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Economic Appraisal of Non-Grant Aided Work

Mott MacDonald Ltd
NRA Project Record 435/2/NW

NRA

National Rivers Authority

ECONOMIC APPRAISAL OF NON-GRANT AIDED WORK

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Project Record

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ECONOMIC APPRAISAL OF NON GRANT AIDED WORK
USER GUIDELINES

Project Record

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FOREWORD

This project has been carried out as part of the NRA's Research and Development Programme.

This report which comprises the Project Record, has been prepared by Mott MacDonald with contributions also made by Silsoe College. The principal authors were:

Mott MacDonald	Keith Howells
	Chris Finney
	Donald Brown
Silsoe College	Joe Morris

The NRA Steering Group for the project comprised Deryck Major (Project Leader), John Fitzsimons, B. Tinkler, C. Candish, G. Beel and J. Croft.

The principal output from this project is the Economic Appraisal of Non-Grant Aided Work User Guidelines (R&D Note 187).

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1 INTRODUCTION

1.1 General

The objective of the study, as stated in Section 2 of the Consultant's Brief of October 1992, is the production of a consistent appraisal method to replace the current varying regional practices which have been developed over the years, for non-grant-aided flood defence projects; that is, those costing under £500 000. Sections 4.0 and 5.0 of the brief both imply that the methodology developed will be 'to appraise the *economic* (our italics) worthwhileness' of such works.

In view of the importance of economic viability in determining project justification, the difficulties often involved in estimating economic benefits and the fact that most of those carrying out flood defence project appraisals are likely to be non-economists (for whom clear guidelines will be essential), the study is assumed to be concerned essentially with economic appraisal. It is recognised, of course, that social, environmental and other factors must also be considered when evaluating a project's justification and priority. Valuation of some of these factors so that they can be included in economic appraisals is discussed in Section 4.3.

The appraisal system to be developed should be as simple and robust as possible and should make maximum use of outputs from existing NRA research and other existing reports and information. Wherever possible, tables should be produced which can be used directly by those doing appraisals, just as the tables from the Middlesex Polytechnic Flood Hazard Research Centre's (MPFHRC) 'Blue', 'Red' and 'Yellow' manuals are used. In addition to the CRIMS User Manual, other NRA R&D reports of particular relevance include Asset Management Planning for Flood Defence, Programming and Prioritisation of River Works (the P&P report) and Evaluation of River Maintenance Strategies.

Guidelines on NRA economic analysis methodology were produced in April 1993. These have been taken into account in the formulation of the proposed methodology.

In developing the methodology, cost-effectiveness is an important factor, the aim being to ensure that appraisal costs are not excessive in relation to the cost of the project itself. It has been agreed with the NRA that, as a general guideline, appraisal costs should not exceed 5% of the project cost, and perhaps 2½% for larger schemes. The all-in daily cost of a typical engineer or other professional could be taken as, say, £300. For schemes below £100 000 the inference is that, as a general rule, professional staff inputs should not exceed 15 to 20 days, and for schemes in the £100 000 to £500 000 range the upper limit would be 40 to 45 days. Clearly, such limits should be applied with judgement, depending on the relative complexity of the scheme being appraised, but they do provide a rough indication of the appropriate level of appraisal effort and thus appraisal detail.

For maintenance projects, where the operations covered by the project will be repeated at regular intervals in the future, the above limits can be relaxed, if necessary, because the total expenditure on the project will, in practice, be several times the quoted project cost for each interval.

Work on the study began in late December 1992 and a Review of Literature report was submitted in late January 1993. Meetings were held with the NRA in January, February, April and May. Specific points emerging from these meetings include:

(i) As regards the types of projects to be considered, these will be 'works on the ground', both capital and maintenance, and will exclude other 'projects' such as, for example, purchase of vehicles or office equipment for general NRA use.

(ii) Within the next 2 to 3 years SOS (Standard of Service) data should be available for the whole country. Since the SOS data are likely to be the starting point for much of the benefit estimation this will be of great assistance for the future appraisal of projects.

(iii) The study should be based on readily available data which the NRA and other organisations already have.

(iv) In future appraisals conservation and other environmental benefits and disbenefits of projects should be clearly identified. Such aspects are now being given increased emphasis by the NRA. In view of the considerable effort required in the valuation of such benefits, however, the Consultant should refer to more detailed analyses and methodologies developed elsewhere.

(v) The lower scheme cost limit for economic appraisal would be £25 000, although the appraisal methodology developed for schemes of this size could also be applied to smaller schemes. Since, in specifying the standard of appraisal required, the NRA distinguishes between schemes costing below and above £100 000, two size ranges in terms of level of appraisal detail could be taken, namely £25 000 to £100 000 and £100 000 to £500 000.

(vi) In the Review of Literature report two Appraisal Framework options were put forward. Option 1 proposed a uniform appraisal procedure to be applied for all projects whereas Option 2 would involve a two stage process, with a more detailed analysis being carried out for projects with benefit-cost ratios, estimated in the initial screening, of between 0.5 : 1 and 3 : 1. It was agreed that Option 1 would be adopted for the study.

(vii) The April meeting discussed the Preliminary Draft Report and recommended that further examples should be carried out with information provided by the NRA. At least one example should be worked through to include a comparison of the RIMS methodology.

1.2 The Review of Literature

The review of literature was carried out in order to assess the information available for the study and to help provide ideas for the content and execution of the work and the approach to be adopted. It is reported in full in the January 1993 report. A brief summary of the main conclusions is reproduced below.

(a) Under NRA regulations there is a clear and binding requirement to carry out formal appraisals of all projects. Projects costing over £100 000 should be subject to full appraisal in line with Treasury guidelines. However, the level of study detail and effort provided should, quite rightly, be varied according to the size and importance of the project.

(b) As the Laurence Gould Consultants' proposal on a Simplified Benefit Assessment Technique suggests, study detail and effort could be varied in accordance with the likely marginality of the project, although the limits set to determine the appropriate level of study should be much wider than the LGC proposal indicated. This was the thinking behind our proposed Option 2, but, following discussion with the NRA Steering Group, this idea has been dropped (see Section 1.1)

(c) It is essential that, in addition to analysing the preferred project option, a proper, costed, comparison should be made of technically feasible options before selecting the option to be adopted. Such comparisons have often been lacking in the past.

(d) The Land Use Assessment data collected as part of the Standard of Service analyses in each NRA region provides a good base for the estimation of flood defence benefits.

(e) The benefit estimation methodology developed in the NRA Prioritisation and Programming Study and incorporated into the CRIMS User Manual constitutes a very suitable framework for the development of an appropriate appraisal methodology for projects costing below £500 000. However, a more simplified method of estimating agricultural and traffic disruption benefits is probably required than that proposed for the P&P system.

(f) Despite the need for economy in appraisal costs and the resultant need to use standardised values wherever possible for each project, specific analyses will be required, wherever possible, for:

- flood frequency - level - extent relationships;
- floor levels, to establish approximate flooding depths, by means of sample surveys.

(g) Though probably capable of further refinement, the Severity Weighting, Salinity Weighting and Drainage Factors recommended in the CRIMS User Manual are adequate for use in appraisals of projects costing below £500 000. Revised factors derived from future research should, of course, be introduced into the system as they become available, but in the meantime, the existing factors can be used.

(h) The CRIMS system provides a suitable base for the estimation of agricultural benefits, but benefit estimation will need to take account of the following:

- possible regional differences in crop costs and returns and net farm returns;
- the effects of Set Aside and the CAP price reforms;
- the build-up period required to reach the full level of benefits.

(i) There may be scope for a more standardised system of project costing.

(j) Future maintenance costs should be included in project economic analyses. In the past they have been omitted in some analyses.

(k) Sensitivity tests should be undertaken as a standard part of the economic analysis.

(l) Though not strictly within the scope of the present study, there is a need for more post-project appraisals of flood defences schemes.

1.3 Report Structure

The next section of this Report reviews sample appraisal reports that were supplied to the Consultant for a range of typical NRA flood defence schemes, in order to assess current appraisal approaches and levels of detail. The NRA supplied the Consultant with scheme reports from North West, Severn Trent, Thames, Wessex and Anglian regions.

A methodology for carrying out a cost-effective economic assessment of schemes is set out in Section 3.

Section 4 then discusses ways of assessing benefits from proposed projects. Four categories of benefits are discussed - agricultural, environmental, property, and traffic.

Worked examples are given in Section 5 as a means of testing the approach developed. Further details are provided in the appendices.

The principal output from this project is the Economic Appraisal of Non-Grant Aided Work User Guidelines (R&D Note 187). These are produced as a separate report and include all the required tables and graphs to carry out the simplified methodology for economic appraisal.

2 REVIEW OF THE SAMPLE NRA APPRAISAL REPORTS

2.1 General Review

Table 2.1 summarises the main details for the 27 NRA scheme reports received. Since this study is concerned with economic appraisal, for many of the scheme reports only those sections dealing with the economic appraisal were received. In the table we have classified schemes into three categories, Capital, Asset Renewal and Maintenance (see Section 3.1) and the type of works has also been specified in broad terms.

We have reviewed the received reports in some detail and have the following comments:

(a) As might be expected, there are differences in approach and reporting between regions, but the overall standard of project appraisal in the reports seen appeared to be satisfactory.

(b) Nevertheless, many reports give relatively little detailed explanation of how the economic results were derived. Generally, the emphasis is on figures rather than text. Clearly, the production of lengthy reports for small schemes would be difficult to justify in cost-effectiveness terms, but in most reports the level of explanation given would be insufficient to convince sceptical outside reviewers who might wish to confirm the validity of the economic results. This comment is given increased validity by the fact that many of the schemes analysed gave only modest economic returns, with benefit-cost ratios not greatly in excess of 1:1.

In a few cases the extent (hectarage) of land protected was not specified. For those schemes for which flood damage - frequency curves were derived no description was given of flood extents, depths and durations for different return periods, even though these parameters would generally have been estimated as part of the damage cost calculations.

(c) As can be seen in Table 2.1, the level of detail in the economic appraisals varied widely between schemes and regions. For a few capital projects full flood damage-frequency curves were produced whereas in some maintenance projects no economic analysis was undertaken. As demonstrated in Section 2.2, appraisal costs per scheme varied very greatly. This variability in appraisal detail underlines the need for increased standardisation in economic appraisal methodology between regions.

TABLE 2.1

Details of the NRA Scheme Reports Received[1]

Name	Scheme cost (£'000)	Scheme category	Type of works	Benefit-cost ratio	Damage-frequency curve calculated	Extent of land protected specified in report	Alternative options compared	
ANGLIAN								
Trimley Foreshore recharge	57	Asset renewal	Wall refurbishment	Not given	No	Yes	Yes	Appraisal based on eventual collapse of flood defence system in Do Nothing situation
Improvement of Tidal Walls, Mell House	710	Asset renewal	Wall refurbishment	1.22-1.66	No	Yes	Yes	Appraisal based on eventual collapse of flood defence system in Do Nothing situation
NORTH WEST								
Four Revenue projects	10-41	Maintenance	Repairs, dredging, regrading, watercourse clearance	Not calculated	No	No	No	Simple qualitative scheme justifications were given
Burnside	65	Capital	Walls, channel improvement	1.12	No	NA	Yes	
Bolton le Sands	107	Capital	Bank raising	1.78	Yes	Yes	No	Detailed house-by-house damage assessments made
River Douglas	489	Capital	Bank strengthening	5.43	No	Yes	Yes	Appraisal based on eventual collapse of flood defences in Do Nothing situation
Centre Drain Tidal Outfall	209	Capital	New tidal outfall, channel resectioning	1.59	No	Yes	Yes	Modification to plans to allow for views of the NCC & RSPB
Deys Brook	80 (+425)	Capital	Channel improvement (Culvert improvement)	1.63	Yes	Yes	No	Private developer to contribute £425,000 to associated works
Janson Pool Sea Embankment, Thurnham	80	Asset renewal	Embankment improvement	1.81	Yes	yes	No?	
River Mersey	400	Capital	Raise defence levels	0.5	Yes	Yes	Yes	

TABLE 2.1 (cont)

Details of the NRA Scheme Reports Received[1]

Name	Scheme cost (£'000)	Scheme category	Type of works	Benefit-cost ratio	Damage-frequency curve calculated	Extent of land protected specified in report	Alternative options compared	
SEVERN TRENT (all analysed using RIMS II)								
W Stockwith		Asset renewal?	Retaining wall	5.30	No?	Yes (1930 HE)	No?	
Five maintenance schemes	3-18	Maintenance	Dredging and clearance, weed control	0.72-22.70	No?	Yes, in HE	No?	
Rylands Wall/ Beeston Canal Embankment	1.5 million	Capital	Walls	37	Yes	Yes	Yes	Larger cost scheme, included to allow for a comparison using the RIMS approach
THAMES								
Thornwood	283-526	Capital	?	<1	Yes	?	Yes	Only the economic sections of the report were received. Questionnaire survey done
Sor Brook	22-101	Capital	Bank protection and flood relief	0.2-0.78	No	?	Yes	Only the economic section received
WESSEX								
Sturminster Marshall	369	Capital	Banks, walls, etc	1.28	Yes	?	?	House-by-house damage assessment made
Muchelvey	45	Capital	Banks	1.12	Yes	No	?	
Long Load pump station	114	Asset renewal	Pump replacement/ improvement	4.2	No	Yes	Yes	Appraisal based on serious drainage deterioration in Do Nothing situation
Yeovilton Weir	36	Capital	Weir improvements	NA	No	No	No	Weir improvements essential for health and safety reasons

Source: Appraisal report excerpts supplied to Mott MacDonald by the NRA.

Notes: (1) For many schemes only brief excerpts from the reports (often just the economic appraisal section) were provided.

(d) The variation in methodology is greatest in the case of maintenance projects. For the five North West Region schemes the justification for these small revenue projects was given in qualitative terms only, whereas full benefit-cost (B/C) ratios were calculated for the five Severn Trent maintenance projects, using RIMS II. As noted in Section 3.2 of our January 1993 report, the need for formal B/C analysis of projects involving clearly necessary routine maintenance may well be questionable, but some kind of quantified measure, perhaps one based on cost-effectiveness, is desirable in order to demonstrate a maintenance project's justification. One useful parameter might be the annual equivalent cost (at 6% discount rate) per HE (house equivalent) protected, using the SOS data (see below).

(e) RIMS II calculates benefits in terms mainly of a comparison of flood damage with and without project and involves complex assumptions and calculations. A simpler approach to estimating the benefits from maintenance and asset renewal schemes is that adopted for three schemes listed in Table 2.1, namely that, in the Do Nothing situation, the flood defence system will deteriorate until flooding eventually reverts to its natural condition. As a simplifying assumption the current level of protection is taken to continue for another 5 or 10 years, after which the level of economic output and/or flood damage falls directly to its assumed level.

Although this method involves arbitrary assumptions regarding the length of time to reach flood defence collapse, and the full reduction in economic benefit is then considered to take place immediately, the method is sound in principle and is easy to understand and apply. RIMS II and other more sophisticated systems may appear to give more accurate results, but they usually involve even more assumptions, some of them just as arbitrary (see below).

(f) It is encouraging to note that, for most of the schemes, alternative technical options were assessed, rather than just that option finally selected.

(g) For two schemes detailed assessments of house-by-house flood damages were made and a questionnaire survey was undertaken in a third. Data on floor levels were available for at least two schemes.

RIMS II Analyses

The six Severn-Trent schemes initially supplied to the Consultants were all analysed using RIMS II, the material received by us comprising a considerable volume of computer printouts and some hand-written data and explanation. Table 2.2 summarises key economic data derived from the material supplied.

Subsequently, analysis for another scheme (Rylands Wall/Beeston Canal Embankment) was provided to the Consultants. This was a more expensive capital scheme and was used to provide a comparison of approaches in the methodology, see Section 5.4.

TABLE 2.2

Economic Data for the Six Severn Trent Schemes Analysed with RIMS II

Scheme	HEs at risk	Scheme life (years)	Cost (£'000)	Annual benefits (£'000)	B/C ratio	Annual equivalent cost per HE protected (at 6%)	Agricultural benefit area (ha)	Annual agricultural benefits per ha (£)
River Sow	3 734	1	2.5	56.7	21.4	0.7	-	-
W Stockwith	1 930	25	360.0	149.3	5.30	14.6	5 980 (extensive arable)	3.0
River Tame (Oldbury Arm)	1 247	10	18.0	55.5	22.7	2.0	-	-
River Alne	228	10	11.1	1.1	0.72	6.6	20 (mixed land use)	-
Hermitage Brook	4	1	3.5	7.85	2.11	-	19 (mixed)	414.4
Bromley Brook	33	5	8.0	3.4	1.77	57.6	192 (mixed)	17.5

Source: Derived from report material supplied to Mott MacDonald by the NRA.

At first sight RIMS II could provide the basis for estimating project benefits and economic viability in all regions, not only Severn Trent. However, this may not be appropriate at this stage, for the following reasons:

- setting up a system such as RIMS is time-consuming and has heavy data requirements;

- its accuracy in estimating project benefits is not yet proven. Severn Trent recognises that there are still problems with the agricultural benefit calculation, because in many cases the model assumes that a significant change in drainage status results in a change in land use scenario (eg intensification of farming) rather than just a change in productivity within the existing land use system. The latter is probably a more common outcome of improved drainage conditions, the result being that the model as set up at present tends to over-estimate agricultural benefits. This may be the reason for the apparently unrealistically high level of benefits calculated for the Hermitage Brook scheme. Solutions to the problem are currently being investigated by Severn Trent and Silsoe College;

- within the model there are numerous assumptions on the physical benefits of five different types of channel maintenance and the dis-benefits of not carrying out maintenance. These are recognised to be rule of the thumb figures rather than the product of research.

- formulation of such assumptions is essential in order to provide the coefficients required for operation of the RIMS II. Nevertheless, with the totality of these and the other benefit assumptions combined together, the end result may be no more accurate and reliable than that obtained from other, simpler, methodologies such as the Do Nothing deterioration approach outlined above;

- the RIMS II output received by us for the six schemes is user-unfriendly and not easy to follow. With a highly mechanised computer-based system such as RIMS this may be unavoidable, but the lack of explanation and 'transparency' in the figures presented reduces its attractiveness. Maybe this deficiency can be overcome in the future;

- the justification for using bank full capacity under differing maintenance systems (ie with and without works) as a proxy for flood extent is not well explained.

For each of the six schemes the NRA also provided figures on the total HEs at risk in the area to be protected. A brief analysis was made (Table 2.2), to see if there was any correlation between the B/C ratios and the cost-effectiveness criterion of annual equivalent cost of the scheme per HE protected. The degree of correlation was not high, as might be expected, because the HE parameter refers only to the total stock of assets being protected, not the 'without project' incidence of flooding of these assets and its economic effects. Using the SOS data on average annual flood damage in HE per km of watercourse, however, an estimate of average annual damage per hectare of land protected could be derived. Annual equivalent project cost per HE of average annual flood damage in the protected area could be expected to give a much closer correlation with B/C ratios for particular schemes.

2.2 Appraisal Effort and Cost for Sample NRA Schemes

To obtain an impression of the level of appraisal effort and cost expended in relation to the level of detail in the economic appraisal report and scheme cost, the NRA was asked to provide information on the approximate number of person-days spent on the economic appraisal of many of the sample schemes. It was stressed that scheme design, cost estimation and other study components outside the economic appraisal should be excluded from these estimates, but the very high figures quoted for certain schemes suggests that perhaps some non-appraisal input figures have crept into the estimates. The information provided is summarised in Table 2.3, along with broad estimates of the inputs for two Mott MacDonald studies.

