through a Do Nothing or Managed retreat approach.

For SMP2, Hold the Line remains the preferred policy in the long term for only the major population centres of Sheringham, Cromer, Great Yarmouth, Gorleston and Lowestoft. For those other locations where Hold the Line was previously the preferred policy, this has been revised to allow retreat in the medium to long term, through no active intervention or with management.

At this stage of the SMP2 development, the proposed policies meet the objectives stated in Section 7.1 of this report. The draft SMP2 proposes to adopt more appropriate options for the coast, which are more sustainable in the long term when compared against the SMP1 policies.

Table 7.3 Preferred Coastal Defence Policy

SMP1 (1996)		SMP2 (2004)			
Management Unit	Preferred Policy	Policy Unit	Preferred Policy		
			Present Day – c.2025	Medium Term (c.2025-2050)	Long Term (c.2055 – 2105)
-	-	3b01:Kelling Hard - Sheringham	No Active Intervention		
RUN 1: Sheringham L.S. to Beeston	Hold the Line	3b02: Sheringham	Hold the Line		
RUN 2: Beeston to Cromer	Managed Retreat	3b03: Sheringham to Cromer	No Active Intervention		
RUN 3: Cromer	Hold the Line	3b04: Cromer	Hold the Line		
TRI 1: Cromer to Overstrand	Do Nothing	3b05: Cromer to Overstrand	No Active Intervention		
TRI 2: Overstrand	Hold the Line	3b06: Overstrand	Hold the Line	Managed Realignment	
TRI 3: Overstrand to Trimingham North	Do Nothing	3b07:Overstrand to Mundesley	No Active Intervention		
TRI 4: Trimingham	Hold the Line				
TRI 5: Trimingham to Mundesley	Managed Retreat				
TRI 6: Mundesley	Hold the Line	3b08: Mundesley	Hold the Line		Managed Realignment
BAC 1: Mundesley to Bacton G.T.	Do Nothing	3b09: Mundesley to Bacton G.T.	No Active Intervention		
BAC 2: Bacton G.T. to Walcott & Ostend	Hold the Line	3b10: Bacton Gas Terminal	Hold the Line		Managed Realignment
		3b11: Bacton, Walcott & Ostend	Hold the Line	Managed Realignment	
SEA 1: Ostend to Happisburgh	Managed Retreat	3b12: Ostend to Eccles	No Active Intervention		
SEA 2: Happisburgh to Eccles	Hold the Line				
SEA 3: Eccles to Winterton Ness	Hold the Line	3b13: Eccles to Winterton Beach Rd	Hold the Line		Managed Realignment
WIN 1: Winterton Ness to Beach Road	Hold the Line				
WIN 2: Beach Road to Hemsby	Do Nothing	3b14: Winterton to Scratby	No Active Intervention		
CAI 1: Hemsby	Hold the Line				
CAI 2: Newport Cottages to Caister	Hold the Line	3b15: California to Caister	Hold the Line	Managed Realignment	
		3b16: Caister-on-Sea	Hold the Line		Managed Realignment
CAI 3: Caister to Great Yarmouth	Do Nothing	3b17 Great Yarmouth:	Hold the Line		
GYA 1: Salisbury Rd to Pleasure Beach	Do Nothing				
GYA 2: Pleasure Beach to Gorleston	Hold the Line				
COR 1: Gorleston	Hold the Line	3b18: Gorleston	Hold the Line		
COR 2: Gorleston to Hopton	Managed Retreat	3b19: Gorleston to Hopton	No Active Intervention		
COR 3: Hopton	Hold the Line	3b20: Hopton	Hold the Line	No Active Intervention	
COR 4: Hopton to Corton	Managed Retreat	3b21: Hopton to Corton	No Active Intervention		
COR 5: Corton Caravan Site to Woods	Hold the Line	3b22: Corton	Hold the Line	Managed Realignment	
COR 6: Corton Woods to Lowestoft	Do Nothing	3b23: Corton to Lowestoft	No Active Intervention		
COR 7: Lowestoft North	Hold the Line	3b24: Lowestoft North	Hold the Line		

Strategy Studies
The strategy studies for Overstrand to Mundesley and Mundesley to Walcott have been developed based on the based on the strategic management policies adopted by SMP1. For these policy units, the preferred policy options have changed between SMP1 and SMP2, with the overall long-term policy for this area being one of retreat, through either no active intervention or with management.

The development of policy in SMP2 has taken into account the findings of the more detailed strategy studies, in which the economic justification of particular defence options was considered in some detail. This appraisal determined that the continued defence of this section of coast would not be economically justified once any existing defences have failed.

By feeding the output from the strategy studies back into the higher level SMP it has been possible to develop a more appropriate and sustainable long-term policy for this particular part of the SMP frontage.

Assessment of Approach to Stakeholder Engagement
SMP1
In the first-round SMP, stakeholder involvement enabled identification of key issues as follows:

- erosion and flooding trends
- identification of properties (and other assets) at risk from erosion and flooding
- operations and maintenance issues
- identification of important habitats
- recommendations for potential sites for habitat development
- access issues.

Stakeholders also recommended preferred policies. These proposals were considered in the assessment of strategic level options for the draft SMP1. The draft plan was then put forward for public examination. This stage of the consultation process is understood to have resulted in a significant number of changes to the proposed policy. It is therefore not possible to fully assess the influence of the earlier stakeholder engagement on the sustainability of the final policy adopted in SMP1.

SMP2
It is currently possible, however, to consider how stakeholder involvement has fed into the development of sustainable policies for the draft SMP2. The current status of the public examination stage gives an indication of the likely outcome for the finalised plan.

The stakeholder involvement strategy adopted for SMP2 has enabled greater involvement of stakeholders at all stages of the SMP development than was possible for the first round SMP. The success of this strategy in enabling more sustainable policy to be developed was discussed with North Norfolk District Council's Project Manager (Gary Watson) and with the consultants carrying out

the stakeholder engagement process and objective setting (Terry Oakes Associates, as sub-consultants to Halcrow Group Ltd.).

Both Gary Watson and Terry Oakes highlighted that the success of the process could not yet be fully assessed because the programme of consultation has not yet been competed, with the public examination stage currently underway. The comments made by these members of the SMP2 project team are included in Appendix A and summarised in the sections which follow.

7.2.3 Review of Barriers, Successes and Failures

Table 7.4 Barriers, Successes and Failures

SMP1 (1996)	***SMP2 (2004)***
Barriers	
• Conflicting key issues mean that agreement of preferred policy is very difficult	• Conflicting key issues (particularly socio-economic factors) mean that agreement of preferred policy is very difficult • Public cynicism about consultation; assumption that decisions have already been taken • Initial stakeholder understanding of technical issues was very limited • Uncertainties over predictions of erosion rates and impacts of offshore dredging • High cost of making plans available to those wishing to be consulted • Local Authority doesn't have the tools to implement the proposed policy, particularly in the short term • No land available for alternative development • Lack of compensation to home-owners / land-owners
Successes	
• Stakeholder involvement in the provision of information and the identification of key issues • Stakeholder feedback provided on the draft policy options • SMP document completed and adopted by responsible authorities	• SMP updated to include new information • Significant stakeholder involvement throughout the development of the SMP, through Extended Steering Group • Wide range of stakeholders engaged • Education of the public on the behaviour of the coast and their influences on it, including technical issues and the fact that coastal erosion remains a problem in North Norfolk; public previously considered it to be 'a thing of the past' • Particular socio-economic issues identified that would not otherwise have been covered • Preferred policy determined for 3 epochs; short, medium and long-term, to 2105 • Policy revised from SMP1 to be more sustainable in long term, with 'no active intervention' and 'managed retreat' policies adopted for locations previously designated as 'Hold the Line' • Draft SMP completed without political influences
Failures	
• Preferred policy not necessarily achievable or sustainable in long term, predominantly due to lack of	• Extensive consultation requires the SMP process to be undertaken over a long time frame • Public dissemination using internet unsuccessful due to lack

SMP1 (1996)	*SMP2 (2004)*
economic benefits where the preferred policy is Hold the Line	of access in rural areas • Although there was involvement of a wide range of stakeholders throughout the SMP development process, further issues have been identified during the wider dissemination of the draft report to the general public. Therefore, this wider public involvement was possibly undertaken too late in the process. • Potential for stakeholders to be over-consulted • Agreement on final policy may not be achieved and therefore SMP2 would not be adopted

7.2.4 Assessment of Benefits of Techniques / Tools

The changes in SMP process have had the following benefits for achieving sustainable coastal management policy in North Norfolk:

- Coastal management policy is now determined for a 100 year period
- Greater consideration of economic factors is possible, in particular the affordability of the proposed options
- Definitions of strategic policy options have been clarified, leading to improved understanding of what is intended by the preferred policies.

The increased involvement of stakeholders in the SMP development process, through the stakeholder engagement strategy, has had the following benefits for SMP2:

- Involved a wide variety of people in the development of the SMP
- Improved stakeholders' understanding of coastal management issues and appreciation of the need for sustainable coastal management policy
- Improved identification of socio-economic issues

7.2.5 Review of Opportunities & Limitations, Lessons Learnt, Wider Applicability

Opportunities

Education of the public

The stakeholder engagement strategy enabled key stakeholders to be better informed of the particular coastal management issues that were being considered as part of the SMP. Stakeholders were then able to provide more appropriate input, considering the effect that their particular concerns and issues might have on the overall management of the coast.

Affordability of proposed options

A key issue relating to coastal defence is the affordability of the 'Hold the Line' strategic level option. This option may have been assessed to be the most appropriate strategic approach in technical, environmental and economic terms and sustainable in the long term but may not actually be affordable in the short to medium term. This was one of the significant limitations of the original SMPs.

The issue of affordability was previously only considered at a strategic level. Available finance for flood and coastal defence is understandably limited and therefore some degree of prioritisation is necessary. If affordability is only considered by strategic studies, the outcome of such assessments may affect the implementation of higher level policy. This was in fact the case for the strategies for Overstrand to Mundesley and Mundesley to Walcott. With current Defra guidelines recommending that affordability be considered at SMP (policy) level, the potential effects of shorter-term policies on the long term sustainability of a management approach can be determined.

Therefore, the pilot SMP2s aim to consider this issue, aided by the definition of policy for the separate short, medium and long-term 'epochs'. This is one of the main reasons why the preferred policy for parts of sub-cell 3b has changed between SMP1 and SMP2, and why there is a variation in policy with time. The output from the two strategy studies fed into the SMP development and allowed affordability to be taken into account to some extent in the development of the revised policy.

Assessment of options for 3 epochs over 100-year timeframe
Defra and Treasury guidance has meant that the SMP2 considered the risks from coastal evolution over the next 100years. The assessment of preferred policy over the 3 epochs represents a significant improvement on the previous SMP in terms of sustainability, in that the long term requirements for coastal management are known, with the short term aims assessed so as not to be detrimental to the longer term policy. This presents an opportunity to define different options for each epoch where this may be necessary to achieve sustainability.