TABLE 2.3

Reported Appraisal Costs for the NRA Sample Schemes and Two Mott MacDonald Studies

Scheme	Capital cost (£'000)	Person-day input[1]	Cost at £300/d (£'000)	Cost as % of scheme cost	
North West Region					
Burnside	65	5	1.5	2.3	
Bolton-le-Sands	107	8	2.4	2.2	Flood damage-frequency curve produced
R Douglas (whole scheme)	489	8	2.4	0.5	
Thames Region					
Sor Brook	33-101	17	5.1	5.0-15.5	
Thornwood	283-526	415	124.5	30.0-44.0	Flood damage-frequency curve produced. 130 days spent on hydraulic modelling
Wessex Region					
Sturminster Marshall	369	80	24.0	6.5	Damage-frequency curve produced
Muchelney	46	30	9.0	19.6	Damage-frequency curve produced
Long Load	123	5	1.5	1.2	
Yeovilton Weir	35	1	0.3	0.8	No economic analysis done
Mott MacDonald Studies					
Fox Brook	187	10-15	3.0-4.5	1.6-2.4	Damage-frequency curve produced
Boroughbridge	549-1 573	20-30	6.0-9.0	0.4-1.6	Damage-frequency curve produced

Source: Data from NRA and Mott MacDonald.

Note: (1) In engineer-day equivalents. Cost assumptions: technicians 0.75, chainmen and typists 0.5 of an engineer's cost.

Although the accuracy of the data is very approximate, the variation in the level of appraisal effort and cost between the various studies is striking. For schemes for which economic analyses were undertaken, total inputs ranged from 5 to 415 professional person-day equivalents, although all but one were below 80 days. In some cases the appraisal cost, at an assumed all-in cost of £300 per professional person-day, was equivalent to a very substantial percentage of the scheme capital cost. In four of the 10 schemes for which economic analyses were undertaken the assumed appraisal cost exceeded 5% of the scheme capital cost. The fact that flood damage-frequency curves were produced for three of these four schemes suggests that the hydrological and hydraulic modelling involved in producing such curves can be extremely time-consuming. In other studies in which such curves were produced, however, the appraisal costs were not excessive.

Perhaps the main conclusions to be drawn from the above analysis are, first, that it is certainly possible to carry out an acceptable cost-benefit analysis for some capital schemes costing below £500 000 for less than 2.5% of its capital cost and, secondly, that the hydrological modelling and other tasks related to the production of a flood damage-frequency curve are likely to be the main cause of excessive appraisal study inputs and cost. Tight control of the effort put into deriving acceptable flood damage-frequency curves will therefore be a key task for those responsible for managing studies of schemes costing less than £500 000.

Ideally, a flood damage-frequency curve should be produced for all projects in the £100 000 to £500 000, because such a curve does generally improve the accuracy of the benefit estimates. On the basis of the limited data available in Table 2.3, however, the study costs involved in producing a flood damage-frequency curve can easily become excessive in relation to project costs. On the Thornwood scheme, for example, 130 days were spent on hydraulic modelling. Where the data available are insufficient to enable a flood damage-frequency curve to be produced at an acceptable cost, a suitable short cut method (see Section 2.3) should be used.

For schemes of £25 000 to £100 000 the formulation of a flood damage-frequency curve will not normally be justified on cost-effectiveness grounds. Short-cut methods should normally be employed.

2.3 Flood Damage-Frequency Curves for the Sample Schemes

For any particular scheme the shape of the flood damage-frequency curve has a major influence on the level of average annual benefits, which is based on the total area under the curve. In the CRIMS system the derivation of the average annual flood damage values from the land use assessment (the estimation of total HEs in the flood risk area) is based on an assumed curve. In the Rapid Benefit Assessment Technique proposed by P D Younge, the aim of which is to simplify benefit assessment for smaller schemes, a straight line ‘curve’ based on the flooding threshold return period flood and the 1-in-50 year flood was proposed.

In order to ascertain curve shapes 'in practice' the flood damage curves derived for the four NRA sample schemes for which they were produced, and for three schemes studied by Mott Macdonald, are presented in Figure 2.1. To facilitate comparison, the values have been semi-normalised so that the 1-in-100 year return period damage is in the £400 000 to £500 000 range.

All seven curves follow a similar trend, with a distinct crescent shape of curve. Clearly, the adoption of a straight line curve, as proposed by Younge, seems unlikely to be valid. By increasing the area under the curve above that which is likely to apply for most projects, it has the effect of substantially exaggerating the average annual benefit.

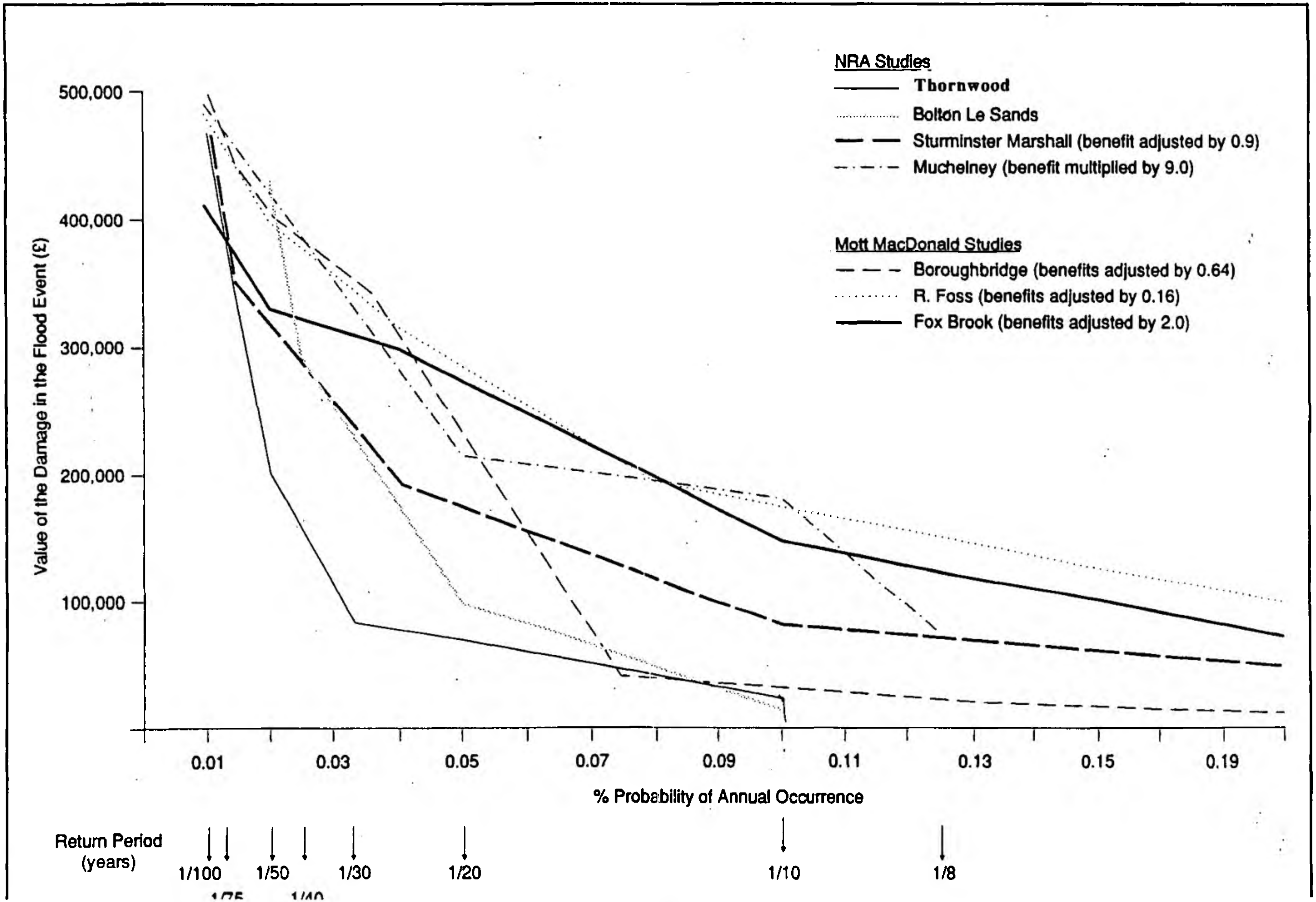


Figure 2.1
Flood Damage Frequency Curve
From Existing Studie

3 METHODOLOGY AND APPROACH

3.1 Introduction

This report is primarily concerned with the development of simplified approaches to benefit assessment in the economic appraisal of non-grant aided flood defence works, which have a cost ceiling of £500 000. The aim is to provide a robust method of appraisal which is appropriate to the value of works carried out. The methodology adopted is thus to be related to the magnitude of the works. The limits applicable to this have been agreed (see Section 1.1) as:

Category 1	>£500 000	Full MAFF Appraisal
Category 2	£100 000 to £500 000	Intermediate level methods
Category 3	<100 000	Simplified methods

The principal types of work which need to be considered (see Section 4.1) are:

- small capital schemes
- maintenance works
- asset renewal

Appraisal is based on the 'with' and 'without' project approach and the most critical factors are the assumptions made regarding system hydraulic performance in either case. In the case of asset renewal, for example, the assumptions made regarding failure mechanism will generally be critical. For this reason, it is important that some form of sensitivity analysis is carried out as part of the appraisal.

A 'project' is defined as any single action or sequence of actions which serves to modify the flooding or drainage characteristics of the reach being considered. These actions may be construction of capital works, maintenance operations, etc.

It should be kept in mind that the economic justification is only one of the factors to be taken into account in the decision making process regarding the provision of flood defence. It is noted, however, that under Treasury rules all 'projects' need to be economically justified.

The approach to benefit assessment for Category 2 and 3 projects is described in Section 3.4. Prior to discussing this, however, the economic appraisal framework is outlined in Section 3.2 and the general approach to physical flood impact assessment in Section 3.3.

3.2 Economic Appraisal Framework

The broad approach to economic appraisal, see Figure 3.1, can be summarised as follows:

1. Identify the problem (eg, flood risk, waterlogging, asset needs replacing).

2. Identify the objectives of any solution (eg, are there wider issues to be considered than the immediate problem ?).

3. Identify the options (improve, sustain, retreat strategies; capital, maintenance, asset renewal, replacement; short term, long term, phased programs) for solving the problem for comparison with the 'do nothing' (ie without project) case.

4. For each option:

   - Estimate the costs (capital, maintenance, renewals, etc & the project life)
   - Select the benefit assessment methodology (simple, intermediate, full) based on cost threshold
   - Identify impacts and benefits to consider
   - Quantify benefits in relation to the 'do nothing' case
   - Discount benefits and costs over the project life to calculate the benefit-cost ratio and the net present value using the Treasury discount rate (6% in 1993).

5. Test sensitivity of assumptions.

6. Compare options.

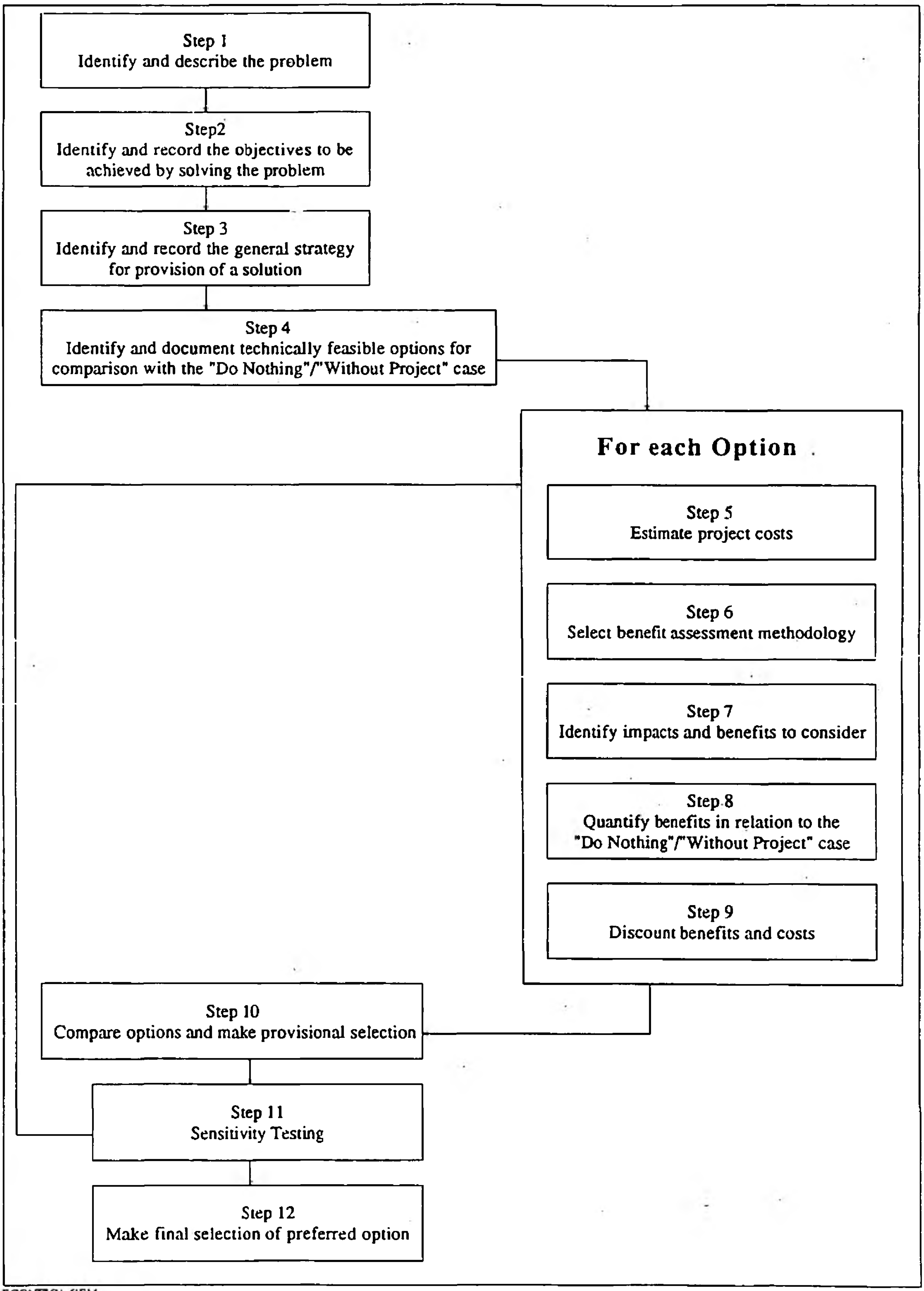
7. Select 'best' option also taking account of other non-economic factors, eg social and environmental considerations.

The major assumptions generally relate to hydrology/hydraulics and hence to flood extent, although other assumptions may be critical in some instances (eg, failure mechanisms for existing defences, delay in realisation of benefits).

3.3 Physical Impact Assessment

The damage caused by flooding is related to flood extent, depth and duration. In a full appraisal, all these factors would need to be estimated with reasonable accuracy. However, for simplified appraisals, a less demanding analysis would be acceptable.

Figure 3.1
Economic Appraisal Methodology



ECONFIG1.GEM

Two approaches have been adopted to flood impact assessment in previous appraisal methodologies:

- the estimation of flood extent for various return period events using hydrological, hydraulic and topographic information to establish the land use interests affected;

- the RIMS approach, which uses bank full capacity as a proxy for flood extent.

The RIMS approach assumes that once the flow is out of bank, all land use interests within the floodplain are affected. The method incorporates an empirical adjustment factor which makes allowance for the fact that low return period events flood properties to a lesser depth than high return period events.

There is little doubt that the first approach is more rigorous, although it also requires more effort. For the purposes of economic justification of works, it is the recommended approach, although the RIMS approach may also be considered as an alternative for works less than £100 000. This is discussed later.

It is not the purpose of this report to elaborate on the techniques for estimating flood extent, depth and duration. As noted earlier, the greatest assumptions and uncertainties regarding the economic justification of works relate to this aspect of the calculation, and appropriate sensitivity analyses need to be carried out. It is thus important that the best available information is adopted for this part of the analysis. Previous studies, hydrological analyses, hydraulic model studies, etc may be available. Where not, resort will need to be made to (simple) hydrological analysis (eg: Flood Studies Report catchment parameter methodology or local equivalent), hydraulics (Manning or simple backwater programs), and also local information relating to historical events.

The approach developed also allows for drainage impact assessment, see Table 4.3. This is explained further in Appendix A.

3.4 Approaches to Simplified Benefits Assessment

3.4.1 General

The approaches to simplified benefits assessment described have been built up from related work carried out under the NRA Research and Development Programme on Standards of Service (SoS) and Prioritisation and Programming (P&P) of Flood Defence Work. Various approaches have been tried for a variety of works and validated against full MAFF-type assessments provided by NRA Regional Offices in order to establish a range of techniques and identify the most appropriate relative to the scale of works involved.

As part of the validation exercise, appraisals for a number of small capital schemes were examined. In most cases, it was observed that the number of land use interests affected was relatively small and a full MAFF appraisal would not be that onerous. It is thus possible that the simplified methods discussed here will be more applicable to maintenance works and asset renewal than capital schemes.

All of the approaches to flood damage assessment described follow the same basic principles:

(a) establish the physical flood impact 'without project' for a range of design return period events;
(b) establish the land use interests affected for each return period event;
(c) estimate the damage caused for each return period event;
(d) establish the physical flood impact 'with project' for the same range of return period events;
(e) establish the land use interests affected for each return period event;
(f) estimate the damage caused for each return period event.

The difference between items (f) and (c) represents the benefit of the project in terms of damage avoided. Any additional benefits (eg, amenity, waterlogging) should be added, if appropriate: these are discussed separately later. The benefits of the project can then be discounted and compared with the discounted cost to establish the Benefit-Cost Ratio and the Net Present Value (NPV). If required, the Capital Rationing Ratio (NPK) calculated as NPV divided by capital cost can also be calculated as an indicator of efficiency of use of capital.

3.4.2 Land Use Assessment

Under the SoS approach, all land use subject to flood risk is to be recorded and evaluated using a common numeraire, referred to as the Household Equivalent (HE). This database provides a source of information which can be used to estimate flood damages as part of the simplified benefits assessment.

A key determinant in the use of the HE for this purpose is the 'value' of one HE in economic terms. Two approaches have previously been used when calculating HE values for other (ie non-housing) land uses. Chatterton and Green (1988) used the conventional annual average damage (AAD) approach to derive a value of £153 per HE. Gould Consultants (1990) used the 'average cost of a flood' approach to derive a (recently updated) value of £1 134 per HE.

In terms of calculating *relative* HE values for other land use types for the purposes of land use assessment, either approach is acceptable, as long as the methodology is consistently applied: a comparison made during the P&P study indicated little significant difference in HE values calculated. These values do, however, clearly represent quite different things, and care needs to be taken of which value is appropriate when converting HEs to currency for the purposes of benefit assessment.

3.4.3 Rough Estimate of Order of Benefits

In the simplest case, a rough estimate of the maximum value of works which might be justified in a reach (or series of reaches) could be obtained by adding up all the HE values in the reach and multiplying by the HE annual average damage figure. This would give an indication of the broad order of annual benefits which might accrue if flooding could be completely mitigated by the project. While crude, this approach may be of help in developing a 'feel' for the order of benefits which can be obtained and hence the amount worth spending. It may thus give an early indication of the type of solution (if any) which could be justified in a particular reach.

The HE annual average damage figure has been updated and is estimated to be £1135 (1993). The methodology adopted and assumptions made differ slightly from those used by Chatterton and Green.

3.4.4 Benefit Assessment

Four approaches have been identified as having potential for flood impact benefit assessment:

1. A 'short cut' approach for low cost schemes where limited information is available.

2. Use of flood extent mapping for different return period events and recorded HE values within these flood extents to establish benefits.

3. Use of bank full capacity as an indicator of flooding impact and use of recorded HE values in floodplain as an indicator of benefits (RIMS) approach.

4. Use of flood extent mapping for different return period events and with separation of land use interests within flood extents into categories to establish benefits with greater accuracy, following the methods used in the P&P study.

These approaches are described more fully below. Quantification of environmental benefits has not been attempted in this study, see Section 4.3.

Most of the methods outlined in this note rely on the availability of land use data collected for Standards of Service (SoS) purposes and expressed in terms of Household Equivalents (HEs). HE values for different land uses are given in Tables 3.1 to 3.3.

The with and without project assumptions may relate to maintenance (eg roughness or cross-section assumptions), to capital works (new defences, raised defences, re-sectioning) or to asset renewal (impacts of failure without project). The physical impacts with and without project need to be evaluated using appropriate methods. Guidelines on maintenance and asset renewal in this respect are provided in Appendix B of the User Guidelines (see R&D Note 187), although these should not overrule the judgement of the engineer responsible for the appraisal.

Approach 1 (Based on Normalised Damage Frequency Curve)

This very simple approach requires little data but has limited accuracy. At present, it can only be recommended for small capital schemes where there is little information available and the man-day budget precludes the data collection and analysis effort required to obtain better information. The method uses a normalised Flood Damage-Frequency Curve and relies on there being basic information from one (or more) historic flood(s) which can be used to quantify the damages attributable to that flood.

Step 1 Based on existing flooding information, quantify the damages which have occurred during an event of known or estimated return period. If the number of HEs affected is known, the damage can be assessed from:

Nr HEs affected x £1135

Step 2 For the known return period of the event, use Figure 3.2 (normalised depth-damage curve) to estimate D^*, the normalised damage value.

Step 3 Divide the actual calculated damage value by D^*, to give the Annual Average Damage value without project.

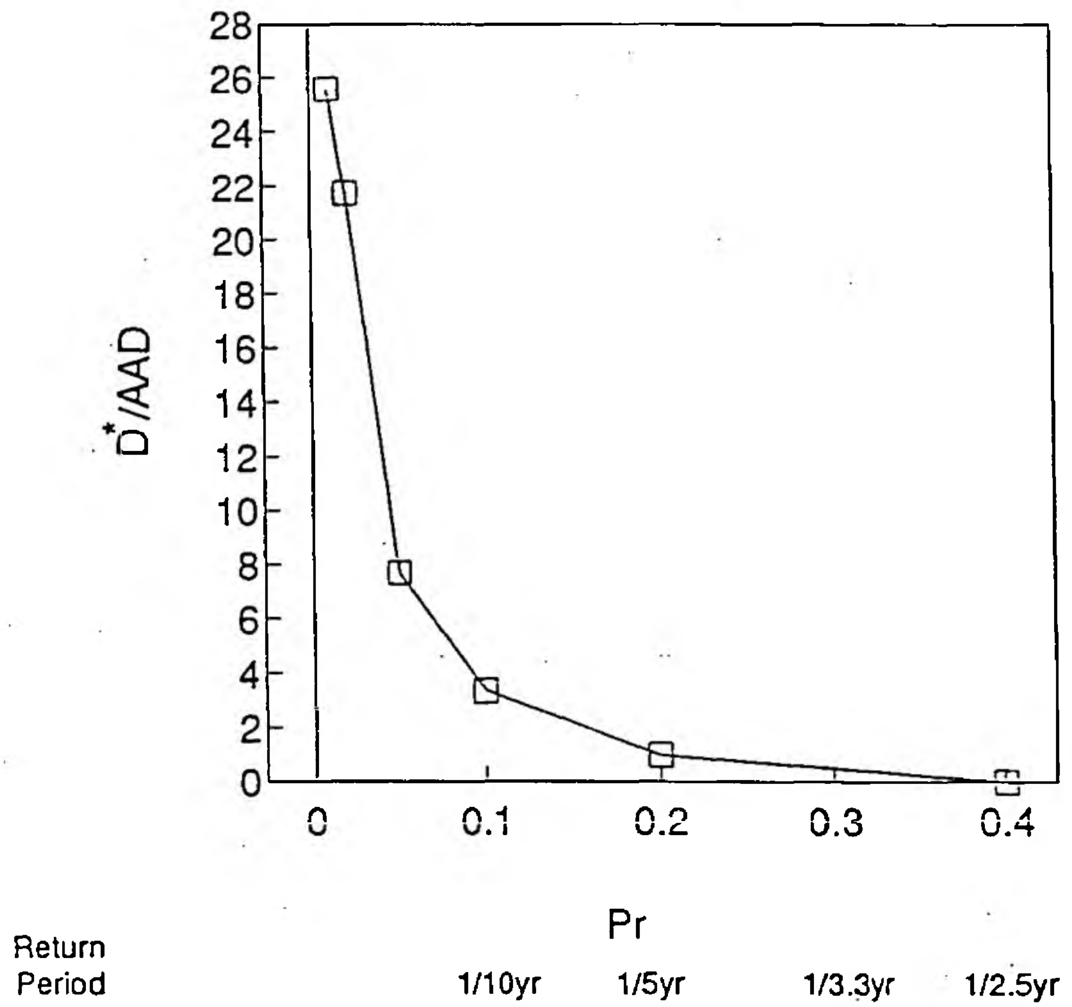
Step 4 Depending on the design standard of the solution, estimate the annual benefit of the project using Table 3.4, which gives a factor used to adjust the without project annual average damages to reflect the design standard. For example, for a 10 year design standard, the annual benefit would be 25% of the without project annual average damage.

Approach 2 (Based on HEs affected by floods of varying magnitude)

This approach relies solely on HE values for all land uses within known or calculated flood extents.

Step 1 Establish flood extent for "without project" situation using best information for a range of floods (eg: 2, 5, 10, 20, 50, 100).

Step 2 Calculate the number of HEs affected (all land uses) within flood extent for each



Notes:- D^* = normalised damage value = V / AAD
V = actual calculated damage value
AAD = annual average damage value
Pr = return period

Return Period, Years	Normalised Damage Value, D^*
2.5	0.00
5	1.00
10	3.36
20	7.71
50	21.75
100	25.60

Step 3 Calculate Annual Average Number ($AAN_{without}$) of HEs affected without project, as indicated in Figure 3.3.

Step 4 Establish flood extents for "with project" situation for the same range of floods (eg: 2, 5, 10, 20, 50, 100).

Step 5 Calculate HEs affected (all land uses) within flood extent for each flood return period with project: will be none up to "design" standard.

Step 6 Calculate Annual Average Number (AAN_{with}) of HEs affected with project (see Figure 3.3).

Step 7 Difference in $AAN_{without}$ and AAN_{with} is the flooding impact annual average benefit of the "project", expressed in HEs.

Step 8 This can be multiplied by the average damage caused to one HE by a flood (£1135) to derive the annual average benefit expressed in financial terms.

Step 9 Other annual benefits (amenity, conservation, waterlogging) are added to this, where appropriate.

Approach 3 (Based on Flood Capacity)

This approach uses flood capacity as a proxy for flood extent: in essence, it assumes that all land use interests in the floodplain are affected to some extent, once the river banks/defences are overtopped. It is thus most appropriate to channels and defences with flat floodplains and raised defences of limited capacity. It requires information relating to the return periods of floods of varying magnitude, such as a simple flood discharge frequency curve.

Step 1 Estimate the return periods of floods of a range of magnitudes for the catchment upstream of the reach being considered.

Step 2 Estimate the bank full capacity of the channel/defence without project and the associated probability of overtopping ($Pr_{without}$).

Step 3 Estimate bank full capacity with project and the associated probability of overtopping (Pr_{with}).

Step 4 Calculate ($Pr_{without}$-Pr_{with}) and multiply this by the number of HEs in the floodplain to derive the annual average benefit, expressed in HEs. This can be expressed in financial terms by multiplying by the average HE damage figure (£1135).

Step 5 Add other benefits (amenity, conservation, waterlogging).

Approach 4 (Based on Separated Damage Categories)

This method is more rigorous than the methods outlined above and closer to MAFF appraisal requirements. As a consequence, it is more data and effort intensive and is more suited to the larger projects.

Step 1 Establish flood impacts (extent, depth, duration) for "without project" situation using appropriate information (hydrology, hydraulics, past experience) for a range of design events (eg: 2, 5, 10, 20, 50, 100).

Step 2 ***For property damages***, calculate number of HEs affected (all property types) within each flood extent for 6 flood depth categories, as outlined in Table 3.5, and apply the standard HE depth-damage values from Table 3.5 to the number of HEs in each depth category to establish property damages for each design event. For saline flooding, values are increased by 15%. Table 3.6 presents adjustment factors to allow for flood warning.

Step 3 ***For agricultural damages***, Table 3.7 presents the cost of flood damage (£ per ha) for single floods for various land uses for large and small catchments. For each option (including without project), the damage is calculated by multiplying the areas of flooded land of different uses by the appropriate values selected from the table. Table 3.8 presents multipliers to be used if flooding is with saline water.

Step 4 ***For traffic disruption***, Table 3.9 presents a summary of costs (£ per hour) for different road categories for different lengths of diversions around floods at different diversion speeds. The damage is calculated by multiplying the appropriate value selected from the Table by the duration of road flooding (estimated from the flood hydrograph using a threshold trafficability value of 0.20m depth of water over road). For shallow flooding, the diversion length can be taken as being the same as the normal route (ie Diversion Length/Normal Route Length of 1 in Table 3.9), but a speed reduction can be assumed.

Step 5 Sum damages for each return period event.

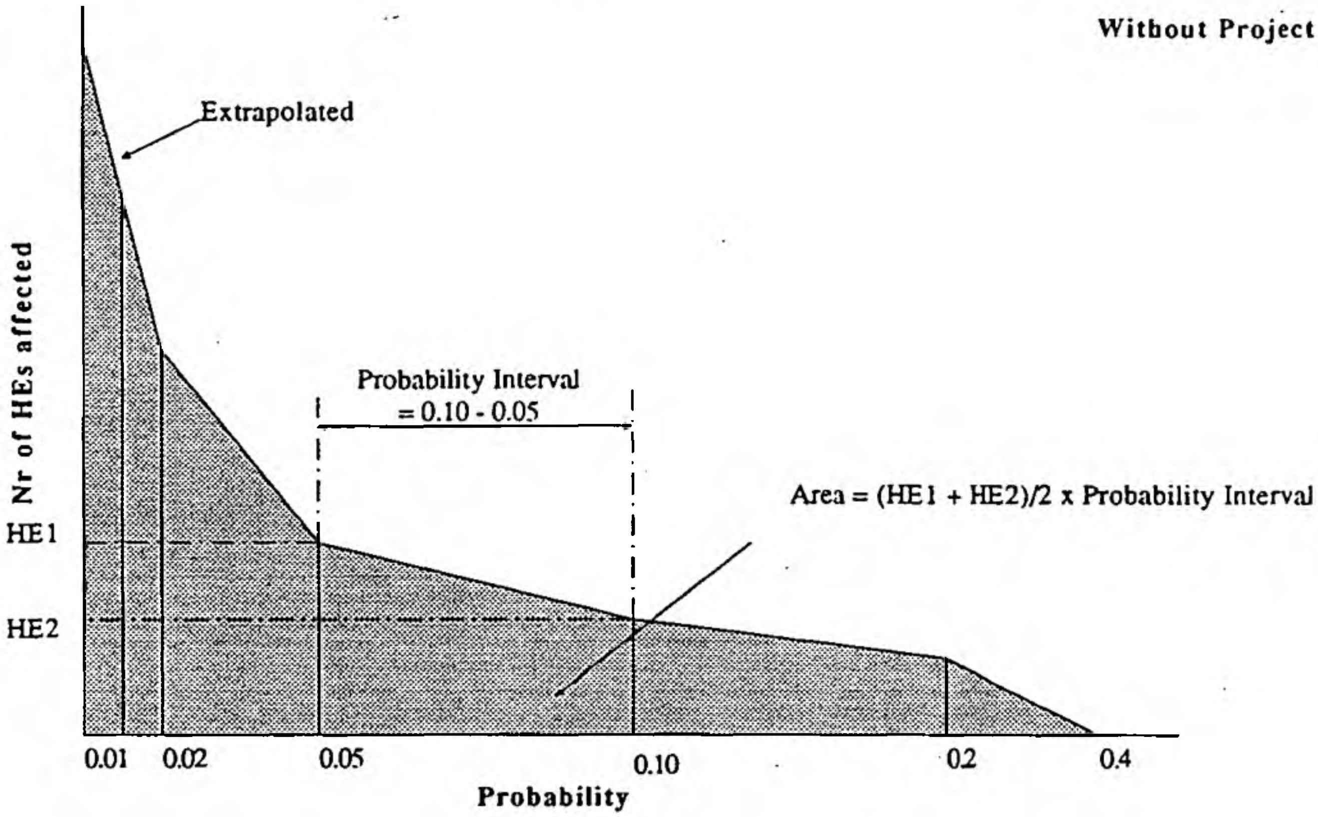
Step 6 Calculate annual average damages without project ($AAD_{without}$) as indicated by Figure 3.4.

Step 7 Establish flood impacts for "with project" situation for the same range of floods (eg: 2, 5, 10, 20, 50, 100).

Step 8 Repeat steps 2 through 5 for with project case.

Step 9 Calculate annual average damages with project (AAD_{with}). See Figure 3.4.

Figure 3.3
Annual Average Number of HEs Affected



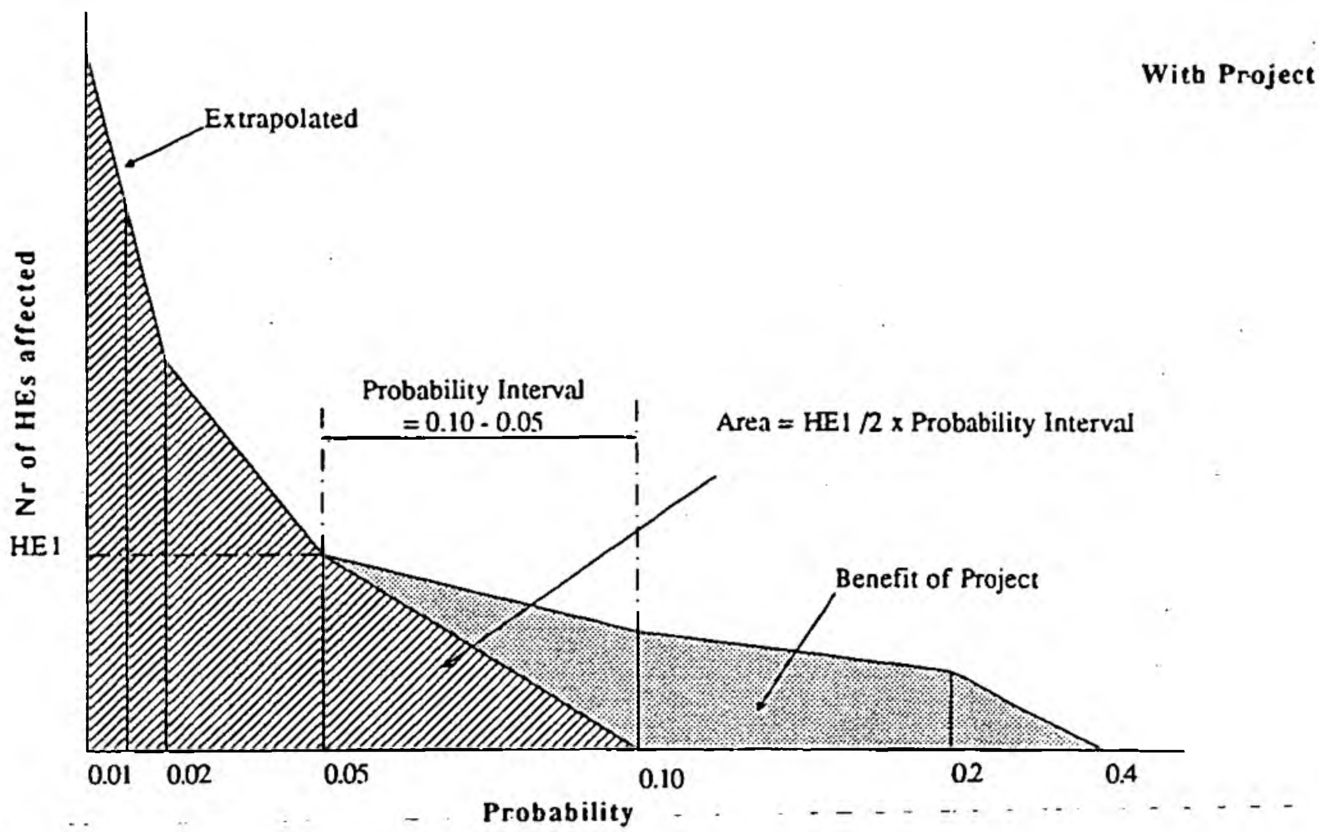
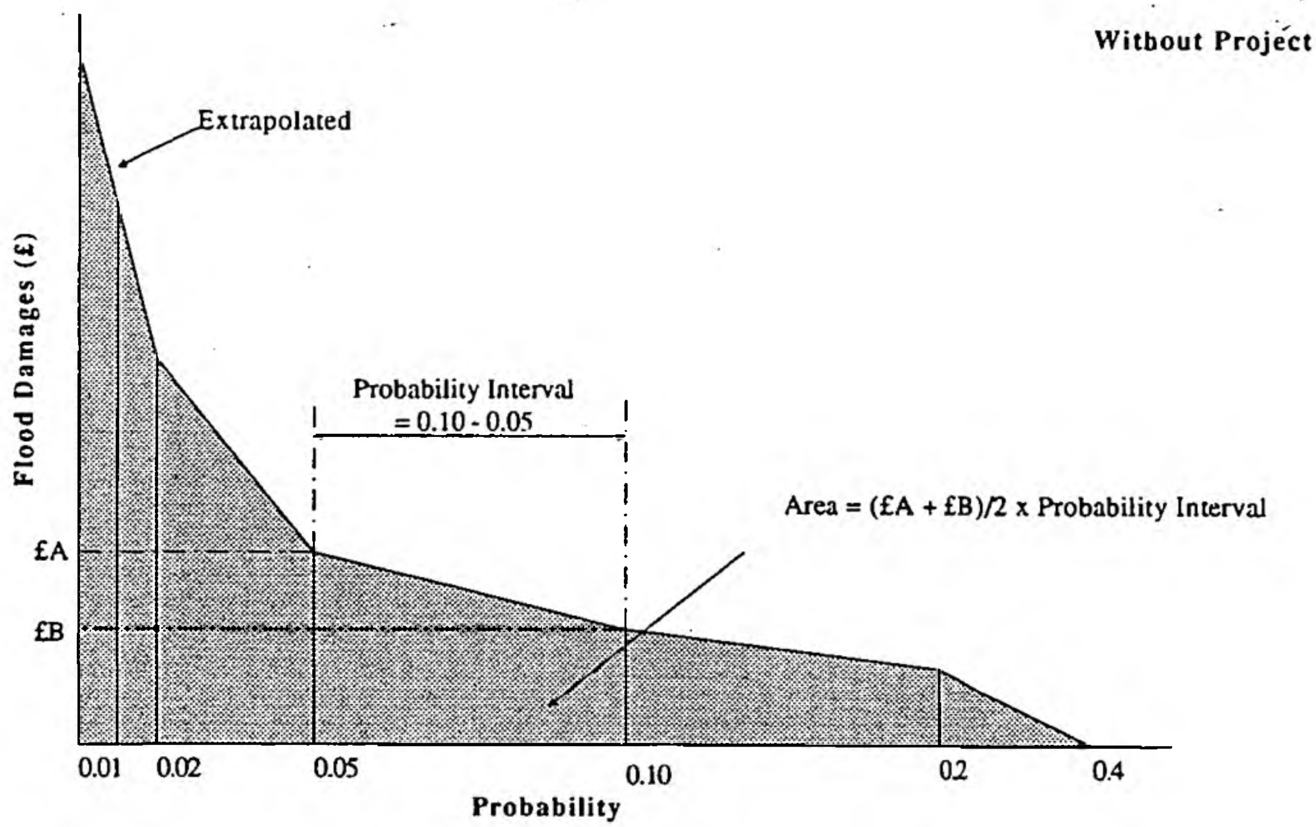
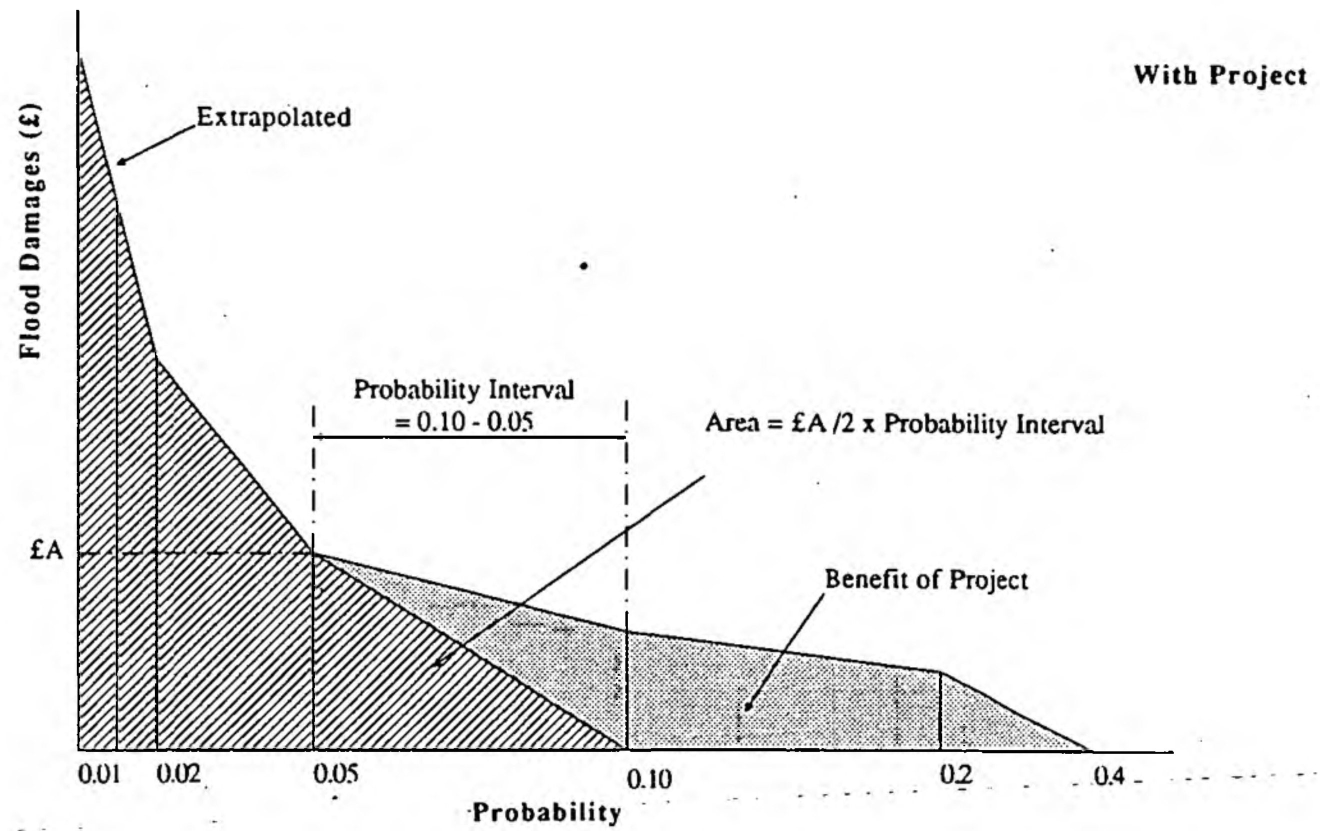