Limitations
Ease of implementation of proposed policies
The SMP2 process for North Norfolk has identified that the local authority is unlikely to be able to implement the proposed policy, particularly in the short-term. This is principally due to financial constraints; although affordability has been considered, there were a number of issues that the SMP was not able to address. For example, without financial provisions for re-location, or suitable areas for alternative development, those people whose properties are at risk will be unwilling to move. If the proposed short-term policies are not adopted it may not be possible to implement sustainable policies in the long-term.

Conflicting issues
The first-round SMP for North Norfolk identified a significant number of conflicting issues relating to the risks of coastal evolution. The extent of stakeholder involvement was increased for SMP2 to try to resolve these issues at an earlier stage. Although this process has enabled a more informed development of appropriate, sustainable policies, the conflicting socio-economic issues remain.

The recommendations of the draft SMP2 are seen to be very different to those of the previous plan, and people whose properties were previously within an area with a policy 'Hold the Line' have found that continued defence will no

longer be guaranteed. This is seen to be affecting property values, often many years in advance of when the policy will become effective, and indeed the policy may change in the intervening years. In addition, there is very limited availability of land for new development in this area and compensation will not currently be offered to those in affected areas.

Long-term options for sustainable coastal management have therefore been demonstrated as having economic implications in the short term. These (often intangible) economic implications have not as yet been considered by the SMP. Therefore, it has not yet been possible to fully resolve all these conflicts and consequently it is possible that the SMP2 will not be adopted or implemented.

Unknown factors
There are a number of unknowns still remaining at this stage in the SMP development, for example; the actual rate of cliff erosion that will occur in the future, or the effects of offshore dredging. Such unknowns are inherent in coastal management and it is for this reason that the SMP is intended to be a document that evolves with time. However, the public have not yet fully appreciated this, as may be seen by the effect on property values, as discussed above.

Lessons Learnt
Political involvement
The senior politicians for the local area and those representing relevant government departments have not been involved in the development process for this SMP2 until the current public dissemination phase, to ensure that the draft proposed policies were not politically corrupted. However, the local authority members who formed part of the ESG do not have the power to ensure that the proposed policies are implemented. As political issues will influence the finalised plan, it may in fact be better to know what their impact will be at an early stage, through the involvement of the relevant senior politicians. This would enable education of the decision makers about the particular local issues and would enable consideration of the wider government issues that could affect decisions taken and future implementation of policy.

Wider Applicability
Dissemination of the draft SMP to the general public is necessarily undertaken at a relatively late stage in the overall programme. However, the further issues that have arisen at this stage mean that there may now have to be considerable revisions made to the draft document to attempt to arrive at an approach that could be adopted.

It may therefore be considered that the general public should be able to have individual input into the SMP at an earlier stage in its development, rather than through representative stakeholders. However, management of the SMP process in its current form is already an enormous task with a very high cost. More extensive consultation with the general public would compound these factors.

For SMPs that are to be developed for other parts of the coast of England and Wales, the extent of stakeholder involvement should be considered carefully. As well as the issues discussed above, key stakeholders are consulted on a variety of issues to do with the coast and surrounding area and there is consequently the potential for 'over-consultation' (although the SMP is a key policy document and as such has some priority).

The consultation process is likely to result in an extended timeframe for the completion of a policy document and significantly increase study costs. The consultation process should increase stakeholder involvement and improve the public's awareness of the various conflicting issues along the coast and how their own particular issue relates to those of others. However, there is no guarantee that this process will aid the resolution of issues or the eventual agreement of policy.

7.3 Summary of Findings

At this stage, the SMP2 has not yet been fully disseminated and adopted. It is therefore likely that further barriers, successes and failures of the SMP process will be identified in the ongoing stages. Even though there has been significant stakeholder involvement in the process to this point, it remains likely that particular individuals and organisations will feel that their views have not been sufficiently taken into account in the development of preferred policy. However, the stakeholder involvement strategy adopted for the SMP2 has been much more successful at "developing a heightened public awareness of the overall behaviour of the coast and the influences they and others have over it" than was the case for SMP1. This process of informing and educating the public makes it more likely that the final adopted policy will "reconcile conflicting needs so that the SMP consists of a set of shared objectives".

8 Case Study No 6: Sustainable Use and Materials – Brighton Marine to Ovingdean Coast*

8.1 Introduction

This case study is one of the seven carried out as part of the Defra funded R&D project Sustainability of Flood and Coastal Erosion Risk Management. It involved the assessment of the sustainability of the Brighton to Ovingdean Coast Protection Scheme and the strategy within which it was carried out. Background information about a tool to measure the environmental impact of a construction scheme - the 'eco-point estimator' – was also sourced and reviewed. Consultations were held with the Project Manager and other key staff of the Brighton and Ovingdean Scheme development.

The study reviewed the way in which materials from the existing defences were designed into the new works, the value and sustainability of this approach, the issues and challenges faced by the scheme and the lessons learnt from its delivery. The eco-point estimator was used as a tool to assess the environmental impact in terms of materials use in the construction process.

8.1.1 Background Information on Brighton to Ovingdean Coastal Defence Scheme

This is a length of coast within the South Downs Shoreline Management Plan (SMP) area on the south coast of England. The frontage forms part of Management Unit 12, identified in the 1997 SMP for coastal sub-cell 4d, Selsey Bill to Beachy Head, undertaken by Gifford Associated Consultants on behalf of the South Downs Coastal Group.

The coastline between Brighton Marina and Saltdean is dominated by chalk cliffs and is fully exposed to prevailing south-westerly wind and waves from the Atlantic Ocean. As these cliffs would form a naturally eroding chalk-cliff coastline, coastal defence schemes have been implemented over the last century to prevent erosion.

The first concrete groynes were built at Black Rock Brighton (location of present-day marina) in 1906, to help reduce the rate of cliff erosion and to protect a sewer that runs from Brighton to an outfall at Portabello, 5 km to the east. Erosion continued and, in the 1930s a large coastal defence scheme was constructed comprising a sea-wall, a promenade and groynes to help retain the shingle beach and to protect the seawall.

The existing seawall, promenade and rear splashwall are now some 70 years old and are coming to the end of the low maintenance period of their life. An earlier policy of constructing concrete groynes to retain the shingle beach had only been partially successful, with the shingle exacerbating abrasion damage

* Protection scheme and Eco-point Estimator T001

to the concrete wall and exposed chalk foreshore. The continued erosion of the chalk wave-cut platform in front of the sea wall led to undermining, loss of fill and subsequent collapse of the promenade. Repairs after winter storm damage were becoming increasingly frequent and more extensive.

Since minor failures to this coastal defence scheme were being experienced at an increasing rate, a strategy was developed to address the issues facing this frontage. The coastal management strategy identified a 'hold the line' policy for the full length of the defended coast between Brighton Marina and Saltdean. This was in line with the findings of the SMP. The needs for these works include the protection of the sewer located directly behind the existing seawall and a busy coastal trunk road running parallel and close to the cliff edge. Environmentally important land is also protected. A consultation period was held for comment on the draft strategy, with no adverse comments received.

In 1996, prior to the implementation of the third and final construction phase, MAFF (now Defra) required a periodic review of the strategy, which was about ten years after its initial acceptance. This requirement was in line with what is now considered to be good practice. The revised strategy and five-year implementation plan was published in 2001. The objective for this frontage was to formulate options to reduce the risk from coastal erosion to people and the developed and natural environment. Furthermore, it was concluded that among other requirements any solution must be based on sustainable development principles. For the Brighton Marina to Ovingdean frontage there was an opportunity to implement this.

The coastal defence strategy proposed works in three phases; Phase 1 – the coastline from Ovingdean to Rottingdean (where construction works were completed in 1996); Phase 2 – the coastline connecting Rottingdean to the City Council's boundary with Lewes District Council (where works were completed in 1999) and Phase 3 (works nearing completion). Work on the 300 m section controlled by Lewes District Council (within Phase 3) at Saltdean was carried out in 1993.

The third phase of the coastal strategy is now nearing completion, with the replacement of the original 1930's protection to the chalk cliffs between Brighton Marina and Ovingdean. A scheme is being undertaken to renovate the defence system, involving the encasement of the front face of the seawall, the removal and replacement of the bullnose, the raising of the promenade and the replacement of the rear splashwall.

Plate 8.1 Brighton to Ovingdean coastal frontage during construction

8.1.2 Background Information on Eco-points Tool

Introduction
The calculation of Eco-points is a method for comparing the environmental impacts of scheme design options in coastal and fluvial engineering. The method, developed by the BRE (Building Research Establishment) and presented in Masters (2001), provides a good indication of the relative environmental impacts of different structural options and enables the user to make informed decisions about construction materials and scheme design.

Eco-points are calculated for the effects on the environment of the extraction, processing and transport components of the life cycle of each material.

Eco-points were developed by the BRE using a methodology for Life Cycle Assessment of building materials and the formulation Environmental Profiles. The full Life Cycle Assessment methodology as developed by the BRE is described in detail by Howard *et al* (1999). From the work on Environmental Profiles a weighting system was developed, enabling the creation of Eco-points.

The BRE Methodology for Environmental Profiles
The Environmental Profiles methodology and database are the result of an extensive study in collaboration with representatives of the construction materials sector through a DETR Partners in Technology project. The development of common rules and guidelines for applying LCA to UK construction products enables materials producers in the UK to produce LCA data in the form of Environmental Profiles.

Figure 8.1 The Eco-points Estimator

Environmental Profiles may be calculated for materials, components and building elements. The building element profiles can be presented “as built” or over a nominal life. Materials are presented as “cradle to factory gate” profiles on a per tonne basis.

Profiles that have been created over the life of the project are held in the UK database of Environmental profiles of construction materials and components and are available on www.bre.co.uk. Materials producers can add new Environmental profiles for additional products and the database is to be regularly updated.

Weightings of Sustainability Issues

The BRE has carried out detailed research on the relative weightings of sustainability issues arising from buildings and construction. This research has addressed economic, environmental and social aspects of sustainability relevant to construction.

In order to establish the range of key issues for sustainable construction to be considered in the weighting, issues were identified and placed in three broad themes: economic, environmental and social. Each theme had two or three sub-themes, see Table 8.1 below:

Table 8.1 Sustainable Construction Themes, Sub-Themes and Issues

Theme	1. Environmental	2. Economic	3. Social
Sub-theme	1.1 Global 1.2 Local and site 1.3 Internal	2.1 Construction 2.2 Materials 2.3 Infrastructure	3.1 Equity 3.2 Community
Under each sub-theme an extensive range of issues was identified, including:	Climate change Resources Internal environment External environment Wildlife	Profitability Employment Productivity Transport and utilities Stock value	Poverty Minorities Inner cities Transport Communications

The themes, sub-themes and issues were presented to expert panels, with professionals from across the industry, for discussion and weighting. A good consensus was found in the overall significance of the main sustainability themes arising from the aggregate weighting for environmental issues 40%, for economic issues just over 30% and for social issues just over 20%. Accordingly, the average results are considered meaningful for comparisons of the environmental, social and economic themes of sustainability, and for evaluation of the issues within each of these themes. The weighing of the environmental issues is the basis for Eco-points.

Eco-points

An Eco-point is a single score that measures total environmental impact. In the present version it is calculated relative to absolute data on the state of the environment in the UK in 1999. Eco-points are calculated from life cycle assessment inventory data through four distinct steps:

1. classification
2. characterisation
3. normalisation
4. weighting.