Figure 3.4
Annual Average Damages





Step 9 Calculate annual average damages with project (AAD_{with}). See Figure 3.4.

Step 10 Difference in $AAD_{without}$ and AAD_{with} is the annual average flooding impact benefit of the "project".

Step 11 Add other benefits (amenity, conservation, waterlogging).

3.4.5 Discounting

The use of tables to simplify discounting (derived in the P&P study) has been retained. These are reproduced as Table 3.1.

3.4.6 Sensitivity Analysis

The most sensitive assumptions will generally relate to hydrology and hydraulics and it may be necessary to repeat the basic analysis of flood impact using differing assumptions (eg, lower confidence limits on flood magnitude implying fewer benefits or less severe assumptions regarding roughness, implying lesser flood extents). This will depend on the accuracy and reliability of the approach and data used.

Other fundamental assumptions may involve failure mechanisms (eg, for asset renewal) and the impact which channel maintenance can have on system performance. With regard to the former, an approach has been suggested previously (Gould Consultants, 1990).

This report is concerned with the assumptions relating specifically to benefit assessment. In those terms, the major assumptions which might be tested relate to:

- increase in costs;
- decrease in benefits;
- delay in project;
- delay in realisation of benefits (agricultural land use change only).

A standard set of sensitivity tests for this component of the appraisal has been derived, as follows:

- Costs + 25%;
- Benefits -25%;
- Project delays of 5 years (capital, asset renewal), 1 year (maintenance), 5 years (heavy maintenance);
- Delay in realisation of benefits of 5 and 10 years.

TABLE 3.1
Present Value Factors

Capital Cost	Expenditure Profile by Year					PV Factor
Construction Period (Yrs)	1	2	3	4	5	
1	100%					0.94
2	50%	50%				0.92
3	30%	40%	30%			0.89
4	20%	30%	30%	20%		0.87
5	15%	20%	30%	20%	15%	0.84

Annual Benefits	PV Factors for Benefits Delayed by (yrs)								
Project Life	0	1	2	3	4	5	7	10	15
1	0.94								
2	1.83	0.89							
3	2.67	1.73	0.84						
4	3.47	2.52	1.63	0.79					
5	4.21	3.27	2.38	1.54	0.75				
6	4.92	3.97	3.08	2.24	1.45	0.70			
7	5.58	4.64	3.75	2.91	2.12	1.37			
8	6.21	5.27	4.38	3.54	2.74	2.00	0.63		
9	6.80	5.86	4.97	4.13	3.34	2.59	1.22		
10	7.36	6.42	5.53	4.69	3.89	3.15	1.78		
11	7.89	6.94	6.05	5.21	4.42	3.67	2.30	0.53	
12	8.38	7.44	6.55	5.71	4.92	4.17	2.80	1.02	
13	8.85	7.91	7.02	6.18	5.39	4.64	3.27	1.49	
14	9.29	8.35	7.46	6.62	5.83	5.08	3.71	1.93	
15	9.71	8.77	7.88	7.04	6.25	5.50	4.13	2.35	
16	10.11	9.16	9.27	7.43	6.64	5.89	4.52	2.75	0.39
17	10.48	9.53	8.64	7.80	7.01	6.26	4.89	3.12	0.77
18	10.83	9.88	8.99	8.15	7.36	6.62	5.25	3.47	1.12
19	11.16	10.21	9.32	8.49	7.69	6.95	5.58	3.80	1.45
20	11.47	10.53	9.64	8.80	8.00	7.26	5.89	4.11	1.76
21	11.76	10.82	9.93	9.09	8.30	7.55	6.18	4.40	2.05
22	12.04	11.10	10.21	9.37	8.58	7.83	6.46	4.68	2.33
23	12.30	11.36	10.47	9.63	8.84	8.09	6.72	4.94	2.59
24	12.55	11.61	10.72	9.88	9.09	8.34	6.97	5.19	2.84
25	12.78	11.84	10.95	10.11	9.32	8.57	7.20	5.42	3.07
26	13.00	12.06	11.17	10.33	9.54	8.79	7.42	5.64	3.29
27	13.21	12.27	11.38	10.54	9.75	9.00	7.63	5.85	3.50
28	13.41	12.46	11.57	10.73	9.94	9.19	7.82	6.05	3.69
29	13.59	12.65	11.76	10.92	10.13	9.38	8.01	6.23	3.88
30	13.76	12.82	11.93	11.09	10.30	9.55	8.18	6.40	4.05
31	13.93	12.99	12.10	11.26	10.46	9.72	8.35	6.57	4.22
32	14.08	13.14	12.25	11.41	10.62	9.87	8.50	6.72	4.37
33	14.23	13.29	12.40	11.56	10.77	10.02	8.65	6.87	4.52
34	14.37	13.42	12.53	11.70	10.90	10.16	8.79	7.01	4.66
35	14.50	13.55	12.66	11.83	11.03	10.29	8.92	7.14	4.79
36	14.62	13.68	12.79	11.95	11.16	10.41	9.04	7.26	4.91
37	14.74	13.79	12.90	12.06	11.27	10.52	9.15	7.38	5.02
38	14.85	13.90	13.01	12.17	11.38	10.63	9.26	7.49	5.13
39	14.95	14.01	13.12	12.28	11.48	10.74	9.37	7.59	5.24
40	15.05	14.10	13.21	12.37	11.58	10.83	9.46	7.69	5.33
41	15.14	14.19	13.30	12.47	11.67	10.93	9.56	7.78	5.43
42	15.22	14.28	13.39	12.55	11.76	11.01	9.64	7.86	5.51
43	15.31	14.36	13.47	12.63	11.84	11.09	9.72	7.95	5.59
44	15.38	14.44	13.55	12.71	11.92	11.17	9.80	8.02	5.67
45	15.46	14.51	13.62	12.78	11.99	11.24	9.87	8.10	5.74
46	15.52	14.58	13.69	12.85	12.06	11.31	9.94	8.16	5.81
47	15.59	14.65	13.76	12.92	12.12	11.38	10.01	8.23	5.88
48	15.65	14.71	13.82	12.98	12.18	11.44	10.07	8.29	5.94
49	15.71	14.76	13.87	13.03	12.24	11.50	10.13	8.35	6.00
50	15.76	14.82	13.93	13.09	12.30	11.55	10.18	8.40	6.05
51	15.81	14.87	13.98	13.14	12.35	11.60	10.23	8.45	6.10
52	15.86	14.92	14.03	13.19	12.40	11.65	10.28	8.50	6.15
53	15.91	14.96	14.07	13.23	12.44	11.69	10.32	8.55	6.19
54	15.95	15.01	14.12	13.28	12.48	11.74	10.37	8.59	6.24
55	15.99	15.05	14.16	13.32	12.53	11.78	10.41	8.63	6.28
56	16.03	15.09	14.20	13.36	12.56	11.82	10.45	8.67	6.32
57	16.06	15.12	14.23	13.39	12.60	11.85	10.48	8.70	6.35
58	16.10	15.16	14.27	13.43	12.63	11.89	10.52	8.74	6.39
59	16.13	15.19	14.30	13.46	12.67	11.92	10.55	8.77	6.42
60	16.16	15.22	14.33	13.49	12.70	11.95	10.58	8.80	6.45

TABLE 3.1 (Contd.)

Present Value Factors

Recurrent Costs						
	PV Factors for Maintenance Cycles of:					
Project Life	1	2	3	5	7	10
1	0.94					
2	1.83	0.89				
3	2.67		0.84			
4	3.47	1.68				
5	4.21			0.75		
6	4.92	2.39	1.54			
7	5.58				0.67	
8	6.21	3.01				
9	6.80		2.14			
10	7.36	3.57		1.31		0.56
11	7.89					
12	8.38	4.07	2.63			
13	8.85					
14	9.29	4.51			1.11	
15	9.71		3.05	1.72		
16	10.11	4.91				
17	10.48					
18	10.83	5.26	3.40			
19	11.16					
20	11.47	5.57		2.03		0.87
21	11.76		3.70		1.40	
22	12.04	5.85				
23	12.30					
24	12.55	6.09	3.94			
25	12.78			2.27		
26	13.00	6.31				
27	13.21		4.15			
28	13.41	6.51			1.60	
29	13.59					
30	13.76	6.68	4.32	2.44		1.04
31	13.93					
32	14.08	6.84				
33	14.23		4.47			
34	14.37	6.97				
35	14.50			2.57	1.73	
36	14.62	7.10	4.59			
37	14.74					
38	14.85	7.21				
39	14.95		4.70			
40	15.05	7.30		2.67		1.14
41	15.14					
42	15.22	7.39	4.78		1.81	
43	15.31					
44	15.38	7.47				
45	15.46		4.85	2.74		
46	15.52	7.54				
47	15.59					
48	15.65	7.60	4.92			
49	15.71				1.87	
50	15.76	7.65		2.80		1.20
51	15.81		4.97			
52	15.86	7.70				
53	15.91					
54	15.95	7.74	5.01			
55	15.99			2.84		
56	16.03	7.78			1.91	
57	16.06		5.05			
58	16.10	7.82				
59	16.13					
60	16.16	7.85	5.08	2.87		1.23

4 PROJECT BENEFITS

4.1 General

Before discussing the development of suitable methodologies for benefit assessment, it is necessary to consider the different types of projects for which the proposed methodology will be applied and the mechanisms by which they will produce economic benefits.

Flood defence projects comprise the following main categories of works:

- flood embankments, walls, etc;
- channel improvements;
- flood storage schemes: washland storage, reservoir storage (rare), etc;
- river diversions (rare);
- structures: weirs, sluices, etc;
- drainage pumping stations;
- combined schemes involving two or more of these categories.

These works can be for either coastal or inland schemes. Coastal schemes will usually give higher benefits per hectare, because saline flooding is more damaging than freshwater flooding, especially for agriculture.

As noted in Section 2.1, the principal types of project to be considered in this study are:

(1) Small capital schemes (costing less than £500 000). Capital schemes can be defined as those which increase the stock of flood defence assets, regardless of whether they are funded by the Capital or Revenue Budget. Their effect is to improve flood protection, and possibly also drainage status, in comparison with that prevailing in the present ('Do Nothing' or 'Without Project') situation.

(2) Maintenance work, including both routine maintenance and 'periodic' maintenance. From the benefit viewpoint the two categories can be regarded as the same, their effect being essentially to maintain, but not significantly improve, the existing standard of flood defence. If such works are not undertaken the present level of flood protection will decline, with a consequent increase in flood damage in the future and, possibly, a deterioration in drainage status.

(3) Asset renewal; measures such as the replacement of mechanical and electrical plant, sluice gates and other items which require periodic replacement. In practice, the distinction between maintenance and asset renewal is often blurred, because timely renewal of assets in a flood defence system is a normal part of good maintenance practice. Its benefits are the same; namely the avoidance of flood damage and other losses which would occur in the future if the system were not kept in a sound condition.

Such works produce two main types of benefits, namely:

(a) Reduction of flood risk, and thus flood damage. By increasing the flood return period against which protection is assured, the frequency of flooding, and thus the average annual flood damage, is reduced. Within the life of a project, of course, this benefit is actually obtained only in those few years of unusually high river flows or tidal levels.

(b) Improvement of drainage conditions; watertables are lowered through the increase in watercourse freeboard levels resulting from improvement of watercourse channel characteristics, more effective evacuation of drainage waters by pumping, and other measures. Agriculture is the main beneficiary of better drainage conditions.

In contrast to flood damage benefits, drainage benefits are actually obtained in many, if not most, years of a flood defence project's life. In general, they would be negligible only in years of below average rainfall, when watercourse discharges and levels are well below normal. By contrast, benefits would be above 'average' levels in high rainfall years.

With regard to which type of benefit will be produced by which categories of works, the following broad assumptions can be made:

- Flood embankments, walls and other barriers, and flood storage schemes produce only flood damage benefits.

- All the other works can produce both flood damage and drainage benefits. For example, channel and pump station maintenance or improvement enables freeboards to be increased, and watertables to be lowered, which will produce drainage benefits in most years, but also increases the system's capacity to absorb and evacuate the unusually high river flows which occur on an occasional, rather than regular, basis. For such schemes, therefore, the impact on both flooding and drainage conditions should, in principle, be assessed.

As discussed in the P&P and CRIMS reports, and elsewhere, the major benefits of flood defence to be considered in project appraisal cover the following:

(a) Flood damage to residential and other property, comprising both physical damage and, in the case of commercial, industrial and other non-residential premises, the disruption caused to business activity.

(b) Agricultural benefits, including both the reduction of flood damage and the increase in output resulting from better drainage conditions.

(c) Traffic disruption benefits, resulting from the reduction in the disruption to traffic movement (usually road traffic - rail traffic disruption is rare) caused by flooding.

(d) Amenity benefits and disbenefits, for recreation and aesthetic enjoyment.

(e) Other environmental benefits and disbenefits.

(f) Other benefits, such as savings in the costs of emergency services.

Accurate quantification of amenity and environmental benefits in economic terms is difficult. Appropriate techniques are still being developed and tested, being still in the pioneer stage. At present, therefore, our formulation of a detailed appraisal methodology and standardised benefit values has concentrated on the other benefit types. Valuation of environmental and amenity benefits is, however, discussed in Section 4.3.

Savings in emergency services costs, and other benefits not covered above, are usually small. In the P&P study it was proposed that they should be ignored for the purposes of project analysis and prioritisation. We have adopted the same approach here.

Thus, for the present, the economic appraisal of schemes below £500 000 is concerned primarily with agricultural, property, and traffic disruption benefits, with environmental and amenity issues being raised for further consideration where appropriate.

4.2 Agricultural Benefits

4.2.1 The P&P and CRIMS Estimates

Agricultural benefits from flood defence were considered in the P&P Phase 1 Report of January 1991 and in the CRIMS study of 1992. These sources provide a good starting point for the development of a suitable methodology and, where appropriate, standardised benefit values for schemes costing under £500 000.

In these two studies agricultural benefits from flood alleviation were considered to come from three main sources:

- change in flood risk (flood damages avoided)
- change in land use (enhancement of land use potential)
- change in yield.

(a) Flood Damages Avoided

In the CRIMS report calculations were made of the cost of flood damage. Five different categories of land use were distinguished, namely, forestry and scrub, extensive pasture, intensive pasture, extensive arable and intensive arable. Flood damage to forestry and scrub was estimated to be insignificant, the average potential damage being calculated to be £0.21/ha at 1991 prices. With saline flooding, however, it would be significant.