The BRE's Environmental Profiles LCA methodology produces an inventory of all the inputs and outputs (the environmental burdens) from the product system according to agreed boundaries.

Classification assigns these burdens to the environmental impact categories where they cause an impact. For example, CO_2 is assigned to "Global warming" and SO_2 is assigned to both "Acidification" and "Toxicity".

Characterisation aggregates the environmental impact of each environmental burden in each category. It is necessary to combine components contributing to each issue using a single measurement unit, taking into account of their relative potencies. For example, the global warming implications of different gases are converted to kg of CO_2 per 100 yr equivalent, taking into account their global warming potential and the time they remain in the atmosphere. By being of the same unit, these burdens can then be summed to calculate the total impact in each category.

Units of impact are chosen as a way of measuring the effects of environmental issues on sustainability. For environmental impacts, there is a good consensus on the units that are suitable. The units used are shown in Table 8.2 below.

Normalisation compares characterised impacts to a defined norm, for example UK Eco-points compare to the impacts of one UK citizen – hence the relationship to the UK. National statistics (1999) have been used to derive the data needed as a basis for normalisation. The impact per person is given in Table 8.2.

Weighting is added to the normalisation in order to achieve Eco-points. This step multiplies the normalised score in each environmental impact category by the weighting assigned to that category as follows:

$$\text{Ecopoint} = \frac{\text{Impact in approriate units}}{\text{1 UK citizen in the same units}} \times \text{weight}(\%)$$

The weight is the product of the BREs sustainability weighting research and is given in Table 8.2.

UK Eco-points are derived, by adding together the points that are calculated for each environmental issue. The normalisation process is aligned so that the total number of Eco-points for all the impacts arising from a UK citizen in a year amounts to 100. Higher Eco-points represent greater environmental impact.

Table 8.2 Basic UK Eco-point scores and units

Issues	UK impacts per person	Unit	Weight: %	Basic Eco-point scores for 1 unit
Global issues				
Climate change	11.4	t CO_2 eq.(100 yr)	19%	1.69
Acid deposition	40.4	kg SO_2 eq.	3%	0.0647
Ozone depletion	30	g CFC11 eq	4%	0.133
Toxic air pollution:				
human toxicity	117	kg tox	2%	0.014
ecotoxicity	1.84	kg tox	2%	0.891
Fossil fuel depletion	3.35	Toe	5%	1.36
Marine water pollution:				
ecotoxicity	0.40	kg tox	1%	2.22
eutrophication	4.36	kg PO_4 eq.	1%	0.204
Habitats and ecosystems:				
land	no data available	ha species	5%	no data available
river	no data available	ha species		
Local and site issues				
Air pollution:				
human toxicity	1.18	kg tox	2%	0.475
ecotoxicity	0.03	kg tox	2%	52.2

Issues	UK impacts per person	Unit	Weight: %	Basic Eco-point scores for 1 unit
asthma	19.8	kg ethene eq.	2%	0.0991
River water pollution:				
human toxicity	0.03	kg tox	1%	49.8
ecotoxicity	0.34	kg tox	1%	3.87
eutrophication	2.40	kg tox	1%	0.549
Contaminated land	1.62	ha	3%	1.66
Noise pollution	204	person days > 55 dB eq (24 h)	3%	5.01
Dust pollution:				
black smoke	23.1	kg tox	1%	0.0226
Mineral extraction	5.74	t	2%	0.309
Fossil fuel depletion	3.35	Toe	2%	0.469
Water extraction	349	Litre	3%	7.95
Waste disposal	7.06	t	3%	0.446
Waste recycling	7.06	Mt	4%	0.573
Transport pollution and congestion:				
people	12.0	000s person km	4%	1.03
freight	3.89	000s t km	4%	0.335
Habitats and ecosystems	5.06	ha species	8%	1.65
Forestry	Included in above	ha species	1%	N/A
Farming			1%	N/A
Internal environment				
Comfort	no data available	N/A	6%	N/A
Heath		N/A	3%	N/A

8.1.3 Particular Sustainability Issues

Particular sustainability issues on this project are identified in Table 8.3. These have been considered and grouped in the table below according to the main sustainability themes identified in the Stage 1 report.

Table 8.3 Sustainability Issues

Climate Change and Energy
• Consideration of climate change and associated sea-level rise • Erosion of beach and wave-cut platform • Limit energy requirements (e.g. transport)
Sustainable Management and Use of Resources
• Technically viable strategy over 50 years • Economically viable strategy over 50 years • Limit disposal requirements • Limit demand for primary aggregates • Reduce impacts of materials deliveries • Maximise life of scheme • Limit maintenance requirements

Social and Environmental Justice
• Compatible with natural processes through use of rock armour toe protection • Maintain existing beaches • Protection of SSSI (geological exposures - chalk cliffs) • Protection of Sites of Nature Conservation Interest • Protection of Area of Important Landscape and Environmental Value • Compatible with SMP and Local Plans • Limit land-take of exposed chalk wave-cut platform • Prevent damage to chalk during construction works
Helping Communities Help Themselves
• Joint establishment of strategic aims and objectives through consultation with stakeholders • Economically viable strategy over 50 years • Continue to defend important infrastructure assets

8.1.4 Objective of Case Study

The objective of this case study is to assess the effect of re-use of construction waste and reduction of the need for primary aggregates on sustainability and review its use within the Brighton to Ovingdean Coast Protection Scheme. The use and effectiveness of the eco-point estimator (a tool for assessing the relative environmental qualities based on the whole life management of materials) will also be tested on the scheme.

The overall aim of the South Downs SMP (1996) was to provide the basis for sustainable coastal defence policies within sediment sub-cell 4d and to set objectives for the future management of the shoreline. Sustainable coastal defence policies need to take account of the inter-relationships between defences, development and coastal processes within the sub-cell, and should as far as possible avoid tying future generations into inflexible and expensive options for coastal defence. The primary management objectives identified by the SMP, are given in Table 8.4 below, with those relating to sustainability shown in bold. Secondary objectives were also identified but have not been included here:

Table 8.4 Strategy Sustainability Objectives

Shoreline Management
1.1 To adopt an agreed Strategic Defence Option for each Management Unit
1.2 To implement the options based on sound economic and technical principles
Shoreline Evolution and Development
2.6 To plan and assess schemes and management activities within a regional model
Existing Coastal Defences
3.1 To achieve and maintain standards of coastal defence in accordance with MAFF (now Defra) strategy and with the agreed Strategic Defence Option
3.2 To monitor the condition and performance of existing coastal defences, both man-made and natural and to monitor their interaction with coastal processes
3.3 To carry out strategic forward planning of maintenance, upgrading and replacement
3.4 To include 'flexibility' in the design of coastal defence schemes, so as to enable them to be adapted to changes in process or strategy, or to be removed
Material Resources
4.1 To identify the quantities and qualities of recharge materials that are available both locally and elsewhere
4.2 To inform regional and local policies with a view to securing material resources for the future
4.3 To review regional coastal defence strategy periodically with regard to the future availability of material resources
Climate Change and Sea Level Rise
5.1 To plan for the probable effects of climatic change on coastal defence, within the context of coastal zone planning
Planning and Policies
6.1 To contribute to and comply with the statutory planning process and related Coastal Zone Planning
6.2 To provide inputs to future reviews of the development plans of the constituent local planning authorities
6.3 To maintain arrangements for future dialogue with key consultees
Erosion and Flood Hazard
7.1 To identify, monitor and analyse coastal processes affecting flood and erosion risk
Conservation and the Natural Environment
9.1 To identify opportunities for maintaining and enhancing the natural coastal environment taking account of statutory and non-statutory designations
Flexibility
12.1 To review and update the Shoreline Management Plan periodically
12.2 To keep alternative long term options for the coastal defences strategy under consideration

Particular issues identified for the coast between Brighton Marina and Ovingdean (Management Unit 12) included the requirement for continued defence of the road (A259), urban development and interceptor sewer. The SMP determined that the unit is starved of sediment supply from the west (up-drift), whilst the supply of sediment from the east (down-drift) is partially controlled by groynes. Therefore it was considered that 'Hold the Line' was the only viable strategic defence option for this management unit.

The Brighton to Ovingdean Coast Protection Strategy included the following objectives:

- Continue to provide protection to infrastructure and environmental assets, where this remains technically, economically and environmentally viable.
- Ensure that any proposed solutions do not alter the current coastal processes.
- The Strategy should be in harmony with the SMP and local plans.
- Ensure that the proposed strategy is sustainable in the long term, and does not prejudice the options available to future generations in respect of resource use and development.
- Maintain public access to the beaches.

The overall objective of the Brighton to Ovingdean Coast Protection Scheme was the continued protection of major road and sewer infrastructure and environmentally important land. The design and construction phases of the project did not have any specific objectives relating to sustainability, however, the scheme was designed with the intention of minimising any impacts on the natural, human and built environments.

In terms of this Defra R&D project, this case study is being used to review the opportunities for and barriers to the re-use of materials within coastal defence construction projects. The case study will also enable tools for estimating indicators of environmental performance for flood and coastal defences to be tested.

8.1.5 Summary of Available Information

- South Downs Shoreline Management Plan, Selsey Bill to Beachy Head (Executive Summary). Gifford Associated Consultants for South Downs Coastal Group, 1997.
- Brighton Marina to Saltdean Coastal Defence Strategy. Posford Haskoning for Brighton and Hove City Council, 2001.
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- Winfield, P.G. (2004) Brighton Marina to Ovingdean Gap Coast Protection Scheme. CIWEM Journal (Water & Environment), Volume 18, August 2004.
- Howard, N., Edwards, S and Anderson, J. (1999) BRE methodology for environmental profiles of construction materials, components and buildings, CRC Ltd., ISBN 1 86081 294.
- Masters, N. (2001) Sustainable use of new and recycled materials in coastal and fluvial construction, a guidance manual, Thomas Telford, ISBN 0 7277 2950 0.

8.2 Case study assessment

8.2.1 Objectives of Scheme

At a strategic level, the aims and objectives of the scheme were established jointly through consultation with stakeholders, and were expressed in suitable terms to address the identified problems without presupposing any specific solution. The strategy recognised the need to adopt the concept of sustainable development, acknowledging the need to ensure that schemes undertaken today do not prejudice the options available to future generations in respect of resource use and development. The strategy determined a technically, economically and environmentally acceptable and sustainable solution to the problems occurring along the Brighton Marina to Ovingdean frontage. The strategy for the frontage was compatible with the previous South Downs SMP.

Although the design and construction phases of the scheme did not have any specific objectives relating to sustainability, these phases were approached with a view to ensuring long-term sustainability and minimal impact on the human, natural and built environments. Opportunities were identified during the design and construction process for reducing impacts and improving sustainability, which are discussed further below.

8.2.2 Assessment of Sustainability

Construction Process
In the appraisal process, the preferred option identified on economic and environmental criteria was to encase the seawall with rock-toe fillet and encase nine groynes, before maintenance costs started to spiral upwards, i.e. within two years of the assessment.

The most financially advantageous time to undertake works was established based upon economic considerations of the current maintenance costs and residual life of the wall.

The site is linear in nature, about 1.8 km in length and is located at the bottom of the 20 - 30 m high chalk cliff. The promenade varies in width from about 15m to 3.4m. The cross-section in Figure 8.2 illustrates some of the construction works which comprised:

- Encasement of the old seawall with pre-cast flint-faced concrete blocks and in-situ concrete for the central section of the site
- Placement of granite boulders along the foot of the wall for scour protection for the central section of the site
- Renovation of three existing groynes at Ovingdean Gap and six groynes adjacent to the Marina
- Reconstruction of the promenade and splashwall.

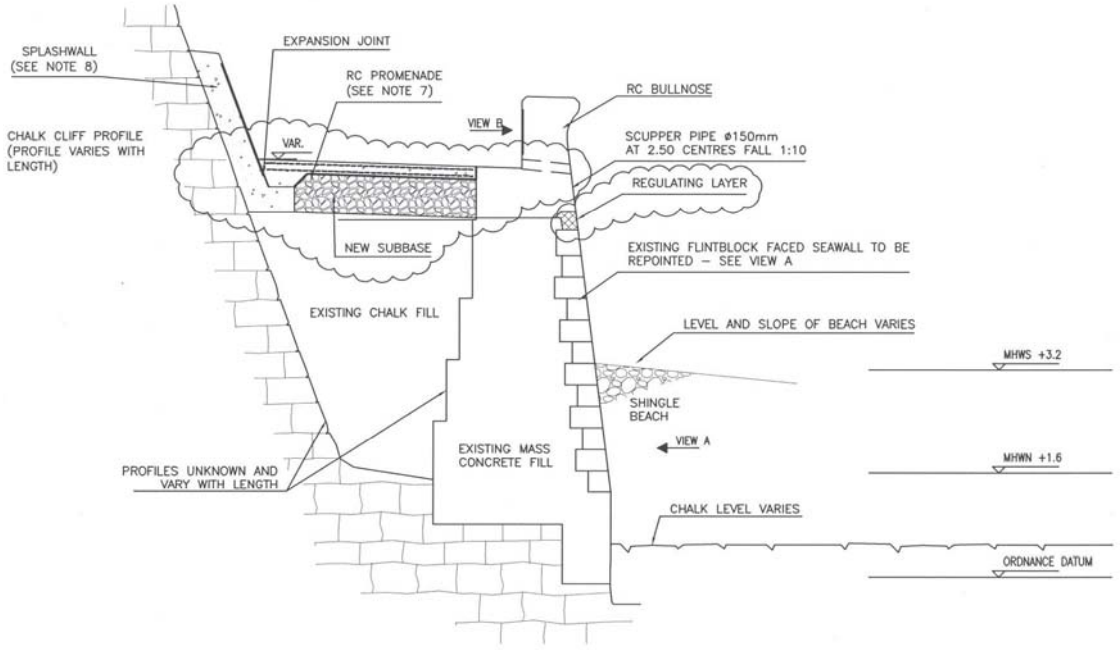

Figure 8.2 Typical Cross-Section

The scheme design and construction process incorporated significant reuse of materials from the existing defences in the new works. The removal of demolished concrete from site would have environmental impacts and consequently would incur significant disposal costs, in the form of transport, government levies and associated costs, if it could not be sold as fill for other works. In addition, by reusing these materials as fill the requirement for primary aggregates is limited.

The concrete arisings from the demolition works were used in the following three ways:

1. Some of the larger sections of the demolished bull nose were used as secondary armour under the new rock armour revetment. Although very limited in extent, this minimised the importation of granite armour from Norway. This granite is in itself a waste product from the stone quarried to produce ‘dimension stone’ which is principally used for polished architectural facing units.

2. Some of the demolition arisings were used as fill within the two ‘box structure’ ramps from the promenade onto the foreshore. The fill is needed as dead weight to stop the structures moving under wave loading. Concrete blocks and the friable no fines concrete from behind the existing splashwall were utilised in this way.

3. The promenade was raised by 600mm, to take account of sea level rise resulting from climate change over the coming 50 years. Crushed concrete blocks from the old groyne structures and dilapidated sections of seawall were used in this area of the works.

Plate 8.2 Use of demolished bullnose as secondary armour

The construction of a rock armour toe revetment also contributed to the long term sustainability of the scheme. The rock armour will act to dissipate wave energy and will reduce abrasion damage to the wall. Consequently, the risk of undermining of the defences is reduced and the life of the scheme increased. In addition, it is possible that the presence of the revetment will act to build the beach in front of the defences, providing further protection and associated extension of life.

A further design consideration that also affects the sustainability of the project was the use of a proprietary concrete mix for encasing the groynes. This Tarmac product, Toproc, is described as having enhanced abrasion resistance qualities. The use of this material was intended to reduce maintenance requirements and extend the life of the defences.

As yet it has not been possible to measure the performance of the concrete, and there are some concerns that it may not in fact be an improvement on standard concrete. Quality control of this material proved difficult on site as the declared measurable characteristics were difficult to enforce.

Plate 8.3 Use of demolition arisings as fill for promenade raising

During the construction phase, through discussion with the contractor, it was decided that polypropylene fibre reinforced concrete should be used for the construction of the concrete promenade slab, rather than steel mesh reinforcement. This simplified promenade construction operations and avoided future problems with reinforcement corrosion. The relative performance of this material can only be assessed in the longer term.

A proportion of secondary rather than primary aggregate was used in the construction of the concrete crest wall, in the form of ground granulated blast furnace slag, which is used as a cement replacement. This is a recognised suitable alternative to a proportion of the cement content in concrete, which is regularly specified for construction works.

There is little scope for the direct replacement of rock armour used in coastal protection with alternative materials, due to the required size of the armour units. Such rock armour is currently considered to be a primary aggregate and as such the aggregates levy applies. However, heavy gradings of rock armour are generally produced as a by-product in the quarry process. This is therefore a more sustainable use of the material than if the rock was crushed to a lighter grade.

The scheme effectively ensures the long-term protection of SSSI and other natural environment interests. Infrastructure, including the A259 road linking Brighton to Peacehaven and Newhaven to the east, is also protected, enabling

continued mobility of the local population. The opportunities for recreational use of the shingle beaches is also maintained. However, the long-term performance of the scheme and any effects of climate change on its performance cannot yet be assessed. The scheme design also aimed to minimise whole life costs, with minimal maintenance requirements. Again, its effectiveness on this basis can only be assessed once the scheme has been in place for a few years.

The strategy recommendations considered that the scheme would not alter the current coastal processes. However, the feed of beach material to the frontage from the west is very limited. Consequently, beach levels need to be closely monitored and the strategy reviewed periodically to take into account any natural changes to coastal processes, to ensure that there are no impacts on the wider area.

The sustainability of the scheme construction may be assessed against the issues and objectives identified in the strategy (Tables 8.3 and 8.4). This demonstrates that the approach taken had positive impacts on all aspects of sustainability.

Calculation of Eco-points

As described in Section 8.1, the Eco-point estimator was originally developed as a method for comparing the environmental impact of scheme design options. In this case study ecopoints are not used in the design selection process, but as a comparison for what was actually done on site and the score for the same scheme without recycling and durability improvements.

During the design and construction process of the scheme (construction works started in January 2003), the following changes were made with regard to the use of materials. The impact of these changes are analysed below using the Eco-points estimator. The two major changes on which the estimation is based are:

1. Concrete arising from the demolition of the existing splash-wall was crushed for use as fill material under the new promenade slab.
2. Mesh reinforcement in the promenade slab concrete was substituted for polypropylene reinforcing fibres. This sped up the operation of the promenade construction and avoids future reinforcement corrosion issues with the promenade slab.

The first point on the reuse of crushed concrete has led to a reduction of the need for aggregates. The second point has caused a shift in the use of materials, by using polypropylene-reinforcing fibres instead of mesh reinforcement.

In Table 8.5 (second column), the quantities of materials used for construction are listed, as provided by the contractor. The quantities that potentially would have been used (if the two discussed changes weren't made) are presented in the third column of Table 8.5. This information was used as input for the Eco-points estimator.

Table 8.5 Material Quantities

Materials	*Used quantities*	*Potentially used quantities*
Toproc Concrete	4900 m3	4900 m3
Promenade Concrete	2500 m3	2500 m3
Other Concrete	11600 m3	11600 m3
Area A393 mesh substituted for fibres in promenade	(11000 m2)	
Mass of other fibre reinforcement	803 t	
Area of (other) A393 Mesh	4350 m2	15350 m2
Crushed Concrete fill, recycled on site	4900 m3	
Aggregate		4900 m3
Rock Armour 6-10t	23500 m3	23500 m3
3-6t	9850 m3	9850 m3
0.3-1t	4700 m3	4700 m3

The following information on transport modes and distances was provided, as required for calculating the Eco-points.

- The granite armour rock were brought to the site by sea from Larvik in Norway - approx 3200 km round trip
- The concrete batching plant was in Newhaven, transport by road - approx 25 km round trip

The effect of the substituting polypropylene fibres for the steel mesh reinforcement in the original design for the promenade slab will have an effect on component life of the concrete structure. In this case study it is assumed, that the life of the entire seawall will be significantly increased by this decision.

In projects such as RASP (Risk Assessment for Strategic Planning) and PAMS (Performance based Asset Management System), values have been identified for condition grade deterioration of defences. For the rate of deterioration (time in years to reach a condition grade 5 from new with normal maintenance) a value of 32 years is being used for seawalls, while for revetments 40 years has been identified. In this analysis it is assumed that the use of polypropylene fibres will lead to an extension of the life of the seawall from 32 years to 40 years. See for these assumptions also Table 8.6 below.

Table 8.6 Assumptions on Component Life

Component	*Assumed life, with substitution of mesh reinforcement for fibres*	*Life, without substitution of reinforcement*
Seawall – concrete structure	40 years	32 years
Revetment – toe protection	40 years	-

The Eco-points estimator also needs input on the required operational life of the project. For this parameter a period of 50 years is assumed in this analysis. This is a commonly used time horizon in cost-benefit analysis of engineering assets.

All the information provided by the contractor and the assumptions discussed above, were used for calculating the Eco-points scores as presented in Table 8.7. The input spreadsheets for these calculations can be found in Appendix 5.

Table 8.7 Results of Eco-points estimator (summary calculation tables and example of input spreadsheets included in Appendix 1)

Case A - Eco-points for scheme as implemented: • Reuse of crushed concrete • Substitution of fibre reinforcement for steel mesh • Extended life of seawall	412200
Case B - Eco-points, potential score (testing sensitivity of assumption of extended life of seawall): • Reuse of crushed concrete • Substitution of fibre reinforcement for steel mesh • Life of seawall not extended	431600
Case C - Eco-points, potential score without sustainability improvements: • No reuse of crushed concrete • No substitution of mesh reinforcement • Life of seawall not extended	422000

Interpretation of Results

These results demonstrate that improvements to the sustainability of the scheme in terms of materials usage were made in both the design and construction phases.

The results of the Eco-points calculation above show a lower Eco-points score for the implemented scheme (case A) compared to the potential score without the reuse of crushed concrete or substitution of concrete reinforcement (case C). The difference in Eco-points score, between these alternatives is about 3%. It should be noted that this calculation is based on some assumptions, as discussed in Section 8.2.