The CRIMS values calculated represented the cost (loss of agricultural net return) of a typical flood event on a single hectare of land in a large catchment (over 25 km^2). At the level of detail of the CRIMS study the calculation of separate values for small catchments was not considered to be justified. On the basis of data from gauging station records in the Severn-Trent NRA region, monthly flood probabilities were established, so that due account could be taken of the seasonality of flooding. Flood duration was taken to be one week or less. Flooding lasting more than one week would cause somewhat larger crop yield losses but, in terms of agricultural damage, duration is a much less important factor than seasonality; a flood in, say, late spring or early summer is much more damaging than one in the depths of winter. For the purposes of land use assessment this enabled HE values to be calculated for the different farming systems.

In the CRIMS Standard of Service calculation system a Flood Event Severity Weighting Factor is applied in the calculation of HE (house equivalent) scores. This factor takes account of two variables, flood timing (seasonality) and duration. The factor is used to adjust the "averaged" HE values developed for land use assessment, so that they can be used for flood event scoring of a specific event when assessing current standards of service.

For each of the four land use categories, the physical and economic losses resulting from a typical flood were calculated. A brief description of the four agricultural land use categories is given below:-

Extensive Pasture

Many floodplain areas are under extensive pasture. The cut-off point between extensive and intensive pasture cannot be easily defined in terms of level of forage output. Consequently, it was defined in relation to styles of management. For the purposes of the damage assessments, extensive pasture was assumed to include low intensity grazing of grassland (for example, by horses, beef animals, etc) and rough pasture. Experience from rural benefit studies indicates that most farmers who have the choice conserve grass from fields outside the floodplain.

It was assumed that a flood would last on average seven days and a further seven days would be needed for the crop to recuperate. Losses were therefore calculated assuming a reduction of 0.5 month's growth.
The losses calculated did not include any clear-up costs or the cumulative effect of several floods.

Intensive Pasture

Dairying and intensive beef cattle production are the predominant enterprises on intensive pasture. Higher intensity grassland management is usually achieved by tighter grazing, additional nitrogen usage and multiple cutting for silage where grazing is not practicable. It was assumed that grazing and cutting yields would be similar under intensive management at the same level (300 kg N/ha) of fertiliser use. Cut grassland is not subject to continuous harvesting and therefore losses vary with the time of flooding in relation to planned cutting dates.

Extensive Arable

Extensive arable was taken to include all crops which can be combine-harvested, but experience suggests that winter wheat is the most commonly grown arable crop in floodplains. In addition, more comprehensive data on flooding are available for wheat than for many of the other crops. The assessments made were thus of potential losses from flooding of winter-sown wheat. Data from Silsoe College were used to calculate the losses, and assumed a 6% probability of complete crop loss and a 6% yield penalty for other floods.

Intensive Arable

Data on the effect of flooding on intensive arable crops are very limited, as these crops are not commonly grown in floodplains. Potatoes and sugar beet were examined in most detail and an average of the two was taken as representative for this category.

(b) Change in Land Use

In the past, enhanced land use (eg due to the ability of farmers to plant intensive arable crops once flood risk is reduced) was generally considered to be the major benefit of many land drainage/flood alleviation schemes. This is because it provides an annual benefit, whereas flood damages avoided are often low, due to low value cropping in the floodplain and flood frequency considerations. Although full advantage of the reduced risk has not always been taken up by farmers, and benefits have been lower than expected on some land drainage schemes, they have nonetheless been the most significant in the overall context of agricultural benefits.

Current policy towards agricultural land drainage would suggest that it is now unlikely that new schemes would be promoted by the NRA for agricultural land drainage. Similarly, where existing schemes have been completed it is unlikely that there would be much further scope for enhanced land use in the current agricultural climate. On these arguments, it might seem reasonable to ignore these benefits. However, the benefits still merit attention since:

- they may be incidental to other objectives (eg urban flood protection);
- they may have bearing on maintenance projects (eg, in terms of reversion to pasture, in the event that existing maintenance effort is reduced);
- agricultural policies may change in the future.

For the current study the second is the most relevant. For maintenance and asset renewal projects the Do Nothing (Without Project) situation will normally involve a future deterioration in the level of flood protection provided. As a consequence, the land use capability of the protected area will be reduced, with a resultant loss in the economic value of agricultural production.

An extreme example is the Fens and other former wetlands. Virtually the whole of the Fens is under arable cropping, much of it intensive. If the existing flood defence system were allowed to deteriorate because of inadequate maintenance, most of the land would revert to extensive pasture used for seasonal grazing, parts even being under permanent or seasonal swamp. In this case the agricultural benefits of continued maintenance and asset renewal comprise the difference in net economic returns between intensive/extensive arable and extensive pasture/unfarmed land. This was the approach used in the benefit assessments done by the NRA for the Long Load Pumping Station and the River Douglas Proposed Channel Stabilisation schemes (see Table 2.1).

(c) Yield Improvement

Although improvement of drainage conditions can lead to a change in land use (land use enhancement), increased productivity within the same land use is often the main result. Appendix G in the CRIMS Project Record contains detailed calculations of the agricultural effects of poor drainage and the benefits of carrying out adequate river maintenance. This takes account of soil type and natural drainage conditions, land use type and cropping, and whether or not field drains have been installed.

Standardised benefit values per hectare for the four land use categories are given in Table 6B.4 of the CRIMS Manual. They range from £28/ha to £120/ha, before deduction of field drainage costs.

4.2.2 The new MAFF Guidelines

Under the CAP (Common Agricultural Policy) reforms two major changes are being made to the CAP agricultural regime, namely the reduction of many crop and livestock prices towards their real economic levels and the introduction of compulsory Set Aside.
Provided that they agree to set aside 15% of their farm area (excluding the area of ineligible crops -see below), farmers will receive 'area compensation payments' for the land set aside and also an 'area payment' per hectare of eligible crop grown; the latter will vary from crop to crop. As subsidies, these are, of course, transfer payments rather than real economic benefits and should not be included in the benefit estimates. The intention of the subsidy changes is that, by applying the subsidies to acreages rather than output, they will have the effect of reducing output while still maintaining farmers' incomes somewhere near current levels. The Wye Farm Management Pocketbook estimates of gross outputs from different farming enterprises quite correctly includes the area payments (though not the Set Aside payments) as well as the revenue from the crop and livestock sales in the calculation of financial gross output (farmers' gross income) per hectare.

Under the Set Aside rules farmers will be required to take out of production 15% of their present area of 'eligible' crops; ie cereals, oilseeds and proteins (beans, peas, lupins, etc). Sugar beet and potato acreages and milk output are already controlled by quotas.

The new MAFF Guidelines (Flood and Coastal Defence: Project Appraisal Guidance Notes) were received in early April 1993. As expected, with regard to agricultural benefits there are significant changes from the previous (1985) Guidelines owing to the CAP reforms and other factors. From the viewpoint of the present study the main points are as follows:

1. New reduction factors are stipulated for the conversion of gross output per hectare values from financial (farmers') prices to economic prices. These take account of the recent CAP reforms and the effects of Set Aside. They are as follows:

	Cereals, oilseeds, peas and beans	Beef	Sheep
Scenario II (occasional flood damage ie flood alleviation benefits)	0.35	0.35	0.25
Scenario III (long-term yield reduction owing to flooding)	0.10	0.35	0.25

From telephone discussions with MAFF we understand that different adjustment factors for cereals, oilseeds, peas and beans were developed for the two scenarios because area payments (ie subsidies) under Scenario III would be much less than under Scenario II.

MAFF's proposed 0.35 reduction factor for cereals is presumably based on average crop yields. Taking wheat as the most widely grown cereal and the Wye Farm Management Pocketbook (J Nix) estimates for 1993 as a basis, the breakdown of the 0.35 factor for an average wheat crop yielding 7.2 t/ha (for feed) would appear to be as follows:

Financial gross output per hectare of wheat		100
Deductions:	Allowance for 15% of present wheat acreage being set aside in the future	15
Area payment for wheat:	$\frac{£115}{£763}$	15
Balance:	Assumed subsidy in the financial wheat price (£90/t for feed wheat in 1993)	5
		35

To obtain a more accurate assessment of the real economic benefits of additional arable crop (cereals) output resulting from flood protection we have disaggregated the MAFF 0.35 adjustment factor on the basis of the above figures. In calculating the economic gross output of cereals the area payment has been excluded and the economic price of the output sold has been taken as 95% of the financial (sales) price. Gross and net margins have been calculated per cereal hectare cropped, excluding land under Set Aside. Set Aside has been taken into account separately, outside the gross and net margin calculations.

2. MAFF's Scenario I envisages land going permanently out of production due to flooding. Valuation of this loss is based on the prevailing market price for land for similar quality and a factor of 0.4 is then applied to arrive at the economic benefit. The relevant annual probability of breaching, leading to permanent flooding, is applied in order to calculate the total present value of the damage.

   Under our proposed system, which again is based on CRIMS, valuation of the economic losses resulting from deterioration of flood defences etc, and a consequent permanent reduction in agricultural production, is dealt with very differently, under the land use enhancement/deterioration heading. This approach seems, in principle, more comprehensible and valid. One possible disadvantage with the MAFF approach is that, with the various possible distortions to land prices, one cannot be absolutely certain that market prices of land really reflect differences in agricultural productivity.

3. MAFF states that, where land is producing quota commodities (milk, sugar beet and potatoes) or horticultural crops, the production should be valued in terms of cereals. As explained on page 4 - 8 of our April 1993 Preliminary Draft Final Report, and repeated below, we accept this approach for land use enhancement and yield change benefits but not for flood damage alleviation benefits. One possible drawback with MAFF Guidelines, which is recognised within MAFF, is that the three scenarios may need modification. The categorisation of agricultural benefits into three types, the system described in Section 4.2.1 and used in CRIMS, is considered to provide a better framework for agricultural benefit assessment.

For the economic valuation of flood-induced losses of sugar beet, potatoes and milk output (as noted above, MAFF, of course, proposes that these should all be valued in terms of cereals), economic prices are required. Unfortunately, these are not readily available. MAFF has not done recent calculations of economic prices, so does not have reduction factors which could be applied to convert farmers' prices of these commodities to economic prices. For sugar beet the average prices paid to farmers are certainly well above real economic levels, which would be based on the cost of imported sugar bought on the world market. Calculations done for our Ely Ouse Flood Protection Strategy Study in late 1992 suggested that the economic price of sugar beet might be at least 20% below the farmers' price.

Potato and liquid milk prices are maintained at well above their natural equilibrium (economic) levels by the quota restrictions on outputs. Since neither are major internationally traded commodities the accurate derivation of economic prices is very difficult. Thus there is no sound basis for deriving reduction factors for potato and milk prices.

Given this situation, the best solution appears to be to accept the MAFF procedure and value sugar beet and potato output in terms of cereals for all three, rather than just two, of the agricultural benefit categories. For dairying, however, the valuation has been done in terms of intensive beef production rather than cereals, because beef production is, like dairying, based on the livestock use of grassland whereas cereal growing is very different kind of operation.

As regards non-agricultural benefits, it is interesting to note that MAFF states firmly that it will not accept inclusion of recreational or health and related benefits in the economic analysis, except in very unusual cases. Presumably this is to prevent the improvement of schemes' B/C ratios by adding arbitrary allowances for such benefits and also reflects the difficulty of quantifying them accurately.

4.2.3 Modification of the CRIMS Agricultural Benefit Estimates

For the current study the CRIMS agricultural benefit estimates have been updated, with the assistance of Dr. J Morris of Silsoe College. Full details are given in Appendix A. Specific changes made include the following:

(a) The gross output reduction factors, discussed above have been applied, in order to convert financial benefit values to economic values.

(b) Benefits per hectare for arable crops have been reduced by 15%, to allow for the effects of Set Aside.

(c) There are substantial differences in the seasonality of flooding between small (less than 25 km^2), large and urban catchments. Owing to greater attenuation of flooding in large catchments, summer flooding, which is agriculturally much more damaging than winter flooding, is less common than in small and urban catchments. As shown in Table 4.1, flood seasonality in small and urban catchments is fairly similar. With regard to seasonality of flooding, therefore, we have calculated agricultural flood damages on two bases, for large catchments and for small or urban catchments (agricultural flood damage in urban catchments would often be insignificant, due to most of the land being built up).

(d) Various changes have been made with regard to the assumed land use and cropping. Here a critical factor is the treatment of crops and livestock enterprises whose acreage or output is controlled by quota. This is the case with sugar beet, potatoes and dairying.

TABLE 4.1

Monthly Flood Probabilities

Month	Large catchment >2 500 ha	Small catchment <2 500 ha	Urban catchment
January	0.23	0.14	0.06
February	0.19	0.08	0.10
March	0.12	0.08	0.13
April	0.04	0.06	0.05
May	0.03	0.03	0.11
June	0.01	0.05	0.06
July	0.01	0.06	0.10
August	0.01	0.08	0.06
September	0.01	0.09	0.11
October	0.03	0.09	0.05
November	0.14	0.08	0.06
December	0.18	0.16	0.11

Source: Table B.23 of the CRIMS Project Record, based on STWA analysis of gauging station records.

Land use enhancement often results in an increase of intensive pasture (and thus dairying) and intensive arable (and thus sugar beet and potatoes). Given the national limitations on total acreage or output for these enterprises, however, this change will not result in any national increase in the output of these commodities. Instead, the outcome will be a reallocation of acreage/output shares from existing producers to the new producers whose land has been provided with better flood defence/drainage. In the case of horticulture the same principle applies, although this is due to market constraints rather than formal quotas. In national terms, therefore, the increase in dairying, potato, sugar beet and horticulture output resulting from the land use enhancement on a specific project is not an economic benefit. This is the reason why MAFF stipulates that flood protection benefits from land under these enterprises should be valued in terms of cereals.

To take this point into consideration, the following land use and cropping assumptions have been made for the **land use enhancement** scenario:

- Intensive pasture has been valued in terms of intensive beef production (18 month Beef and Grass Silage Beef) rather than dairying. At present there are no direct quotas on beef cattle production, unlike dairying.

- In line with the new MAFF Guidelines, all arable land use has been valued in terms of an extensive cropping system based on cereals, with no sugar beet, potatoes or horticulture.

A similar situation applies in the case of **yield change** benefits. Since a reduction in watertable levels and increase in yields due to, for example, better channel maintenance will be an annual, rather than occasional benefit, any rise in dairying, sugar beet or potato output will be achieved only at the expense of existing producers elsewhere, through reallocation of quotas. Over the years the geographical distribution of quotas is progressively adjusted to reflect local and regional production changes resulting from a wide variety of factors. Increased or reduced output of milk and root crops due to the improvement or deterioration of flood defences would, in principle, result eventually in reallocation of quotas. For yield change benefits, therefore, the same cropping and livestock assumptions as for land use enhancement have been applied.

For **flood damage** agricultural benefits, however, the situation is different. Land use in a flood risk area where flooding is infrequent may include some dairying, sugar beet and potatoes, even though less intensive farming systems are likely to predominate. If a substantial flood occurs it may cause a loss of output of these crops, owing to flood damage. This once-and-for-all loss cannot be made good by transferring output quotas to other farmers so that they can increase their production to compensate for the loss. It is too late for this, because the planting period is already over. Thus, such flood damage results in a genuine loss of output to the national economy. For flood damage benefits, therefore, an intensive as well as extensive arable system should, ideally, be included. For all the reasons given in Section 4.2.2, however, arable benefits have been based on cereals. Since returns from intensive forage-based beef production are not that much lower than those from dairying, they have been taken as representative also of dairying.

Detailed calculation of the economic benefits per hectare from changes in flood risk, land use enhancement and changes in yield resulting from flood defence works are presented in Appendix A. Tables 4.2 and 4.3 summarise the values derived.

TABLE 4.2

Change in Flood Risk (Flood Alleviation)
Average Economic Cost of a Single Flood Occurring in a Year
(£/ha in 1993 prices)

Type	1				2				3	
Existing Land Use	Extensive pasture				Intensive pasture				Arable	
Enterprise mix	Single suckler beef				18 month beef				Cereals [3] (wheat)	
Catchment size	Large[1]		Small[1]		Large		Small		Large	Small
Grass use [2]:	sil.	gr.	sil.	gr.	sil.	gr.	sil.	gr.		
Drainage status: good	24.7	11.2	37.4	16.7	34.7	14.3	53.8	22.8	46	158
bad	15.0	9.8	17.0	14.1	30.5	13.0	46.9	20.2	39	130
very bad	-	8.2	-	11.1	18.0	11.2	27.2	16.9	30	93

Source: Appendix A

Note: [1] Large catchment experiencing mainly winter flooding; small catchment having a greater incidence of summer floods.

[2] sil. = silage/hay ; gr.= grazing

[3] Values per crop hectare calculated in Appendix A, minus 15% Set Aside.

Saline Multipliers

Land Use	Saline Multipliers
Forestry and Scrub	1600
Extensive Pasture	44.9
Intensive Pasture	20.1
Extensive Arable	11.4

TABLE 4.3

Agricultural Benefits from Yield and Land Use Changes
(Net margins in £/ha at 1993 economic prices)

Type	1	2	3
Existing land use	Extensive pasture	Intensive pasture	Arable
Enterprise mix	Single suckler beef	18 month beef	Cereals[1] (wheat)
Drainage status:			
- good	-46	-154	180
- bad	-48	-140	82
- very bad	-57	-139	-66
Change in Economic Net Margin owing to Drainage Deterioration/Improvement not leading to land use change:			
- Good to/from bad	-2	+14	-98
- Bad to/from very bad	-9	+1	-148
- Good to/from very bad	-11	+15	-246
Change in Economic Net Margin owing to Land Use Change (examples)			
Extensive pasture (bad) to intensive pasture (good)		-106	
Extensive pasture (bad) to arable (good)		+228	

Source: Data in Appendix A
Notes: (1) After allowance for 15% Set Aside

As described in Appendix A, financial net margins (ie the returns to the farmer) improve with better conditions and as the production system is intensified. Under extensive grass management systems, for example, financial net margins with good drainage are £88 per hectare to £106 per hectare better than with very bad drainage, and the intensive grass system under good drainage produces net margins 2.5 to 3.3 times higher than those from the two extensive systems.

Economic net margins represent the real benefits to the national economy, rather than just to the farmers, and are thus the critical parameters for agricultural benefits under different drainage conditions and from flood protection works. As might be expected improvement of drainage conditions would produce significant economic benefits in the case of arable cropping (cereals) and a change in land use from grassland to arable production would also produce substantial economic benefits.

With grassland, however, the situation is very different. Apart from the fact that all the systems show net economic losses in all three drainage conditions, there is also the peculiar situation whereby improved drainage within a production system produces negligible, or even negative, economic benefits and the intensification of production (the move to an intensive grass system) leads to increased, rather than reduced, economic losses.

Though at first sight an anomalous and illogical result, it does, unfortunately, reflect economic reality. The reasons are the very high costs of livestock production as a percentage of gross output and the fact that the real (economic) value of this output is only 65% of the financial value that the farmer receives. Total variable and semi-fixed costs as a percentage of financial gross output under good drainage conditions are as follows (see Appendix A):

Production costs as a proportion of financial gross output

Extensive grass:		
	- 24 month beef	81%
	- Single suckler	79%
Intensive grass:		75%

Clearly, if production costs are 75% of financial gross output and the economic gross output is only 65% of the financial gross output the economic net margin is bound to be negative. The basic conclusion to be drawn is that beef production in the UK, except on a very low input low cost basis, is economically marginal, owing particularly to the low price of beef on the world market (the economic price of beef is based on the likely price of imported beef).