As may have been expected, the substitution of polypropylene fibre reinforcement for the mesh reinforcement included in the original design is only more profitable in terms of Eco-points when the component life is extended by this substitution. This can be seen by comparing the scores between case B and A.

8.2.3 Barriers, Successes & Failures

Table 8.8 Barriers, Successes and Failures

Barriers
• Specific sustainability objectives not identified at design stage. • Difficult to control quality of abrasion resistant concrete. • Assessment of achievement of sustainability objectives is only possible in the medium to long term.
Successes
• Continued protection provided to infrastructure and environmental assets. • Many opportunities identified for reuse of materials, reducing requirements for primary aggregates, disposal to landfill and associated environmental impacts:. Reduced transport requirements and associated costs and emissions. Minimised disturbance to wave-cut chalk platform. Reduced construction cost. Increased life of scheme components. Reduced construction health and safety risks. Opportunities realised for reducing long-term maintenance requirements. • Reduced environmental impacts can easily be quantified by the Eco-points estimator • The Eco-points estimator, developed for the scheme selection process, has also been found useful for analysing the environmental impact in the construction stage • Improved overall sustainability of scheme whilst meeting strategic objectives.
Failures
• Eco-point tool only covers environmental impacts and may therefore need to be supported by other tools for proper assessment of overall sustainability. • Limited experience in the use of the Eco-points estimator and lack of supporting data make it necessary to make assumptions. • Possible durability issues associated with alternative concrete specification used for groynes. • Further reduction of waste at quarry could have been achieved through design to utilise a wide range rock armour grading. • Potential for increased use of cement substitutes in concrete.

8.2.4 Assessment of Benefits of Techniques/Tools

From the analysis and results presented in this case study, it can be concluded that the Brighton to Ovingdean coastal protection scheme, has achieved a reduction in environmental impact by choices made in the design and construction process with regard to use of materials. It can also be concluded here that Eco-point estimator is a useful tool to easily quantify the environmental impact of these types of decisions.

In this case it is apparent from qualitative assessment of use of materials that the approach increased the sustainability of the scheme. The use of the Eco-point estimator served to confirm this using a more quantitative approach. Where the effect of materials choice on sustainability is more complex, the Eco-point tool can prove to be a very useful assessment tool.

8.2.5 Review of Opportunities & Limitations, Lessons Learnt, Wider Applicability

Opportunities

- Consideration of reuse options and Eco-point estimation where there is significant likelihood of use/demolition/removal/movement of material as part of a flood and coastal erosion management scheme.
- Opportunities exist for reducing use of primary aggregates, production of waste and use of landfill sites.
- It is possible to undertake innovative design that considers both site constraints and the environment.
- When there are complex options where clear qualitative appraisals of sustainable use of materials are difficult, the Eco-point estimator can provide a science-based assessment.
- Eco-point estimation can feed into the environmental part of an overall sustainability appraisal process.

Lessons Learnt

- The potential opportunities for re-use of materials should be considered at an early stage of a project. This may assist in identifying a more sustainable preferred scheme option.
- The use of alternative materials needs to be considered against ease of construction and quality control. Use of materials with a proven track record would be preferable; however, this could be a barrier to innovation.

Issues with Wider Applicability

- Early and project specific identification of objectives relating to project sustainability. These may be inherent in the strategy/appraisal process, but if they are fully identified then the entire project process can be geared to achieving these.
- The need to carry out risk assessments and engage stakeholders in preparing and agreeing risk management actions will be necessary for wider application of techniques for re-use or re-cycling of materials in flood and coastal risk management, particularly for urban or environmentally sensitive areas.
- The classification of some of the Interim by products of waste and associated stringent regulatory or approval mechanisms and costs may reduce the willingness for uptake.
- Where possible, the application of the Eco-points estimator or a similar tool at the option design stage will enable the relative merits of options to be assessed in terms of resource use.

8.3 Summary of findings

From the analysis carried out in this case study, it can be seen that materials re-use enables significant gains to be made in the construction process in terms of overall cost, reduction in extraction of primary aggregates, use of natural materials and reduction in waste sent to land fill sites. However, associated

with this were issues of quality and long term durability as well as local concerns.

Appropriate risk assessments and management as well as proper engagement and education of stakeholders regarding the real risks, benefits and opportunities would be critical to increased re-use or recycling of materials in flood and coastal erosion risk management. This will be particularly important in urbanised or environmentally sensitive areas.

The case study demonstrated that the Eco-points estimator is a useful tool to easily check the environmental impact of decisions made with regard to use of materials in design and construction.

Supporting data for the Eco-points estimator is not always available and there is limited experience of its use. Therefore, assumptions need to be made by the user. It is therefore recommended that more supporting data are made available, parallel to wider implementation and recommendations for use in the design and construction of flood and coastal defence infrastructure.

The Eco-points estimator (developed for the option selection stage) already contains a wide variety of materials for which scores can be calculated. However a further specification might be useful, especially when its use is extended to more detailed design stages and construction. For example in this case study, it was noticed that there is no differentiation for the environmental impact of different armour stone gradings. Also the possibilities for including reductions in mesh reinforcement for concrete structures are limited.

9 Conclusions

9.1 Summary of key findings

9.1.1 General

The detailed outcomes of these studies are presented as annexes to this report. These annexes provide information on the assessments of the associated sustainability issues and the lessons learnt from the application of techniques and tools to managing them. In addition, the benefits and opportunities derivable from the techniques as well as identified barriers and limitations to their use were incorporated. Where barriers or failures were identified, the successes or otherwise of the approaches to manage them were highlighted to feed into guidance for future management. Finally the applicability of the techniques and tools to wider issues/locations were examined to ensure appropriate context of use.

A summary of some of the key points from the annexes are outlined below. This summary is presented in the context of developing and delivering sustainable flood and coastal erosion risk management, as opposed to a repetition of a listing of the outputs of each case study. This approach allows presentation of the cross cutting aspects of the outputs.

The outputs are summarised below under the following headings:

- Developing sustainable strategic plans.
- Developing and appraising sustainable management strategies and options.
- Interaction with land-use and communities
- Delivery of sustainable outcomes

9.1.2 Developing Sustainable Strategic Plans

Due to the early process of development of the CFMP and River Basin Management Plans, only case studies on SMPs were considered appropriate. Most of the outcomes regarding the understanding of physical processes and consultation are generally applicable to these other plans. Some of the key outputs are outlined below.

The increased focus on stakeholder engagement throughout the development and understanding of the physical processes within SMP2 enables better awareness, understanding and ownership of the issues and outcomes by both the project team and the stakeholders. The case studies showed that early and sustained consultation with appropriate stakeholders is critical for the development and agreement of sustainable plans. It should be noted however that there is an additional cost of money, resources and time, and while it leads to the development of more sustainable management options, it does not necessarily guarantee acceptance of the outcome.

Understanding of the physical processes, morphology and their long term effect on the coastline, defences or watercourses is vital to the understanding of management systems for which plans or strategies are being developed. The case studies showed that this is critical for developing long term sustainable solutions as well as informing the stakeholder engagement process, particularly for areas of potential conflict between people, the built and natural environment, and environmental processes.

The ability to prescribe different management options for each epoch within the 100 year SMP2 life and the inclusion of regular updates, enable the development of more sustainable strategies over the whole life in the development. A comparison of SMP1 and SMP2 outputs for the same cell showed improved opportunities for significant changes e.g. into managed retreat options in the longer term, where this was not an appropriate or sustainable strategy in the short term.

The hierarchy of plans, strategies and schemes within flood and coastal erosion risk management and the increasing focus of wide stakeholder engagement will need to be properly managed through efficient and joined up consultation methods to avoid consultation fatigue. This is a very real concern to the stakeholder community.

Potential for partnerships and optimisation of a range of uses of the restored sites are two main opportunities of management approaches such as managed realignment and flood plain restoration. The case studies show that proper identification of these opportunities and integrated management of the zone of influence of the management plan to provide multiple benefits can increase the chance of developing sustainable solutions and their acceptability to the wider community.

The case studies showed that there is currently the tendency to have losers and winners from the acceptance of a sustainable strategy or plan. This works against the win-win objective for sustainable management. While the principle of compensations for environmental losses locally or elsewhere is generally accepted, a similar measure when individuals or communities suffer losses in the process of achieving sustainable solutions continues to be one of the most significant unaddressed barriers to the acceptance and implementation of sustainable strategies and plans. This is particularly a major issue where strategic management plans change the policy of an area e.g. from hold the line to managed realignment. Resolution of this issue within the context of permissive executive powers of operating authorities will be critical to the delivery of sustainable solutions.

9.1.3 Developing and Appraising Sustainable Management Strategies and Options

The case studies confirmed the potential for tools such as multi-criteria analyses, sustainability appraisal and the eco-point estimator to assist in the achievement of sustainable outcomes through their use in strategy and scheme development. They also showed that this potential could be limited by

constraints and overrules, which are evident within the current systems and that further development will be required to maximise the potential they can offer.

In order to maximise the potential of the tools, particularly the wider ranging ones such as MCA or sustainability appraisal, they need to be key parts of the decision process. They should be broad enough to embrace all important issues that are likely to affect the outputs and their outcome should not be subject to overrules by other aspects of sustainability such as economic (e.g. cost-benefit analyses or environmental issues). This only amounts to double counting, working against the sustainability principles of achieving win-win and fairness.

The case studies supported the use of sustainability appraisals aided by sustainability indicators to provide a tool for assessing and improving sustainability of flood and coastal erosion risk management. As with any tool that relies on indicators, there is a need to ensure development of indicators relevant to all aspects and levels of decision making. This need was identified to support the sustainability appraisal process, as the output will only be as relevant as the quality of the input and the decision process.

The case study also showed the potential for tools that target particular aspects of sustainability such as the eco-point estimator tool for inputting into the overall sustainability appraisal process or on their own, where the management of their particular aspect is a significant part of the project.

The appraisal process or make up of the support tools such as indicators need to avoid double counting of particular aspects of sustainability in relation to others to facilitate fair consideration of the different aspects of sustainability.

Where tools such as MCA and sustainability indicators are only applied for the purposes of providing comparisons or ranking of options, they will support the selection of the most sustainable option, but not necessarily assist in improving the sustainability of that option. For maximum benefits, the appraisal process needs to enable the development and enhancement of the options to ensure opportunities for improved sustainability are realised.

The use of MCA and sustainability appraisals can enable the development of the most sustainable option for development or improvement, but still provide an unsustainable scheme unless some measure of minimum acceptable criteria for sustainability is included in the appraisal process.

9.2 Interaction with Land-use and Communities

Flood and erosion risk needs to be managed through continuous reduction of the risks out its source, pathway and receptor areas in an integrated manner to maximise the opportunities for sustainable management. This inevitably implies increased interaction with local communities, land-use, natural, historic and built environment.

The case studies confirmed that for techniques such as SuDS and land management can enable more sustainable management of the sources and their associated run-of before it reaches river systems. Similarly at the other end of the system, techniques such as temporary and demountable flood protection and flood proofing systems have been found to be very effective in the right conditions. Together with other appropriate measures, such techniques can contribute to catchment-wide flood management.