4.2.4 Rates of Buildup of Agricultural Benefits

Flood damage benefits will, in principle, be achieved from the year in which the flood defence works come into operation. No buildup period is required. Yield change benefits resulting from watertable reduction may take slightly longer to achieve in full, because marginal changes in management practices (eg higher nitrogen fertiliser rates) may be involved but, as an approximation, full benefits from the year of project completion is an acceptable assumption.

This is not valid, however, in the case of land use enhancement. A change in land use from, say, extensive pasture to intensive pasture or to arable on any scale may well require capital investment, as well as changes in management and increased input costs, for the farmers concerned. As noted in Section 2.12 of our January 1993 Review of Literature, the post-project appraisal done by Silsoe College in the Severn Trent Region showed that the buildup to full benefits took up to 12 years in some schemes, the buildup curve being not very far from a straight line one.

Schemes costing below £500 000 are likely to involve relatively small areas and few farmers, and buildup rates may be faster. For analysis purposes we propose a straight line buildup over five years, for land use enhancement benefits, with an increment of an extra 20% of the full benefit each year.

4.2.5 Benefit Scenarios for the Estimation of Agricultural Benefits

For the economic appraisal of a project the project analyst will need to decide which of the three categories of benefit are applicable. For some projects only one form of benefit will be obtained whilst for others, especially those combining two or more different types of works, benefits may be achieved in two forms.

On the basis of the discussion in Section 4.1, we propose the following approach:

1 Flood Embankments, Walls and Other Barriers and Flood Storage Schemes

(a) Flood damage benefits (applicable for most schemes)

(b) Land use enhancement (applicable for only a few schemes)

For these types of works, clearly, the analyst can opt for either (a) or (b) for any particular area of land but not for both that would involve double counting. Since the calculation of land use enhancement benefits does not allow for flood losses it intrinsically takes account of the reduced flood damage, as well as the more intensive land use, resulting from a project.

The above comments apply to both capital schemes and maintenance/asset renewal schemes.

2 Other Works (Channel Improvements, Drainage Pumping, Miscellaneous Maintenance Operations, etc)

For these other works the following combinations of agricultural benefits are possible:

(a) Flood damage benefits

(b) Changes in yield due, generally, to drainage benefits

(c) Flood damage benefits and changes in yield (ie both flood risk and watertable levels are reduced)

(d) Land use enhancement. Since this assumes higher levels of productivity than in the 'Without Project' situation it implicitly takes account of yield changes as well as reduced flood risk.

4.2.6 Regional Differences in Agricultural Benefits

(a) Crops

In Section 4.3 of the January 1993 Review of Literature the possibility was raised of there being differences in the level of flood defence agricultural benefits per hectare within England and Wales, owing to different levels of yield or production cost between regions for specific crop and livestock enterprises (eg maybe wheat gross margins are higher in East Anglia than elsewhere). Owing to climatic, soil and other variations between regions, the differences in enterprise mixes, productivity and net returns could be sufficiently large to justify applying different per hectare agricultural benefit values by region rather than applying a single set of national values.

In the report it was proposed that an assessment of agricultural net returns per hectare by region would be made using the annual farm management survey reports produced for MAFF by eight universities and colleges.

For any particular crop, the level of yield is the single largest determinant of that crop's gross margin (output minus variable costs of production) per hectare, so yields have been taken as a proxy for crop net returns. If there are substantial differences in crop yields between regions, adjustment factors for agricultural benefit levels around the national mean could be derived from regional crop yield statistics. An analysis of the yields of major field crops between regions was therefore undertaken; a full description is given in Appendix A.

The main conclusion to be drawn from the analysis is that, considering the variations in climate and soils within England, the differences in major crop yields between regions are remarkably small. The inference is that standards of crop management (ie farming standards) are sufficiently high to overcome the variations in climatic and other conditions between regions. Farmers have adapted their crop production technologies to their local environment sufficiently well to compensate for and overcome climatic constraints such as drought periods in eastern England and the danger of excessive rainfall during the growing season in the west of the country.

In the case of cereals the variation around the national average is generally less than 5% in the main producing regions. York and Humberside had the largest consistent difference, with yields 2% to 8% higher. In East Anglia, the 4% to 6% yield difference in the 1974 to 1982 period had almost disappeared by the 1986 to 1992 period.

In all regions the 1974 to 1982 potato yields did not vary by more than 5% from the national average. Except for East Anglia, the regions with higher potato yields were not those with higher cereal yields; ie there was no consistent pattern of regions having consistently higher major crop yields except, to a very limited extent, in East Anglia.

(b) Grassland Yields (Stocking Rates) by Region

Livestock returns and profitability vary more from farm to farm than is the case with major crops, management efficiency having a greater impact on productivity levels. Nevertheless, the productivity per hectare of the grassland, and also forage crop (eg kale and root crops) land, used to feed a farm's livestock is a critical factor affecting the net returns per hectare. The most convenient means of expressing the productivity of flood-prone land used for livestock is in terms of its stocking rate; that is, the number of Grazing Livestock Units (GLSU - one LSU is equivalent to an adult Friesian cow) per forage hectare. In Appendix A GLSU/ha has therefore been used as the parameter with which to compare grassland yields between regions.

As for crop yields, there is surprisingly little variation in dairying stocking rates between regions. The only region which differs significantly from the national average of 1.9 GLSU per ha (the figure in the Wye Farm Management Pocketbook) is the North, which has a significantly higher stocking rate of the sample farms of 2.2 to 2.4 GLSU/ha. Logically, one would expect the South West to have the highest rate, because of its longer grass-growing period (milder winters) and high rainfall. It is possible that other factors such as higher concentrate feeding rates are distorting the comparison in the case of the North. Since the difference is anyway not that large, we do not consider any specific adjustment for livestock production benefits per hectare should be made.

(c) Conclusions

Agriculture in flood-risk areas is likely to vary substantially from scheme to scheme. Livestock production is the predominant enterprise in many floodplain areas but, where drainage is adequate, arable cropping is also widespread. Whichever type of farming predominates, however, the analyses presented in Appendix A indicate clearly that there are no substantial grounds for introducing regional adjustment factors for agricultural benefits. This conclusion is applicable to project appraisals carried out for CRIMS and for the Prioritisation and Programming of Flood Defence Works as well as for the appraisal of projects costing under £500 000. In all cases the degree of approximation (margin of error) inherent in the benefit assessment is such that making adjustments for regional differences in crop and grassland yields would not be justified.

4.3 Environmental Benefits

4.3.1 Introduction

The Draft NRA Economic Appraisal Guidelines of March 1993 include a discussion of environmental benefits (and disbenefits) of NRA activities. Rather than repeat the material contained therein, the salient points are summarised below; for ease of reference sections from the Guidelines are reproduced verbatim in Appendix B.

It should be appreciated that the quantification of environmental benefits is still very much a matter for discussion at present; and it is not intended to formalise the method for such a quantification within this present study.

4.3.2 Use and Option Values

There are two basic categories of value which individuals hold towards the environment, use and values and non-use values.

1 Use Values

These are the values associated with the direct human use (or 'consumption') of the environment. In relation to NRA flood defence activities they can comprise the following:

(a) Recreation:

- Fishing
- Boating
- Swimming
- Other beach activities
- Walking
- Cycling
- Bird watching and wildlife viewing
- Shooting and other field sports (eg wildfowling on wetlands)
- Photography
- Other forms of recreation.

(b) Amenity:

- Landscape and Countryside.

(c) Water quality for water supply (probably not much affected by flood defence works).

(d) Education.& scientific; eg related to different ecological habitats, heritage sites, geology etc.

2 **Non-use Values**

These comprise two categories, Option Values and Existence Values.

(a) **Option Values** relate to the desire of an individual to maintain the ability for him or her to use the environment at some time in the future (for example, the desire to visit the Norfolk Broads). They reflect an individual's willingness to pay to secure the future of a good and thus express the potential benefits of the good. Option values also represent the benefits attached to preservation or conservation of the environment so that future generations may also have the option of use.

(b) **Existence Values** are defined as those values which result from an individual's altruistic desire to ensure that an environmental asset is preserved and continues to exist into the future. These values are not associated with actual or potential use, but solely with the knowledge that the asset is there.

The distinction between the two types of values can be important. If an analysis captures only the values related to direct use of the environment, it may result in a gross underestimation of the total environmental benefits that would be gained by an action. Several studies have found that benefits related to option and intrinsic values may be greater than those related to direct use.

4.3.3 Valuation of Environmental Benefits

There is a wide range of environmental benefits and disbenefits which can result from NRA activities. The Guidelines group these into five categories, in terms of impact:

- recreation
- amenity
- education and scientific activities
- landscape and countryside characteristics
- conservation, geology and heritage sites.

Naturally, there is considerable overlap between the above groupings. For example, impacts on conservation sites may well affect recreation activities such as bird watching. The first three categories relate primarily to use values whereas the last two can have both use and non-use values.

Impacts can, of course, be negative (ie producing disbenefits, or environmental costs) or positive. Many flood defence projects may produce both benefits and disbenefits.

Various techniques have been developed for the economic valuation of environmental benefits and costs. Four broad categories are distinguished in the Draft Guidelines as follows:

- **Market price approaches:** where environmental effects result in changes in the quantity or price of marketed goods, the value of such changes can be used to estimate welfare gains or losses. The two techniques which fall under this category are the **dose-response approach**, which links changes in the environment to changes in productivity, and the **replacement costs approach (and related shadow project approach)** which uses the costs of restoring or recreating an environmental asset as a measure of its value.

- **Household production function approaches:** the price paid for a complementary or substitute good is assumed to reflect an individual's willingness to pay for an environmental good or service. The techniques in this category include the **aversive expenditure approach** which relies on information concerning expenditure for substitute goods (bottled water for tap water) and the **travel cost method** which values a given site in terms of the costs incurred in travelling to that site for recreation purposes.

- **Hedonic pricing methods:** the implicit value placed on an environmental good is estimated by looking at the price paid for the good in the real markets in which it is effectively traded. For environmental effects, the approach focuses on the property (houses or land) market, where it is assumed that environmental attributes affect property prices.
- **Experimental markets:** social survey methods are used to determine individual's preferences for changes in the environment. Two basic approaches exist: the **contingent valuation method** which asks people their willingness to pay (or to be compensated) for environmental gains (or losses); and the **contingent ranking method** which derives a monetary value for an environmental asset by linking it to rankings given to marketed goods.

At the current stage of the development of environmental economics all of these approaches suffer from uncertainties concerning the accuracy of the estimates derived. Subjective judgement is often an unavoidable feature of the valuation of environmental benefits and costs.

Three of the most commonly used techniques are the contingent valuation method (CVM), hedonic pricing based on property prices and the travel cost method. CVM is particularly useful for estimation of non-use values but is demanding in terms of cost and study effort. It is difficult to produce reliable CVM results at a cost of less than £20 000 to £30 000, because of the intensive survey work required. Choice of technique will be influenced by several factors, including:

- the nature of the policy/project decision;
- the types of impact to be valued;
- data availability; and
- time and financial resource constraints.

Thus, no hard-and-fast rule can be formulated as to which should be used for flood defence projects. However, our broad suggestions as to the applicability of different techniques are given in Table 4.4.

TABLE 4.4

Suggested Applicability of Environmental Assessment Techniques

Category of benefit/disbenefit	Suitable techniques
Use Values	
Recreation	- Travel cost method - Financial payments for the 'good' - CVM
Amenity	- Hedonic pricing - CVM
Educational and Scientific	- CVM
Non-use Values	- CVM

As can be seen from the above list, for many benefit categories CVM appears to be the most suitable, or even the only, suitable technique. With its high cost, however, its use for projects costing below £500 000, and even many larger projects, is not justifiable on cost-effectiveness grounds. A clear need thus exists for the generation of standardised values which can be applied with a reasonable degree of confidence, thereby obviating the need for costly project-specific CVM surveys.

Unfortunately, the quality of CVM and other benefit data currently available is such that this is not feasible at the present time. Unlike property, traffic disruption and agricultural benefits the derivation of reliable standardised values for environmental benefits and costs may not even be practicable - at present, it is too early to say whether this is the case. Clearly, the whole subject of valuation of environmental benefits and costs for flood defence and other NRA activities requires further research.

To provide some indication of the likely order of magnitude of different types of environmental benefit, Table 9.2(a) of the Draft Guidelines presents a summary of the results of UK CVM studies. Table 4.5 shows the values derived for those benefits which might result from flood defence works (water quality improvements are not included).

TABLE 4.5

Contingent Valuation Method - Survey Results From a Selection of Studies

Type of benefit	Study	User values quoted (averages from the different surveys) (£)
Recreational value and quality of beaches	Penning-Rowsell *et al* (1989)	3.90 to 11.50 per adult visit
	Penning-Rowsell *et al* (1989)	7.80 per adult visit
	Green *et al* (1990)	3.70 to 9.20 per adult visit
		WTP: 4.90 per annum
Coastal recreation and amenity	Turner & Brooke (1988)	WTP: 15.00 to 18.80 per household per annum
Recreational value of environmental improvements to a river corridor	Coker *et al* (1989)	0.82 to 1.03 per adult visit WTP: 13.90 to 16.20 per household (per annum?)

Note: WTP - Willingness to pay
Source: Table 9.2(a) in the NRA Draft Guidelines for Economic Appraisal.

Willingness to Pay (WTP) values as well as user values are shown. The values quoted are averages derived from individual surveys; in some studies several CVM surveys were done.

Table 4.5 illustrates the substantial value placed on certain recreational and amenity aspects which might be affected by flood defence works.

User values ascribed to beaches are particularly high, ranging from £3.70 to £11.50 per adult visit. These are based on values quoted by actual users, whereas the WTP values are presumably from the population at large. Since many of the latter are non-users this would drag down the average WTP value and explain the apparent inconsistency between the low WTP values per annum vis-à-vis the user values per visit.

In terms of the possible derivation of standardised values for economic appraisal Table 4.5 illustrates two particular problems. First, there is a wide range of values, such that meaningful average values could not be derived and applied with any confidence. Second, all the values are per head or per household, not per total population of users and others affected. Definition of the total number of individuals or households to which the per capita or per household values should be applied, in order to estimate total values, is a difficult and arbitrary process. This underlines the impossibility of determining reliable standardised environmental values for flood defence project appraisal at this stage.

4.4 Property Benefits

The approach to the assessment of property benefits makes full use of the House Equivalent concept. Certain amenity land uses have been included under the "Property" category for convenience: but it should be noted that buildings associated with the amenity use are treated as non-residential properties. Two approaches have been identified.

(a) Simplified Approach

The simplified approach is to use the HE as a counter to assess the number of properties affected by a flood. This number will then be multiplied by a depth-averaged damage value (£1135 per HE) to derive the flood damages incurred. Values of HEs for different property types are given in Table 4.6 for both fluvial and saline flooding.

For non-residential properties (NRPs), the values in Table 4.6 are expressed in m^2. To simplify the assessment further, the banding categories and midpoint values expressed in Table 4.7 can be used. Guidance on typical sizes for NRP types are given in Table 4.8.

(b) Prioritisation and Programming Approach

The P&P approach is more sophisticated and may be warranted where a refinement of property damages values is required. For amenity uses, the method described above using a depth averaged approach is appropriate.

In this approach, the HE values for properties are counted in a similar manner to that described above, but grouped into the flooded depth bands indicated in Table 4.9. This requires that the distribution of property floor levels is known from sample surveys or can be obtained from maps.

Having obtained the number of HEs in each band, these are than multiplied by the appropriate depth-related damage values given in Table 4.9 to obtain aggregate damages for each band, which can then be totalled.

For either approach, if a flood warning system is in operation, the damage values for property (not amenity) interests obtained can be reduced by the factors given in Table 4.10.

Table 4.6
House Equivalents for Fluvial and Saline Flooding

	Unit	HE Values Fluvial	HE Values Saline
House	Number	1.0	1.14
Garden/Allotment	Number	0.04	0.07
NRP[1] - Agricultural Bldgs	Per m^2	0.01	0.01
NRP - Retail	Per m^2	0.036	0.04
NRP - Office	Per m^2	0.033	0.036
NRP - Leisure	Per m^2	0.031	0.033
NRP - Distribution	Per m^2	0.054	0.06
NRP - Manufacturing	Per m^2	0.029	0.032
Railways[2]	Number	53.9	53.9
Motorways[2]	Number	53.9	53.9
B-U Trunk[2]	Number	20.4	20.4
B-U Principal[2]	Number	21.0	21.0
N B-U Trunk[2]	Number	13.5	13.5
N B-U Principal[2]	Number	6.6	6.6
All Minor Roads[2]	Number	2.1	2.1
Forestry and Scrub	Per 100 ha	0.02	32
Extensive Pasture[3]	Per 100 ha	2.0	90
Intensive Pasture[3]	Per 100 ha	2.8	56
Extensive Arable[3]	Per 100 ha	9.7	111
Formal Park	Number	0.6	1.9
Special Park	Number	9.3	10.1
Playing Field/Pitches	Number	0.1	0.5
Golf Course	Number	0.7	3.3

Note:-
1. NRP = Non Residential Property
2. Approximation based on disruption for 24 hours at 50% normal speed and diversion length of 5 x normal route length. Where data available use Table 4.12
3. Approximation based on average of figures given in Table 4.2. Where data is available use Table 4.2.

Source: CRIMS Project Record

Table 4.7

Non-Residential Property Size Bands and Values

Size Band (m^2)			Manuf'ur -ing	Distribu -tion	Retail	Leisure	Office	Agricul -tural
Nr	Range	Mean						
1	0-50	25	0.7	1.2	0.9	0.8	0.8	0.2
2	51-150	100	3.0	5.4	3.5	3.2	3.3	1.0
3	151-250	200	6.0	10.7	7.0	6.4	6.6	2.0
4	251-500	375	11.2	20.2	13.1	12.0	12.4	3.7
5	501-750	625	18.7	33.7	21.9	20.0	20.6	6.2
6	751-2000	1375	41.2	74.2	48.1	44.0	45.4	13.7
7	2001-5000	3500	105.0	189.0	122.5	112.0	115.5	35.0
8	>5000[1/]	-	0.030	0.054	0.035	0.032	0.033	0.010
Note 1/ Properties over 5000m² are individually measured. HE values quoted are per m².								

Source: CRIMS Project Record

Table 4.8

Non-Residential Property Size Guide

Category and Size (m^2)		Descriptive Examples
1	0-49	Electricity and water substations
2	50-149	Takeaways, newsagents (typical Victorian terrace house = $75m^2$)
3	150-250	Small pub, estate agents, high street shop
4	251-500	Large pub, hotel, 'Little Chef'
5	501-750	Parish church, community centre, fast food outlet
6	751-2000	Small school, large high street store
7	2001-5000	Large factory, hypermarket
8	>5000	Individual measurement

Source: CRIMS Project Record

Table 4.9

HE Depth Damage Data

Depth of Flooding	Short Duration Flooding (Less than 12 hours) Damage £	Long Duration Flooding (More than 12 hours) Damage £
<0.10	576	1166
0.10-0.20	1683	4143
0.21-0.30	4412	8549
0.31-0.60	5953	10889
0.61-0.90	7227	12656
0.91-1.20	8287	15244

Source: Derived from total damage data on pages 173 and page 177 from Appendix 2.3 of the Middlesex "Major Update" document. Updated to 1993 using RPI of 1.414.