The inevitable need for flood management to influence land use planning and development control became evident from the case studies. Flood management measures which interact with the wider land-use and development such as SuDS have a lot of potential to provide significant gains to habitat creation and diversity, as well as local amenities for recreation and community enjoyment, as was shown within the case studies. To maximise the delivery of these multiple objectives, early involvement of such considerations are necessary, allowing the chance to influence the site layouts and planning. This provides better opportunities for integration of source, site and region wide measures. The earlier in the land-use and development planning processes these issues are considered, the more impact they can have on sustainable flood and erosion risk management.

Where sustainable protection against flooding is not achievable due to unacceptable visual impact, economics or conflict of use of land, non permanent flood protection measures such as demountable, temporary or flood proofing of properties have been proven by the case studies to be real alternatives to doing nothing. Their successful use however depends on careful management of the associated operational processes and the availability of a reliable process of flood forecasting and warning on which their operation depends.

Flood and coastal erosion risk management measures that involve significant interaction with land use and communities at any part of the development or operation requires effective engagement with the local community and relevant statutory and planning bodies throughout its development to ensure sustainable outcomes which recognises the impact on the environment and people and should seek to deliver multiple benefits.

9.3 Delivery of Sustainable Outcomes

The process of developing and delivering sustainable outcomes rely on good understanding of the systems being managed, the short and long term effects of management interventions on them, and the breadth of stakeholder issues within their domain of influence. The process of option development, stakeholder engagement and scheme delivery then needs to be underpinned by this understanding and an appreciation of the inherent uncertainties.

Following the process of developing management strategies and schemes for sustainable flood and erosion risk management, achieving sustainable outcomes depend on agreement of the management solution and the process

of implementation through design procurement, construction and operational management.

Consideration of whole life management issues as part of design and construction is important to maintain the character of the desired outcome, particularly issues of clarity of maintenance and operational requirement, consideration of safe access and ease of operation, maintenance and repair. This is particularly critical for techniques such as SuDS and temporary and demountable flood protection, whose operation and maintenance is critical to their performance.

Opportunities for enhancing sustainability can be achieved through resource management. In particular, the case studies showed that consideration of re-use/recycling of materials as well as more sustainable alternatives can be maximised by the proper consideration of the procurement methods and sources, approach to design and specification, and attitude to waste minimisation. These issues can also be incorporated into appraisal and choice of management options through targeted tools that quantify their impacts.

9.4 Conclusions

The case studies showed a significant difference between available best practice and general current practice in the application of sustainable management methods within flood and coastal risk management, justifying the need for guidance to disseminate best practice and support a step change in this area. The case studies also showed the potential of particular management techniques and tools for improving the sustainability of flood and coastal defences.

In order to maximise theses potentials however, efforts should be directed not only on the processes, but on the achievement of the sustainable outcomes. Appropriate use of available good techniques, guided by application of lessons learnt from the case studies can assist in this regard. This is being achieved within the overall project by the incorporation of the outputs from the case studies into the individual guidance sheets produced to target particular sustainability issues.

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Appendices

Appendix 1 Case Study Development

Approach to Case Study Selection

General
To meet the objectives outlined in Section 1.2, it was recognised early in the project development that the case studies would need to be properly targeted to ensure relevance and wide applicability. To achieve this, the selection of the issues to be addressed by case studies and the associated sites was guided by the considerations below:

- Identification of tools and approaches that are relevant to sustainability and for which a case study (as opposed to further research) is the appropriate tool for drawing out issues to feed into the guidance development.
- Coverage of a wide range of flood and coastal management issues and related processes across England and Wales.
- Coverage of projects/initiatives across the management hierarchy at "national", "regional & strategic" and "local & community" levels.
- Coverage of a range of timescales and the consideration of case study examples in relation to their relevant time-frames.
- Achievement of the right balance between coverage of sustainability issues and levels and the detail of each case study.

The discussions that follow show how each of the above issues are approached within the case study development.

Choice of tools and approaches
The scoping study showed that best value will be obtained by further consideration of tools and approaches which are of significance to sustainable flood and coastal erosion risk management, i.e. those that address environmental, social and economic aspects and integrate with wider land and water management approaches. The key issues that affect the sustainability of flood and coastal erosion risk management as well as approaches and tools that could influence them were identified within the scoping study. Following further assessments of these issues, a list of priority sustainability issues, tools and management approaches were identified, which would benefit from further work in order to develop guidance on sustainability. From this, the issues that are best developed by case studies were then identified. These include:

- Flood and erosion risk management practices with the potential for achieving multiple objectives such as managed realignment and flood plain restoration.
- Management approaches and techniques that improve the interaction between flood/coastal management, land-use planning and the wider environment, such as Integrated Coastal Zone Management (ICZM), Strategic Flood Risk Assessments (SFRAs) and Sustainable Drainage Systems (SuDS).
- Methodologies and approaches for effective engagement of stakeholders in flood and coastal erosion risk management at all levels of decision making.

- The development of sustainable policies through Shoreline Management Plans (SMPs) and Catchment Flood Management Plans (CFMPs), and their delivery through strategies and schemes and whole life management.
- Taking proper account of social, environmental and economic issues in decision making and appraisal processes, and assessment of the role and current use of tools such as Multi-criteria Analyses (MCA) and sustainability appraisal systems in its achievement.
- Run-off generation from rural and urban sources and the sustainable management of their quantity and quality through tools such as SuDS and land management practices.
- Sustainable use of materials in the flood and coastal management life-cycle and the use of approaches such as re-use, recycling, sustainable design and procurement, and waste minimisation.
- Sustainable practices in the operation of flood and coastal management infrastructures in normal and emergency scenarios.

Coverage and applicability
To ensure wide coverage and applicability, the choice of case studies ensured incorporation of a wide range of flood and coastal management processes. These range from flood generation, conveyance and management to the management of flooding and coastal erosion in coastal and estuarial situations.

The selection process also ensured coverage of a good variation of geographical, physical and management issues. The coverage also took account of the management hierarchy, ensuring the consideration of flood and coastal erosion management issues from policy development through to delivery and operational management. The process ensured a wide spread across policy development (such as SMPs and CFMPs), strategy development (for sub-catchments and coastal sub-cells), individual improvement and renewal schemes, and operation and maintenance of the systems. In addition, particular effort was made to identify case studies which include a local scheme carried out within a strategic scheme and policy context for the same area of catchment or coastal zone. Similarly, preference was given to projects where plans, strategic studies or individual projects or plans have been re-visited or updated over time. This will enable the linkage of sustainability issues through the flood and coastal defence hierarchy and through time.

Proper attention to the coverage of the case studies should ensure the relevance and applicability of the outputs and the guidance from it to a wide section of the business.

Ideally the approaches and tools would be tested over the whole life of schemes. As the time-scale for this project does not allow this, a different approach which involved choosing case studies over a range of ongoing and completed studies was applied. The spread of the case studies through different time-era provided the opportunity to assess previous work in relation to the management era in which they were developed and learn lessons recognising any changes in the underlying rules or processes. This enables hind-casting to understand how new approaches could have affected past schemes. The inclusion of recently completed schemes enables lessons to be

learnt in situations where the governing issues and constraints are similar to the present. This will complement the ongoing schemes, as these will only be able to assess the expected sustainability of the outcomes (as opposed to the actual post event assessed case).

Balance of coverage and detail
The case studies could be limited to one or two, within which the most promising tools and approaches are tested in great detail. Alternatively, a larger number say five to ten could be considered, providing the opportunity for less detailed, but wider testing. The latter was considered more appropriate to enable achievement of the overall case study objectives due to the reasons outlined below:

- The limited time within the project is not sufficient for detailed case studies.
- The need to cover a wide variety of flood and coastal management issues, sustainability approaches and tools as identified from earlier reviews, and the need for the guidance to be widely applicable will not be served by a few case studies.
- The need for outcomes to cover issues from policy development through to operational management requires a wide case study selection.

Following the process outlined above, an initial set of ten case studies were selected to test particular sustainability tools or processes from over 40 potential case studies identified as part of the scoping phase. Following a desk study assessment and consultations with the project board and targeted stakeholders, seven case studies were finally selected to test and develop approaches to sustainable flood and coastal erosion risk management. This should provide sufficiently wide coverage and enough detail to enable useful outputs. The selected case studies are presented in Section 3.

Case Study Methodology
A consistent methodology of approach was applied to each case study, with the detail and emphases depending on the particular case study objective. Depending on the timing of the case study in relation to the project, three types of case studies were identified.

Type 1 – Completed projects where tools have been used:
These case studies involved the review of particular sustainability tools or approaches which have been used on a project or management process. Here an attempt was made to identify the effects of the approaches on sustainability, as compared to a more standard approach. The actual outcome in terms of sustainability as compared with the planned objectives (where available) was then assessed.

Type 2 – Application of tools retrospectively within a case study.
These case studies involved the application of new approaches retrospectively on a recently completed or ongoing project. Here the result of the management without tools is known. The effect of particular tools on the project or process was then investigated through expert review and consultation with original developers and managers.

Type 3 – Application of tools directly within ongoing projects.
Here the case study involved the actual trial of a tool within an existing project or part of the project. Due to the limited time available for the case study, this was generally supported by information from other parts of the project or outcomes from similar uses of the approaches or tools being tested. The sustainability of the approach or tool was then compared to the expected outputs from the use of a more standard approach.

The methodology for carrying out the case studies for each of the three types is summarised in Figure A1.1 below:

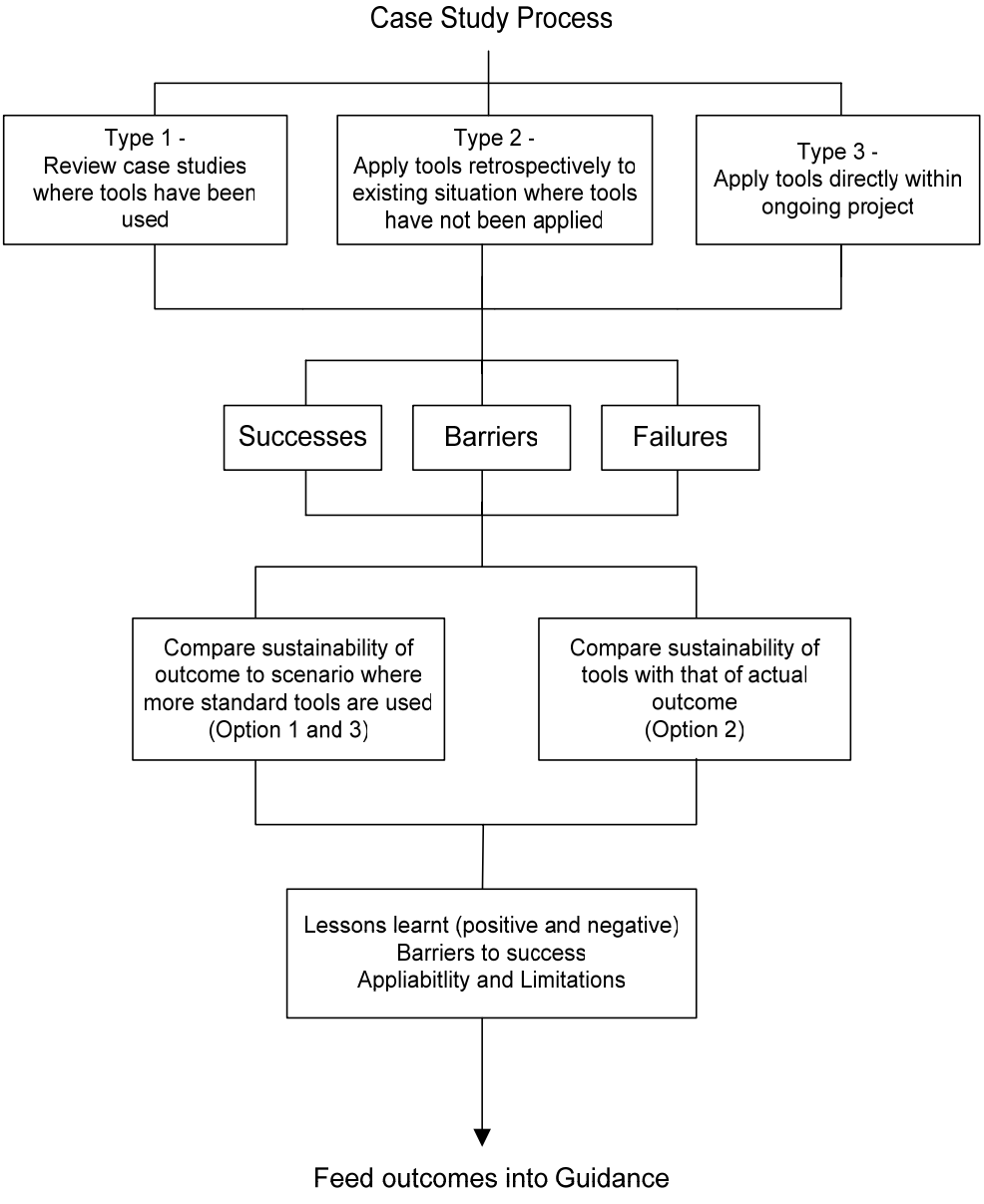

Figure A1.1. The case study methodology

The processes involved with the above methodology are outlined below:

Analysis of case study information:

- Identification through literature review and consultation, the what, why and how of the project and assess the character of the case study (its policy, strategy or delivery context and key peculiarities and issues within it).
- Identification and assessment of the detail of the case study (evidence).

Project review:

- Identification of the overall objectives of the scheme.
- Identification of the sustainability issues within the project or process and its objective.
- Review of the sustainability of the case study with regard to the objectives, techniques and tools – highlight successes, failures, barriers and other issues.

Analyses of management processes:

- Why were barriers there, how were they (or not) overcome and other wider issues?
- Why successes were achieved, what if anything assisted or limited the success?
- What caused failures, how could this be avoided if possible?
- Assessment of sustainability with regards to actual or expected outcome.

Analyses of tools and techniques:

- Was a sustainability tool/technique used?
- If yes, did it help and would outcome have changed if tool wasn't used?
- If no, would technique have changed the outcome?
- Assessment of the effect of tool/technique on overall sustainability (benefits).

Applicability of approaches and tools:

- Assessment of the applicability of approaches/tools to other scenarios.
- Assessment of the limitations of approaches/tools.

Outcomes:

- Identification of key outcomes of the case study to feed into guidance to improve sustainability.

Appendix 2 Moray Flood Alleviation Group Sustainability Indicators

Ref	Indicator	Description
A	**PROJECT DEVELOPMENT - DESIGN AND CONSTRUCTION OF SUSTAINABLE SOLUTIONS**	
Take a long-term perspective to impacts, benefits and constraints		
A1	Few associated natural, long term uncertainties or risks to scheme performance.	Take into account future environmental conditions and loadings (i.e. changes to rainfall, wave conditions, currents etc.). Does the scheme represent a certain long term solution?
A2	Few associated man made, long term uncertainties or risks to scheme performance.	Take into account the effect that future man made developments and landuse changes will have on the solution. Does the scheme represent a certain long term solution?
Apply the precautionary principle and analysis of risks		
A3	Few long-term external risks and impacts on the natural environment.	What are the knock-on effects? Taking a holistic view of existing natural processes, geomorphology, sediment transport etc. What are the consequences of man made intervention? Does the scheme create new problems or transfer existing ones?
Take a holistic and integrated approach to scheme development		
A4	Few long term external risks and impacts on the man made environment including the built environment, land uses and communities.	What are the knock-on effects? Take a holistic view of the man made environment. What are the consequences of man made intervention? Does the scheme create new problems or transfer existing ones?
Use best possible scientific information and anticipate need for dedicated collection		
A5	Best Practice and most up to date information applied.	Is the most up to date information being used? Are the principles of Best Practice being applied?

B	ENVIRONMENT – EFFECTIVE AND LONG TERM PROTECTION OF A HEALTHY ENVIRONMENT	
Use of natural resources, water, land and energy is efficient and prudent		
B1	High ratio of [secondary/recycled/re-used] : [primary] aggregates used.	Is there more secondary, recycled and re-used material being used in the project than primary aggregate?
B2	Minimal material requirement.	First aim of sustainable waste management is minimisation (see relevant Guidance Sheet)
B3	Minimise the amount of green field site development.	Brownfield sites should be used in design where feasible. Can the 'footprint' of a green field site development be minimised?
B4	Conservation of landscape features (hedges, stone walls, archaeological features).	Landscape features such as hedges, stone walls and archaeological features should be conserved.
B5	Minimise requirement for site restoration and remediation following construction.	Minimise the need for restoration and remediation by considering at the design stage and avoiding damage in the first place.
Natural processes are respected and human intervention is limited		
B6	Good use of landform to manage flooding.	Landforms such as flood plains, valley sides and areas of high ground should be considered in the design. Can catchment flood storage be incorporated into the design?
B7	Minimise man-made constraints on channel development.	This means where a channel movement is restricted in some way by new structures, and includes banks or gabions with 'soft' (e.g. green) facings.
Waste is minimised, re-used, recycled or recovered before careful disposal		
B8	Limited amount of construction and decommissioning waste going to landfill or re-used or recycled.	Aim to minimise by re-use and recycling on-site where possible.
B9	Minimal amount of hazardous waste generated.	The production of hazardous waste should be minimised.
Pollution is limited		
B10	Water quality of burns and rivers high (as assessed by SEPA).	The water quality of burns and rivers should be maintained or enhanced. Links with the Water Framework Directive.
B11	Minimise pollution during whole life of scheme.	Consider noise, air and land pollution.

Ref	Indicator	Description
The diversity of nature is valued, protected and, wherever possible, enhanced		
B12	Safeguarding of protected and Biodiversity Action Plan species and habitats.	Biodiversity Action Plan and protected habitats and species should be safeguarded from adverse impacts.
B13	Creation of valuable natural habitats.	Habitat areas over-and-above those required simply to replace that damaged or lost to scheme.

C	ECONOMY - MAINTENANCE OF A PROSPEROUS ECONOMY	
Local needs (including resources) are met locally		
C1	Minimise distance to source of construction materials.	The distance between the source of construction materials and the construction site should be as short as possible.
C2	Minimise distance travelled by waste for disposal.	The distance between the source of waste and landfill site or other re-use/recycling sink should be as short as possible.
Value Engineering and Management techniques are used to make more with less		
C3	Maximise use of re-used, recycled and renewable construction materials.	Alternatives can be cheaper, although use may be limited by technical standards.
Whole-life costs (including maintenance) of schemes are minimised		
C4	Minimised maintenance and operation costs.	The need for maintaining and operating the scheme should be minimised.
C5	Minimised decommissioning costs.	The need for decommissioning costs once the scheme has exceeded its design life should be minimised.
Whole-life values of schemes are maximised		
C6	Benefits beyond scheme operation requirements (e.g. amenity provision, wetland creation).	Includes intangible benefits e.g. amenity, recreation, quality of environment, wetlands.

D	COMMUNITY - AN INCLUSIVE SOCIETY WHICH RECOGNISES THE NEEDS OF EVERYONE	
Health and well-being are promoted through safe, clean and pleasant environments		
D1	Minimise health and safety risks by scheme situation through effective communication and education.	Remove the risks in the first place by careful siting, screening, location of scheme, warning people of the dangers of the scheme.
Flexible scheme development processes are influenced by stakeholder involvement		
D2	Solution represents a consensus of stakeholder interests.	Does the scheme design represent a consensus of stakeholder interests?
Schemes have community support and understanding		
D3	Community support for proposals.	Includes feedback from consultation responses and other anecdotal information.
Amenity and recreation opportunities enhanced wherever possible		
D4	Maximise amenity and recreation opportunity.	Amenity and recreation should be created where possible.
D5	Maximise access opportunities.	New access should be created where possible.

Appendix 3 Background Details of Trial Sites

Appendix 3a Coleham Head - Shrewsbury

BACKGROUND TO COLEHAM HEAD SCHEME, SHREWSBURY

Shrewsbury is the county town of Shropshire and the River Severn has always played a central role in its development. It has a rich architectural and historical heritage and is one of the best preserved medieval towns remaining in England.

Over the years, development in the town has encroached onto the floodplain, resulting
in extensive areas at risk of flooding. It has a long history of flooding problems, with notable events occurring in 1946 & 47, 1960, 1964 & 65 and more recently in 1998, 2000 & 2002. Historically a major flood has caused significant damage on average every ten years, but time between floods can vary enormously. There has been a recent and dramatic increase in the number and severity of floods in Shrewsbury, since 1984 there have been 13 events that have caused serious property flooding.

The English Bridge gyratory system is an important route into the town centre and access is severely disrupted during flooding which has a known effect on trade in the town centre. There are 42 properties within this flood cell, the first of which is effected in a 1 in 3 year event. Temporary defences protect the Abbey Foregate area to a 1 in 10 year event and have no impact on upstream river levels.

During the February 2004 flood event 42 properties were defended and access to the town centre maintained. Approximately 0.4m of water was held back by the water filled barrier in conjunction with Severn Trent Water and Local Authority pumping of ground and surface water. It should be noted that if higher levels than in February 04 were experienced then the temporary barrier could be outflanked and additional loading placed on third party defences/walls.

Post flood event surveys have confirmed that there was no measured increase in water levels either upstream or downstream of the temporary barrier.

Residents of the adjacent undefended areas that flooded did, however, assert that in their opinion flooding was exacerbated by the pumping activities of Severn Trent Water. This opinion was discounted at several public meetings where it was explained that 45 six inch pumps would have been required to raise water levels by approximately 100mm. Only 2 pumps were used intermittently during the flood.

Aerial photograph showing extent of flooding in November 2000 and the line used for the Mobile Dam in February 2004

Aerial photograph of the Abbey Foregate area in flood November 2000.
Shows the approximate extent of areas successfully protected in February 2004 by the temporary defence scheme

Appendix 3b The Wharfage - Ironbridge

BACKGROUND TO THE WHARFAGE SCHEME, IRONBRIDGE

Ironbridge is situated along the banks of the River Severn where it exits the Shropshire Plain and changes character from a slow meandering river in a wide floodplain, to a much straighter channel flowing in a narrow gorge with virtually no floodplain and a much steeper gradient. Telford and Wrekin Council are responsible for all local government services in this area. The Gorge Parish Council further represents interests of residents and businesses.