Table 4.10

Reduction in Damages Owing to Flood Warning

Warning Lead Time	% Reduction
1 hour	10%
2 hours	20%
3 hours	30%
4 hours	40%

Source: The "Blue Book"

Table 4.11

Approach 1 - Annual Benefit Factors

Design Standard (Return Period, Years)	Annual Average Damages Benefit Factor
2.5	0%
5	7%
10	25%
20	45%
50	75%
100	90%

Note:- [1]. Used to estimate the Annual Average Damage value (Figure 3.2 and Step 2 of Section 3.2.2)

4.5 Traffic Benefit Assessment

The approach to traffic benefit assessment adopted follows the methodology outlined in the "Red manual" with a number of simplifying assumptions. National data on average daily traffic flows on different road categories, traffic mix and vehicle operating cost functions and values of time per vehicle have been obtained from the Department of Transport (DTp) and form the basis for the calculations. Traffic mix and flow data for different road types is summarised in Table 4.12.

The major simplifying assumption is that travel speeds along a diversion route are some fraction of the normal speed but that overall daily through-flow of traffic is maintained. With this assumption, it is possible to develop a relationship of cost per hour of disruption for different road categories and for different ratios of diversion length to original route length.

The calculation of the average value of time for vehicles involved in a delay is summarised in Table 4.13, which uses data on time values and vehicle occupancy rates from DTp Highways Economics Note No 2 (1989). A standard value (T) for a vehicle (weighted for traffic mix) is derived for different road types.

Table 4.14 summarises the derivation of vehicle operating costs using Dtp data (1988). These are derived from functions which relate operating cost and travel speed for different vehicle types using coefficients. These are weighted by traffic mix to derive an aggregate value for each road type. Operating costs can be calculated for normal road speeds (O_1) along the normal route and reduced road speeds (O_2) along a diversion route.

Assuming the hourly flow of vehicles is Q, and the lengths of the original route and diversion are L and D respectively. Then:

Along the original route:

Operating Cost =	$O_1 \times Q \times L$	£/h
Value of Time =	$L/V_1 \times T \times Q$	£/h
Total Cost =	$L \times Q \times (O_1 + T/V_1)$	

Along the diversion:

Operating Cost =	$O_2 \times Q \times D$	£/h
Value of Time =	$D/V_2 \times T \times Q$	£/h
Total Cost =	$D \times Q \times (O_2 + T/V_2)$	

Cost of Disruption = $D \times Q \times (O_2 + T/V_2) - L \times Q \times (O_1 + T/V_1)$

Table 4.15 summarises the calculation of costs for vehicles on different road types for a reduction in speed of 75%. Table 4.16 is a summary table of calculations for 25%, 50% and 75% reductions in speed. A judgement on the most appropriate reduction in speed would be based on local knowledge.

Adoption of this approach involves an assessment of duration of flooding (H) above the road level for different return period events. This would be done by considering the hydrograph for the event at or near the road crossing. The calculation of disruption costs would be made by multiplying the number of hours the road is flooded to impassable depths (say, greater than 0.30m) by the cost of disruption derived above. The annual average damages would then be computed by multiplying the probabilities of the flood events by the disruption costs and summing these. This figure would then be used to derive the present value of benefits.

The inputs required are: road type, original and diversion route lengths, and times of submergence for the road above the threshold for different return periods.

TABLE 4.12

Traffic Mix and Flows (Source: Transport Statistics Great Britain 1991)

Mix by billion vehicle km, recorded flow in vehicles/day	Cars	MCs	PSVs	LGV	OGV	Total	Traffic Flow (1990 veh/d)	Nr Lanes	Flow/hr per lane
Motorways	46.65	0.30	0.51	4.98	8.75	61.19	54600	6	379
B-U Trunk	7.84	0.19	0.10	0.92	0.77	9.82	17560	4	183
B-U Principal	55.47	1.55	1.14	5.84	3.35	67.35	14810	4	154
N B-U Trunk	45.32	0.49	0.46	4.88	6.39	57.54	14150	4	147
N B-U Principal	45.01	0.82	0.51	4.96	3.76	55.06	6650	4	69
All Minor roads	130.45	3.06	1.99	14.57	6.57	156.64	1400	2	29

Traffic Mix by %	Cars	MCs	PSVs	LGV	OGV
Motorways	76.2%	0.5%	0.8%	8.1%	14.3%
B-U Trunk	79.8%	1.9%	1.0%	9.4%	7.8%
B-U Principal	82.4%	2.3%	1.7%	8.7%	5.0%
N B-U Trunk	78.8%	0.9%	0.8%	8.5%	11.1%
N B-U Principal	81.7%	1.5%	0.9%	9.0%	6.8%
All Minor roads	83.3%	2.0%	1.3%	9.3%	4.2%

Traffic Speeds and Flows	Nr Lanes	Traffic Flow (pcu/d)	Traffic Flow (pcu/l/h)	Free Flow Speed (Km/h)	Free Flow limit (pcu/l/h)	L'ting Cap'ty (pcu/l/h)	Speed at L'ting Cap'ty (Km/h)	Actual speed (Km/h)
Motorways	6	66767	464	90	1800	2600	76	90
B-U Trunk	4	19804	206	65	1400	2200	56	65
B-U Principal	4	16166	168	50	600	1100	30	50
N B-U Trunk	4	16620	173	90	1800	2600	76	90
N B-U Principal	4	7393	77	79	1600	2400	70	79
All Minor roads	2	1506	31	45	500	1000	25	45

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TABLE 4.13

Average Value of Vehicle Delay Time (Source: Highways Economics Note No 2 1989)

Resource Value of working time (1988)		Resource Value of non-working time (1988)
Car Driver	£8.50 /hr	£2.08 /hr
Car Passenger	£7.05 /hr	£2.08 /hr
Bus Passenger	£7.01 /hr	£2.08 /hr
Bus driver	£6.48 /hr	£2.08 /hr
LGV occupant	£6.61 /hr	£2.08 /hr
OGV driver	£6.23 /hr	£2.08 /hr

RPI Increase (1988-1990)	1.18

Vehicle Occupancies Type	Driver	Passengers	Notes	Weighted Avge Value of Time	At 1990 Values
Working Car	1	0.20	14% of car mileage	£9.91	£11.69
Non-working car	1	0.85	86% of car mileage	£3.85	£4.54
Average car	1	0.76		£4.70	£5.54
MC	1	0.00	14% in working time	£2.98	£3.51
PSV	1	12.20	7% in working time	£36.07	£42.56
LGV	1	0.30		£8.59	£10.14
OGV	1	0.00		£6.23	£7.35

Value of Vehicle Time (1990) Weighted by Traffic Mix for each Road Category

	Cars	MCs	PSVs	LGV	OGV	Weighted Average
Motorways	£4.23	£0.02	£0.35	£0.83	£1.05	£6.47
B-U Trunk	£4.42	£0.07	£0.43	£0.95	£0.58	£6.45
B-U Principal	£4.56	£0.08	£0.72	£0.88	£0.37	£6.61
N B-U Trunk	£4.37	£0.03	£0.34	£0.86	£0.82	£6.41
N B-U Principal	£4.53	£0.05	£0.39	£0.91	£0.50	£6.39
All Minor roads	£4.62	£0.07	£0.54	£0.94	£0.31	£6.48

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TABLE 4.14

Vehicle Operating Costs (Source: Highways Economics Note No 2 1989)

Resource Cost Coefficients	a	b	c	Year
Car	4.893	51.781	0.000114	1988
MC	2.447	25.891	0.000057	1976 No new data
PSV	38.308	219.958	0.000309	1988
LGV	10.770	82.893	0.000173	1988
OGV	25.925	132.024	0.000323	1988

Resource costs p/km/vehicle at normal speed along normal route	Speed	Cars	MCs	PSVs	LGV	OGV	Wtd For Tr.Mix	At 1990 Values
Motorways	90	6.4	3.2	43.3	13.1	30.0	10.2	12.1
B-U Trunk	65	6.2	3.1	43.0	12.8	29.3	8.4	10.0
B-U Principal	50	6.2	3.1	43.5	12.9	29.4	7.7	9.1
N B-U Trunk	90	6.4	3.2	43.3	13.1	30.0	9.5	11.2
N B-U Principal	79	6.3	3.1	43.0	12.9	29.6	8.3	9.8
All Minor roads	45	6.3	3.1	43.8	13.0	29.5	7.7	9.1

Resource costs p/km/vehicle at reduced speed along diversion								
Reduction in Speed to	75% normal assumed						Wtd For	At 1990
	Speed	Cars	MCs	PSVs	LGV	OGV	Tr.Mix	Values
Motorways	67.5	6.2	3.1	43.0	12.8	29.4	10.0	11.7
B-U Trunk	48.8	6.2	3.1	43.6	12.9	29.4	8.5	10.0
B-U Principal	37.5	6.4	3.2	44.6	13.2	29.9	8.0	9.4
N B-U Trunk	67.5	6.2	3.1	43.0	12.8	29.4	9.2	10.9
N B-U Principal	59.3	6.2	3.1	43.1	12.8	29.3	8.2	9.7
All Minor roads	33.8	6.6	3.3	45.2	13.4	30.2	8.0	9.5

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TABLE 4.15
Resource Costs

Resource costs per km of normal route/hr	p/km /veh	veh/hr	Cost /km/hr	Time costs per km of normal route/hr Speed	Time Cost	Total Costs
Motorways	12.1	2275	£274.76	90	£163.64	£438.40
B-U Trunk	10.0	732	£72.95	65	£72.63	£145.58
B-U Principal	9.1	617	£56.41	50	£81.59	£137.99
N B-U Trunk	11.2	590	£66.00	90	£42.00	£108.00
N B-U Principal	9.8	277	£27.20	79	£22.42	£49.62
All Minor roads	9.1	58	£5.30	45	£8.40	£13.70

Resource costs per km of diversion/hr	p/km /veh	veh/hr	Cost /km/hr	Time costs per km of normal route/hr Speed	Time Cost	Total Costs
Motorways	11.7	2275	£267.23	68	£218.18	£485.41
B-U Trunk	10.0	732	£73.47	49	£96.84	£170.31
B-U Principal	9.4	617	£58.17	38	£108.78	£166.95
N B-U Trunk	10.9	590	£64.15	68	£56.00	£120.15
N B-U Principal	9.7	277	£26.85	59	£29.89	£56.74
All Minor roads	9.5	58	£5.52	34	£11.19	£16.71

Costs per hour of disruption at 75% of Normal Speed	Diversion Length/Normal Route Length									
	1	2	3	4	5	6	7	8	9	10
Motorways	£47	£532	£1,018	£1,503	£1,989	£2,474	£2,959	£3,445	£3,930	£4,416
B-U Trunk	£25	£195	£365	£536	£706	£876	£1,047	£1,217	£1,387	£1,558
B-U Principal	£29	£196	£363	£530	£697	£864	£1,031	£1,198	£1,365	£1,532
N B-U Trunk	£12	£132	£252	£373	£493	£613	£733	£853	£973	£1,093
N B-U Principal	£7	£64	£121	£177	£234	£291	£348	£404	£461	£518
All Minor roads	£3	£20	£36	£53	£70	£87	£103	£120	£137	£153

Traffic2.wk1, 22-Jun-93 now

Table 4.16
Traffic Disruption Costs

Costs per hour of disruption at 75% of Normal Speed

Road Type	Diversion Length/Normal Route Length									
	1	2	3	4	5	6	7	8	9	10
Motorways	£47	£532	£1018	£1503	£1989	£2474	£2959	£3445	£3930	£4416
B-U Trunk	£25	£195	£365	£536	£706	£876	£1047	£1217	£1387	£1558
B-U Principal	£29	£196	£363	£530	£697	£864	£1031	£1198	£1365	£1532
N B-U Trunk	£12	£132	£252	£373	£493	£613	£733	£853	£973	£1093
N B-U Principal	£7	£64	£121	£177	£234	£291	£348	£404	£461	£518
All Minor roads	£3	£20	£36	£53	£70	£87	£103	£120	£137	£153

Costs per hour of disruption at 50% of Normal Speed

Road Type	Diversion Length/Normal Route Length									
	1	2	3	4	5	6	7	8	9	10
Motorways	£159	£757	£1354	£1951	£2549	£3146	£3744	£4341	£4939	£5536
B-U Trunk	£77	£299	£522	£744	£967	£1189	£1412	£1635	£1857	£2080
B-U Principal	£88	£314	£541	£767	£993	£1219	£1445	£1671	£1898	£2124
N B-U Trunk	£41	£190	£339	£488	£637	£785	£934	£1083	£1232	£1381
N B-U Principal	£23	£95	£168	£240	£313	£385	£458	£530	£603	£675
All Minor roads	£9	£32	£55	£78	£100	£123	£146	£169	£192	£215

Costs per hour of disruption at 25% of Normal Speed

Road Type	Diversion Length/Normal Route Length									
	1	2	3	4	5	6	7	8	9	10
Motorways	£519	£1477	£2434	£3392	£4350	£5307	£6265	£7222	£8180	£9138
B-U Trunk	£237	£620	£1003	£1385	£1768	£2151	£2534	£2917	£3299	£3682
B-U Principal	£268	£673	£1079	£1484	£1890	£2296	£2701	£3107	£3512	£3918
N B-U Trunk	£133	£314	£615	£856	£1097	£1339	£1580	£1821	£2062	£2303
N B-U Principal	£72	£194	£316	£437	£559	£681	£802	£924	£1046	£1167
All Minor roads	£28	£69	£110	£152	£193	£234	£276	£317	£358	£400

5 TESTING OF METHODOLOGY

5.1 General

The methodology set out in Section 3 allows for different appraisal approaches to be used depending upon the anticipated cost of the scheme (see Figure 3.1). This section works through several examples to test the methodology. The Consultants were supplied with appraisal details from 27 schemes by the NRA (see Table 2.1). Most of these did not include sufficient information for the simplified economic analysis to be carried out, as one of the two key elements of the analysis was missing:- assessment of flood extent (allowing for HE's to be calculated), or the assessment of return period for at least one flood event.

However, although not prepared in the precise format that the simplified methodology would recommend, we have taken three cases that allow for some comparison to be made between existing more rigorous appraisal methodologies and the proposed simplified methodology. These studies are that of Deys Brook, Bolton-Le-Sands and the Rylands Wall/Beeston Canal Embankment.

Reference should also be made to the Guidelines set out in R & D Note 187, which have been prepared as a result of this Research Study and are presented in a separate report. Those guidelines include all the relevant tables and lead the appraiser through the required steps of the analysis. A hand written example using the guidelines is presented as Appendix C to this report.

5.2 Appraisal of Deys Brook

Deys Brook Flood Control Scheme is part of a large scheme promoted by a housing developer. Alternative schemes were considered and a cost benefit analysis carried out on the recommended scheme by the NRA - North West Region. This scheme was for an investment cost of £80 000. The related larger element of the scheme to be built by the developer would cost some £350 000. There is a danger that the benefits for the scheme have been double counted, being applicable to both elements of the scheme but that aspect is ignored for the purposes of the present exercise.

Approach 1("Short Cut")

Referring to the normalised flood damage-frequency curve, see Figure 3.2; and using the calculated damages of :-

1:25 yr.flood, damages £142526, $V_{25}/11$; thus annual average damages(AAD) estimated as £12957
1:50 year flood, damages £257595, $V_{50}/21.75$; thus AAD estimated as £11843

Assuming the 1:50 year estimate to be more representative, the flooding impact benefit of the "project" is thus £11843 x the annual benefit factor for design to a standard of protection of 50 year return period (see Table 4.11). Thus £11843 x 0.75 = £8882

Approach 2

(a) Flood Impacts

Established for:- <1:10 - existing Standard of Protection (SOP), damage = zero
1:25 and 1:50

(b) HE's Affected

	1:10 years	1:25 years	1:50 years
House	-	28 x 1.04 = 29.12	54 x 1.04 = 59.28
Golf Club House	-	0.7	0.7
Golf course	-	20	20
Total	-	49.82	79.98

Note :- No allowance for agriculture or traffic in this case

(c) Annual Average Number (AAN) of HE's affected

Assuming linear interpolation

$$\begin{aligned} AAN &= \frac{(79.98+49.82)}{2} \times 0.02 + \frac{(49.82+0)}{2} \times 0.06 \\ &= 1.298 + 1.4946 \\ &= 2.793 \text{ HE's} \end{aligned}$$

(d) Flood Extent with Project

Assumed to be zero

(e) and (f) Also zero

(g) Difference between (c) & (f) of 2.793 HE's is the flooding impact benefit of the "project"

(h) (g) x £1135 gives an average annual benefit of £ 3170 in financial terms.

(i) Other benefits to be added (methodology yet to be confirmed by NRA)

(j) Discount Benefits

Assume 50 year project life and calculate PV with discount rate of 6%; gives £3170 x 15.76 = £49 959

Costs given as £80 000 all in year 0; no discounting required.

(k) B/C Ratio = $\frac{49\ 959}{80\ 000} = 0.62$

Approach 3 (After RIMS) Not applicable with the information received

Approach 4 (after P & P)

The methodology is very similar to that actually used by the NRA in their Appraisal Report. However, the exercise is repeated below using updated benefit figures:-

(a) Flood Impacts

Established for:- <1:10 - existing SOP damage = zero
1:25 and 1:50

(b) Calculate property damages by HE's for each flood extent with flood depth categories (Table 4.9), assume short duration flooding

Flood Depth Category	Damage Value (£)	1:10 years	1:25 years (HE's)	1:50 years (HE's)
>0.6m	7227	-	-	-
0.31 - 0.6 m	5953	-	-	18+20
0.1 - 0.3 m	3048	-	18+20	23
<0.1m	576	-	10	13
Total Damages(£)	-	-	121584	303806

Note:- Golf Club House taken as equivalent to 20 HE's, see Table 4.7

(c),(d)
& (e) No allowance for agriculture or traffic in this case

(f) Calculate Annual Average Damages (AAD) without project

Assuming linear interpolation

$$AAD = \frac{(304000 + 122000)}{2} \times 0.02 + \frac{(122000 + 0)}{2} \times 0.06$$
$$= 4260 + 3660$$
$$= £7920$$

(g) Flood Extent with Project

Assumed to be zero

(h) and (i) Also zero

(j) Difference between (f) and (i) of £7920 is the flooding impact benefit of the "project"

(k) Other benefits to be added (methodology yet to be confirmed by NRA)

(l) Discount Benefits

Assume 50 year project life and calculate PV with discount rate of 6%; gives £7920 x 15.76 = £124819

Costs given as £80 000 all in year 0; no discounting required.

(m) $$\text{B/C Ratio} = \frac{124819}{80\,000} = 1.56$$

Comparison of Approaches for Deys Brook:-

	Approach 1	Approach 2	Approach 3	Approach 4	NRA
Annual Average Benefit (£)	8882	3170	-	7920	8277 (1990) 9436 (1993)[1]

Note:- [1] Updated to 1993 based on the RPI, using a factor of 1.14

5.3 Appraisal of Bolton-le-Sands

Bolton-le-Sands is a coastal defence scheme, which aims to protect 36 domestic properties, 1 farm,4 caravan parks, 1 electrical sub-station, 1 effluent treatment works, 1 sewage pumping station and 53 hectares of agricultural land from inundation from storm tides. The works consist of heightening and strengthening existing embankments at an estimated cost (1988 prices) of £95000. This heightening is designed to withstand up to the 1:50 year flood. Being coastal the saline multiplier factors are used in the analysis.