The Severn in this area has a long history of flooding, around 74 properties at risk throughout the Gorge at 1:100 event. A smaller number of properties are flooded every one to two years. The November and December 2000 flooding was the worst experienced since 1947 (1 in 100 year flood) and was considered to be a 1 in 50 year event, that is an event having a 2% probability of occurring in any year. The most recent flood hit the area again during February 2002. The site chosen for the trial at Ironbridge is The Wharfage. The road and property at The Wharfage, which has a total of 24 properties at risk of flooding starts to flood at 5.1metres above gauge datum, which is about a 1 in 2 year event. The pallet barrier system protects the Wharfage to approximately a 1 in 50 year event and does not increase water levels upstream or downstream.

Flooding at the Wharfage in Ironbridge

During February 2004 event 1.1m of water was retained by the pallet barrier system which protected 24 properties. The hydraulic modelling and post flood event surveys confirmed that there was no adverse impact on water levels elsewhere.

Appendix 3c Hylton Road - Worcester

BACKGROUND TO HYLTON ROAD, WORCESTER

The City of Worcester is situated on the banks of the River Severn, between the confluence upstream with the River Salwarpe, and downstream with the River Teme. It flows in a gently meandering channel through a wide alluvial floodplain with very little gradient. The City of Worcester Council and Worcestershire County Council are responsible for the government services in this area. The Worcester Action Against Flooding Group represents interests of residents and businesses in promoting the case for flood alleviation measures.

The Severn in this area has a long history of flooding. The 1947 flood peak was 5.0 metres above normal summer river level, and was considered to be in excess of a 1 in 100 year flood (1% probability of occurring in any year). The November and December 2000 flooding was considered to be a 1 in 50 year event, that is an event having a 2% probability of occurring in any year. The most recent floods hit the area again during February 2002. This stretch of river has approximately 15 hours minimum flood warning lead time.

The site chosen for the trial at Worcester is Hylton Road. it is situated on the right bank of the river and has a total of 24 commercial and residential properties at risk of flooding. The first property floods at approximately a 1 in 10 year event but the road itself floods around a 1 in 2 year event, causing major disruption to traffic to and from Worcester and prevents access to homes and business. The temporary defences will protect Hylton Road to a 1 in 50 year event with about 20 – 40mm increase in water levels upstream. During the February 2004 flood event, approximately 0.6m of water was retained by the Pallet Barrier; protecting 24 properties. Although the hydraulic modelling predicted a small increase in water levels during a 1 in 50 year event, the post flood event survey did not detect higher levels than had been expected because of the small return period of the flood events in this location (1 in 5 years).

Line of temporary barrier

Appendix 4 Records of Discussions with SMP2 Project Team

Key Issues Identified by Gary Watson, North Norfolk District Council

- The consultation with the general public is still at an early stage.
- The public dissemination process has been a great success in terms of education and the level of interest.
- The draft SMP was not politically corrupted.
- Prior to this process the public considered coastal erosion to be a thing of the past. The SMP has raised the profile of coastal erosion and demonstrated that it is still an issue.
- The Council's project team would like to see the Plan go forward and be adopted, they feel that coastal zone management is the necessary approach for the future.
- The SMP is now much more of a political issue.
- In terms of enabling understanding of the problems, determining shared objectives and proposing more sustainable long term policies the stakeholder involvement strategy has been successful.
- If the success of the process is judged by whether the SMP is eventually adopted then it may not be seen as successful.

Key Issues identified by Terry Oakes, Terry Oakes Associates

- Consultation with the general public has raised awareness, but was probably undertaken too late in the process.
- Stakeholders have identified socio-economic issues that would not normally be covered.
- A wide range of people have been involved.
- There is a very high cost associated with making hard-copy plans available.
- A decision was taken to consult using the internet, however, in rural areas many people do not have access.
- Initially, stakeholder understanding of the technical issues was limited.
- There is no clear understanding of the implications that offshore dredging may have on the adjacent coast.
- The process followed has enabled more sustainable policies to be developed in the draft plan.
- The local authority does not have the tools to be able to implement the preferred options. For example, assets that are currently defended but no longer justify this economically may now have policies of Managed Realignment or No Active Intervention, but the Council can't implement these options over the short timescales that are required. There is no land available for alternative developments and no compensation offered to the people affected; i.e. the issues are predominantly socio-economic.
- The management of the stakeholder engagement process and ensuring that this is robust is an enormous task with a high associated cost.

- It is crucial to get members involved at an early stage, but it needs to be the *right* members, i.e. senior politicians, as the local authority members don't have sufficient power.
- The involvement of parish council members is also an inssue in a rural area, where there are a large number of individual councils. There needs to be a representative number but with limitations in some way.

Appendix 5 Eco Point Assessment for Brighton to Ovingdean Scheme

Case A - Ecopoints for scheme as implemented (with fibre reinforcement and extension of scheme life)

Material	***Component Life (years)***	***Quantity***		***Transport (km)***		***Transportation Energy (GJ)***	***Environmental Impact***
		Vol (m3)	*Mass (t)*	*Lorry 17-25t*	*Sea*		*Eco-points*
Aggregate (recycled on site)	*40*	*4900*	*-*	*-*	*-*	*-*	*-*
Concrete- general mass 50% cement 50% ggbfs (25N/mm2)	*40*	*19000*	*-*	*25*	*-*	*2243.58*	*61448.75*
Polypropylene	*40*	*-*	*803*	*25*	*-*	*76.39*	*16963.59*
Rock- igneous (granite, diorite)	*40*	*38050*	*-*	*-*	*3200*	*124360.54*	*333835.01*
TOTAL							***412200***

Case B - *Eco-points, potential score (testing sensitivity of assumption of extended life of seawall)*

Material	***Component Life (years)***	***Quantity***		***Transport (km)***		***Transportation Energy (GJ)***	***Environmental Impact***
		Vol (m3)	*Mass (t)*	*Lorry 17-25t*	*Sea*		*Eco-points*
Aggregate (recycled on site)	*32*	*4900*	*-*	*-*	*-*	*-*	*-*
Concrete- general mass 50% cement 50% ggbfs (25N/mm2)	*32*	*19000*	*-*	*25*	*-*	*2243.58*	*76527.46*
Polypropylene	*32*	*-*	*803*	*25*	*-*	*76.39*	*21194.83*
Rock- igneous (granite, diorite)	*40*	*38050*	*-*	*-*	*3200*	*124360.54*	*333835.01*
TOTAL							***431600***

Case C - *Eco-points, potential score without sustainability improvements*

Material	***Component Life (years)***	***Quantity***		***Transport (km)***		***Transportation Energy (GJ)***	***Environmental Impact***
		Vol (m3)	*Mass (t)*	*Lorry 17-25t*	*Sea*		*Eco-points*
Aggregate (typical UK)	*32*	*4900*	*-*	*25*	*-*	*193.58*	*8000.52*
Concrete- reinforced and prestressed 50% cement 50% ggbfs (40N/mm2)	*32*	*19000*	*-*	*25*	*-*	*2242.63*	*80194.08*
Rock- igneous (granite, diorite)	*40*	*38050*	*-*	*-*	*3200*	*124360.54*	*333835.01*

environmental estimator

ecopoints 461600

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Materials

	component life	material volume	material mass	mode of transport: Lorry Rigid <=7.5 tonnes	Lorry Rigid 7.5-14 tonnes	Lorry Rigid 14-17 tonnes	Lorry Rigid 17-25 tonnes	Lorry Rigid 25 tonnes+	mode of transport: Lorry Artic <= 30 tonnes	Lorry Artic 30-33 tonnes	Lorry Artic 33 tonnes+	Ship (coastal /inland)	Train	transportation energy	environmental impact
	years	m3	tonnes	distance in this mode [km]	distance in this mode [km]	distance in this mode [km]	distance in this mode [km]	distance in this mode [km]	distance in this mode [km]	distance in this mode [km]	distance in this mode [km]	distance in this mode [km]	distance in this mode [km]	GJ	ecopoints
Example material	*60*	*1000*	*2000*	*45*		*6*	*20*					*500*		*531.00*	*79.00*
Aggregate (marine dredged)															
Aggregate (typical UK)	**32**	4900					25							**193.58**	8000.52
Aggregate-recycled on-site (crushed concrete)															
Aggregate-recycled off-site (crushed concrete)															
Bitumen															
Blast Furnace Slag															
Brick (common)															
Brick (engineering)															
Concrete blocks (aerated)															
Concrete blocks (light aggregate)															
Concrete blocks (solid dense)															
Concrete - general mass 100% cement (25N/mm2)	**32**	19000					25							**2243.58**	98522.34
Concrete - general mass 70% cement 30% pfa (25N/mm2)															
Concrete - general mass 50% cement 50% ggbfs (25N/mm2)															
Concrete - mass blockwork 100% cement (30N/mm2)															
Concrete - mass blockwork 70% cement 30% pfa (30N/mm2)															
Concrete - mass blockwork 50% cement 50% ggbfs (30N/mm2)															
Concrete - mass armour units 100% cement (30N/mm2)															
Concrete - mass armour units 70% cement 30% pfa (30N/mm2)															
Concrete - mass armour units 50% cement 50% ggbfs (30N/mm2)															
Concrete - mass placed underwater 100% cement (30N/mm2)															
Concrete - mass placed underwater 70% cement 30% pfa (30N/mm2)															
Concrete - mass placed underwater 50% cement 50% ggbfs(30N/mm2)															
Concrete - reinforced and prestressed 100% cement (40N/mm2)															
Concrete - reinforced and prestressed 70% cement 30% pfa (40N/mm2)															
Concrete - reinforced and prestressed 50% cement 50% ggbfs (40N/mm2)															
Concrete - densely reinforced 100% cement (40N/mm2)															
Concrete - densely reinforced 70% cement 30% pfa (40N/mm2)															
Concrete - densely reinforced 50% cement 50% ggbfs (40N/mm2)															
Concrete - reinforced and prestressed 100% cement (45N/mm2)															
Concrete - reinforced and prestressed 70% cement 30% pfa (45N/mm2)															
Concrete - reinforced and prestressed 50% cement 50% ggbfs (45N/mm2)															
Concrete - densely reinforced 100% cement (45N/mm2)															
Concrete - densely reinforced 70% cement 30% pfa (45N/mm2)															
Concrete - densely reinforced 50% cement 50% ggbfs (45N/mm2)															
Cement mortar (very high strength)															
Cement mortar (high strength)															
Cement mortar (moderate strength)															
Cement mortar (low strength)															
Ground granulated blast furnace slag (GGBS)															
Polyester															
Polyethylene (high density)															
Polyethylene (medium density)															
Polypropylene	**32**		803				25							**76.39**	21194.83
Pulverised fuel ash															
PVC															
Rock- gneiss															
Rock- igneous (granite, diorite)	**40**	38050										3200		**124360.54**	333835.01
Rock- limestone															
Rock- reclaimed															
Rock- sandstone															
Rubber (synthetic)															
Sand															
Steel (galvanised)															
Steel (section)															
Steel rebars															
Timber- hardwoods															
Timber -reclaimed															
Timber- softwoods															
Zinc															

PB 12527 TR

Ergon House
Horseferry Road
London SW1P 2AL

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