Approach 1 ("Short Cut")

Referring to the normalised flood damage-frequency curve, see Figure 3.2; and using the calculated damages of :-

1:10 yr.flood, damages £91017, $V_{10}/3.36$ thus annual average damages(AAD) estimated as £27088
1:20 year flood, damages £191182, $V_{20}/7.71$; thus AAD estimated as £24797
1:50 year flood, damages £991757, $V_{50}/21.75$; thus AAD estimated as £45598

Assuming the 1:50 year estimate to be more representative, the flooding impact benefit of the "project" is thus £45598 x the annual benefit factor for design to a 50 year return period standard of protection (see Table 4.11). Thus £45598 x 0.75 = £34200

Approach 2

(a) Flood Impacts

Established for:- <1:10 - existing SOP but limited damages
1:20, 1:40 and 1:50

(b) HE's Affected

	1:10 years	1:20 years	1:40 years	1:50 years
Coastal Properties:-				
Houses	6 x 1.27[1] = 7.6	18 x 1.27 = 22.9	18 x 1.27 = 22.9	18 x 1.27 = 22.9
Caravans	20 x 1.2 = 24	30 x 1.2 = 36	30 x 1.2 = 36	30 x 1.2 = 36
Other	-	3 x 1.2[2] = 3.6	4 x 1.2 =4.8	4 x 1.2 =4.8
Inland Properties:-				
Houses	-	3 x 1.27 = 3.8	16 x 1.27 = 20.3	16 x 1.27 = 20.3
Caravans	-	50 x 1.2 = 60	50 x 1.2 = 60	50 x 1.2 = 60
Other	-	1 x 1.2 = 1.2	3 x 1.2 = 3.6	3 x 1.2 = 3.6
Hest Bank:-				
Houses	1 x 1.27 = 1.27	2 x 1.27 = 2.5	4 x 1.27 = 5.1	4 x 1.27 = 5.1
Caravans	17 x 1.2 = 20.4	17 x 1.2 = 20.4	17 x 1.2 = 20.4	17 x 1.2 = 20.4
Other	-	-	-	-
Sub-Total (Property)	53.3	150.4	173.1	173.1
Agriculture[1]:-				
"Poor land"	12.1x0.449=5.4	12.1x0.449=5.4	12.1x0.449=5.4	12.1x0.449=5.4
"Pasture land"	20.25x0.201=4.1	40.5x0.201=8.1	40.5x0.201=8.1	40.5x0.201=8.1
	62.8	163.9	186.6	186.6

No allowance for traffic in this case

(c) Annual Average Number (AAN)

Assuming linear interpolation

$$\begin{aligned} AAN &= \frac{(186.6+186.6)}{2} \times 0.005 + \frac{(186.6+163.9)}{2} \times 0.025 + \frac{(163.9+62.8)}{2} \times 0.05 \\ &= 0.933 + 4.381 + 5.668 \\ &= 10.982 \text{ HE's} \end{aligned}$$

(d) Flood Extent with Project

Assumed to be zero

(e)&(f) Also zero

(g) Difference between (c) & (f) of 10.982 HE's is the flooding impact benefit of the "project"

(h) (g) x £1135 gives an average annual benefit of £ 12465 in financial terms.

(i) Other benefits to be added (methodology yet to be confirmed by NRA)

(j) Discount Benefits
Assume 50 year project life and calculate NPV with discount rate of 6%; gives £12465 x 15.76 = £196442

Costs given as £107 000 all in year 0; no discounting required.

(k) B/C Ratio = $\frac{196442}{107000}$ = 1.84

Approach 3 (After RIMS) Not applicable with the information received

Approach 4 (after P & P)

The methodology is similar to that actually used by the NRA in their Appraisal Report. However, the exercise is repeated below using updated benefit figures:-

(a) Flood Impacts

Established for:- <1:10 - existing SOP but limited damages
1:20, 1:40 and 1:50

(b) Calculate property damages by HE's for each flood extent with flood depth categories (Table 4.9), assume short duration flooding

Flood Depth Category	Damage Value (£)	1:10 years	1:20 years (HE's)	1:40 years (HE's)	1:50 years (HE's)
<.10m	576	(10x1.27+97x1.2)=129.1	(15x1.27+87x1.2)=123.5	15x1.27=19.1	15x1.27=16.1
0.10-0.20m	1683		8x1.27=10.2	7x1.27=8.9	-
0.21-0.30m	4412	-	1x1.27=1.3	(6x1.27+70x1.2)=91.6	2x1.27=2.5
0.31-0.60m	5953	-	10x1.2=12	(7x1.27+17x1.2)=29.3	(10x1.27+70x1.2)=96.7
0.61-0.90m	7227			(3x1.27+10x1.2)=15.8	(10x1.27+17x1.2)=33.1
0.91-1.20m	8287			-	(3x1.27+10x1.2)=15.8
Emergency Services	-	107x240=25680	121x240=29040	140x240=34080	142x240=34080
Total Damages(£)		100042	194514	752809	1000187

(c) Agricultural Damages

	1:10 years	1:20 years	1:40 years	1:50 years
Agriculture[1]:- "Poor land" "Pasture land"	12.1x14.1*44.9=7660 20.25x22.8*20.1=9280	12.1x14.1*44.9=7660 40.5x22.8*20.1=18560	12.1x14.1*44.9=7660 40.5x22.8*20.1=18560	12.1x14.1*44.9=7660 40.5x22.8*20.1=1856079 90
	16940	26220	26220	26220

Note [1] Assumption is that the catchment size is small and that "poor land" is extensive pasture with bad drainage; "pasture land" is intensive pasture with good drainage.

(d) No allowance for traffic in this case

(e) Sum Damages for Each Return Period Event

	1:10 years	1:20 years	1:40 years	1:50 years
Property (excl. saline damage factor) Property (incl. saline damage factor)	(100042) 115048	(194514) 223691	(752809) 865730	(1000187) 1150215
Agriculture	16940	26220	26220	26220
	131988	249911	891950	1176435

(f) Calculate Annual Average Damages (AAD) without project

Assuming linear interpolation

$$AAD=\frac{(1176435+891950)}{2}x0.005+\ \frac{(891950+249911)}{2}\ x\ 0.025+\ \frac{(249911+131988)}{2}x\ 0.05$$

$= 5171 + 14273 + 9548$
$= 28992$

(g) Flood Extent with Project

Assumed to be zero

(h)&(i) Also zero

(j) Difference between (f) & (i) of £28992 is the flooding impact benefit of the "project"

(k) Other benefits to be added (methodology yet to be confirmed by NRA)

(l) Discount Benefits

Assume 50 year project life and calculate NPV with discount rate of 6%; gives £28992 x 15.76 = £456914
Costs given as £107 000 all in year 0; no discounting required.

(m) B/C Ratio = $\frac{456914}{107000} = 4.3$

Comparison of Approaches for Bolton-le-Sands:-

	Approach 1	Approach 2	Approach 3	Approach 4	NRA
Annual Average Benefit (£)	34200	12465	-	28992	9560 (1988) 13518 (1993)[1]

Note:- [1] Updated to 1993 based on the RPI, using a factor of 1.414

5.4 Rylands Wall/Beeston Canal Embankment

The Rylands Wall/Beeston Canal Embankment scheme has been used to make a comparison between the use of the RIMS approach (see Section 3.4.4, Approach 3) with the other 3 Approaches. It is not a typical scheme that would normally be assessed using RIMS by the Severn Trent Region as it is essentially a Capital Scheme. It has been used, however, because enough information is available to allow a comparison of all 4 approaches.

The Rylands Wall/Beeston Canal Embankment scheme is an urban protection scheme incorporating protection of residential property, works areas and university grounds. The total cost of the scheme would be more than £1.5 million and thus the analysis has been carried out by the NRA to a standard suitable for MAFF grant aid.

Approach 1 ("Short Cut")

Referring to the normalised flood damage-frequency curve, see Figure 3.2; and using the calculated damages of :-

1:25 yr.flood, damages £39.57 million, $V_{25}/11$; thus annual average damages (AAD) estimated as £3.56 million [PV 56.7 million]

1:50 year flood, damages £66.87 million, $V_{50}/21.75$; thus AAD estimated as £3.07 million [PV £48.5million]

1:100 year flood, damages £91.43 million, $V_{50}/21.75$; thus AAD estimated as £3.57 million [PV £56.3 million]

For the 3 Options being considered the calculation on benefits has been made using the normalised flood-damage frequency curve (Figure 3.2) and based on the annual average benefits from the 1:100 year flood event adjusted by the annual benefit factor for the appropriate standard of protection (see Table 4.11) giving:-

Option 1 (1:25 year SOP), AAD = 3.57 x 0.5 = £1.785 mil.= PV £28.1 million (50 yr. life)
Option 2 (1:50 year SOP), AAD = 3.57 x 0.75 = £2.678mill.= PV £42.2 million (50 yr. life)
Option 3 (1:100 year SOP),AAD = 3.57 x 0.9 = £3.213 mill.= PV £50.6 million (50 yr.life)

Approach 2

(a) Flood Impacts

Established for:- 1:10, 1:25, 1:50, 1:100
<1:10 existing SOP damage = zero

(b) HE's Affected

	1:10 years	1:25 years	1:50 years	1:100 years
House	1380x1.04=1435.2	2705x1.04=2813.2	3687x1.04=3834.5	4346x1.04=4519.8
Public Buildings	7x58=406	12x58=696	20x58=1160	22x58=1276
Industrial	21x195x6=24570	27x195x6=31590	36x195x6=42120	42x195x6=49140
Total	26411	35099	47115	54936

Note :- No allowance for agriculture or traffic in this case

(c) Annual Average Number (AAN) of HE's affected

Assuming linear interpolation

$$AAN = \frac{(26411+35099)}{2}x0.06\ \frac{(35099+47115)}{2}x\ 0.02\ +\ +\frac{(471152\ +\ 54936)}{2}\ x\ 0.01$$
$$= 1845 + 822 + 510$$
$$= 3177 \text{ HE's}$$

(d) Flood Extent with Project (Option 3, 1:100 year protection)
Assumed to be zero

(e) and (f) Also zero

(g) Difference between (c) & (f) of 3177 HE's is the flooding impact benefit of the "project"

(h) (g) x £1135 gives an average annual benefit of £ 3.605 million in financial terms.

(i) Other benefits to be added (methodology yet to be confirmed by NRA)

(j) Discount Benefits

Assume 50 year project life and calculate NPV with discount rate of 6%; gives £3.605 million x 15.76 = £56.8 million

Costs given as £1.75 million all in year 0; no discounting required.

(k) B/C Ratio = $\frac{56.8}{1.75}$ = 32.5

(l) Similarly for Options 1 and 2:-

Option 1 (1:25 year protection); NPV = £33.0 million
Option 2 (1:50 year protection); NPV = £47.7 million

Approach 3 (After RIMS)

Calculation has been carried out for the Consultants by the Severn Trent Region with the results as given in Table 5.1.

TABLE 5.1

Benefit Calculation Using RIMS

Return Period	1:25	1:50	1:100
Houses benefit	591056	815744	966115
Manuf./Retail/Distrib./Others benefit	148560	268296	374605
Railways/Roads benefit	0	0	0
Total benefit	739616	1084040	1340720
PV of Benefits[1]	11.7 million	17.1 million	21.1 million

Note:- [1]. Assuming a 50 year life and discount rate of 6%

Approach 4 (after P & P)

The consultants were not provided with sufficient information on flood depths to carry out this analysis, bit it is understood that the NRA methodology used was very similar to the P & P approach with flood depths taken into account through use of the ESTDAM model.

Comparison of Approaches for Rylands Wall/Beeston Canal Embankment:-

		Approach 1	Approach 2	Approach 3	Approach 4	NRA
Present Value	Option 1	24.0	33.0	11.7[1] (12.6)	-	31.1
Benefit (£ million)	Option 2	42.7	47.7	17.1[1] (18.5)		50.5
	Option 3	56.3	56.8	21.1[1] (22.8)		65.0

Note:- [1] 1991 prices the updated figures for 1993 using a factor of 1.08 based on the RPI are given in brackets.

5.5 Conclusion

The above examples have been worked through using information as supplied by the NRA. They consist of existing appraisal reports which were prepared for analysis with existing methodology.

Although some estimation has had to be made in working through the above examples, it has proved to be a relatively quick and straightforward exercise to carry out each of Approaches 1,2 and 4. It has only been practicable to make a comparison using the RIMS methodology (Approach 3) on one scheme (Rylands Wall, Section 5.4) as the other examples provided using RIMS did not contain sufficient information to carry out comparative analysis using the other Approaches.

The comparison of results shows significant differences in the results between Approach 2 and 4, but this may be related to several possible causes:-

- significance of flood depth categories (which are not taken into account in Approach 2)
- particular characteristics of the 2 schemes studied (Bolton-le-Sands in particular may be untypical as it is a coastal scheme with saline flooding and includes a significant number of caravans in the analysis)
- the average damage value placed on HE's (£1 135 per HE)

The most simplified approach (Approach 1) has been shown to produce an assessment of benefits within a reasonably similar order to that of the more comprehensive Approach 4. Thus Approach 1 would appear to be suitable as a quick and cheap method of carrying out an initial assessment. However, it should be recognised that the basis of Approach 1 is the normalised flood damage-frequency curve (Figure 3.2), and that Bolton-le-Sands was one of the example used to create that curve. It is likely therefore that there will be a greater divergence of results if other examples are used.

It is recommended that the four approaches be carried out on more schemes before a reasonable assessment can be made as to the reliability of the methodology. It is also recommended that the reference normalised flood damage-frequency curve be prepared using a greater number of cases. The methodology could be further improved by producing a series of reference curves for different scheme types, e.g.:- capital river schemes, maintenance river schemes, coastal protection schemes, other schemes.

In conclusion, the simplified methodologies provide a quick and reasonable representative analysis technique and that the procedure should follow the decision path as set out in Figure 3.1. However, further development is required as suggested above to improve the methodology further.

Guidelines have been prepared and are presented in R & D Note 187. Those guidelines include all the relevant tables to lead the appraiser through the required steps of the analysis.

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APPENDIX A

AGRICULTURAL BENEFITS

APPENDIX A

AGRICULTURAL BENEFITS

A1 Introduction

Section 4.2 of the Main Report describes the methodology and approach adopted for the calculation of standard agricultural benefit values for the economic appraisal of flood protection schemes costing less than £500 000. Section A2 of this appendix presents the detailed calculations. Section A3 comprises an assessment of whether, for each major farming enterprise different levels of return (gross and net margins) should be assumed for different regions or whether uniform values can be taken for the country as a whole.

A2 Estimation of Standard Agricultural Benefit Values

A2.1 General

For the assessment of the agricultural benefits of flood protection works it is necessary to estimate the following:

(a) the effects of different drainage situations (standards of drainage on land being farmed) on crop and grassland productivity. Flood protection works such as improved channel maintenance can result in better drainage and thus higher agricultural production, through the lowering of watertable levels. From the viewpoint of the quantification of agricultural losses caused by flooding, the value of the loss will be greater the better the normal drainage conditions. Flooding of, for example, rough grazing land is obviously less serious economically than the flooding of arable crop land.

(b) the physical effects of such flooding on crops and grassland farming, in terms of outright losses, yield reductions and other consequences such as the need to replant destroyed crops and to clear up the land;

(c) the economic consequences of the above, in terms of the changes in gross output, variable costs and fixed costs, and gross and net margins, which result.

The detailed calculations presented in the following sections were prepared by Dr. Joe Morris of Silsoe College, with certain minor modifications being made subsequently by ourselves, especially in the light of the new MAFF Guidelines. The assumptions made with regard to drainage and flooding effects are unavoidably approximate in nature, but Silsoe College has particularly detailed experience in this field and the estimates made can be regarded as the best available at the present time. In subsequent years, if and when additional data come available, they can be updated.

Yield, price and cost data are based on figures presented in the 1993 Wye College Farm Management Pocketbook, by John Nix. This is the standard data source for flood protection agricultural benefit data. Its figures are at 1993 prices. For project appraisals carried out in future years the benefit figures will need updating on the basis of an inflation index. This could be either the general Retail Price Index (RPI) or a specifically agricultural price index, that for All Farm Produce. The latter is published in the Pocketbook every year, along with the RPI and indices for input prices. Choice of index is important, because there is often a large difference between the RPI and the All Farm Produce Index (AFPI). Taking 1985 as 100, the 1991 indices are 141 for the RPI and only 112 for the AFPI, because of the general decline in crop and livestock prices in real terms. Since the AFPI relates specifically to agriculture whereas the RPI does not, we propose that the AFPI, as presented each year in the J Nix Pocketbook, should be used for the future updating of the 1993 agricultural benefit values derived here.

A2 Estimation of Drainage Benefits

A2.1 Introduction

The physical and economic consequences of different standards of land drainage, as represented by different watertable depths (ie degrees of waterlogging), are calculated below, to provide the basis for the estimation of the benefits of changes in watertable levels resulting from channel maintenance, pump station works and other flood protection works.

A2.2 Drainage Status (Waterlogging)

Drainage status is described in three categories: good, bad and very bad. These reflect the extent of waterlogging of the soil profile and the consequences for crop growth and the load bearing strength of soils (for machinery and grazing animals). Drainage status and resultant land productivity can be categorised by watertable depth, as follows:

Watertable (depth from surface) (mm)	Drainage status	Productivity class
>500 300 to 500 <300	Good Bad Very bad	Normal Low Breakdown

Good drainage involves no impediment to land use. Bad drainage results in reductions in yields, field work days and grazing season. Very bad drainage results in severe restrictions on land use, cropping options, yields, grazing seasons and the reliability of forage conservation.

Grass growth is reduced by colder, wetter sites (see below). Field access is reduced for the application of fertiliser, for grazing livestock and for taking reliable cuts of silage. These impacts are incorporated into the estimates given below.

Item	Drainage status		
	Good	Bad	Very bad
Percentage of unrestricted nitrogen use	100	75	50
Grass conservation	Silage	Grazing	Grazing
Reduction in grazing days*			
Spring	0	14	28
Autumn	0	14	28
Winter	0	0	0**

Notes: * Zero penalty if pasture is closed up for silage/hay making.
** Could be losses where stock are overwintered on grass (perhaps £15-20/ha per winter).

A2.3 Grass Production

On a given site the level of grass production (yield), which is best expressed in terms of dry matter (DM), is dependent mainly on the level of nitrogen application. Dry matter converts to energy (MJ/tDM) which can be utilised by livestock. Utilised metabolisable energy (UME) (MJ/ha) available to stock depends on drainage conditions, the risk of damage to soils by grazing animals (poaching), and grass conservation/use method. Adjustment factors for these variables are given in Table A2.1 for a site with 'good' potential for grass growth as defined by climate and soils.

TABLE A2.1

Assumptions Regarding Grass Production

Grass production weighting factors	
Drainage status:	
Good	1.00
Bad	0.92
Very bad	0.84
Soil type	
Poaching	1
Non-poaching	0.9
Grass use:	
Graze	1.00
Cut	1.08

UME Available

The following function is used:

Tonnes DM/ha grass = $(0.3419N - 0.0000296N^2 + 2.63)$
x grass energy conversion factor
x grass utilisation reduction factor
x drainage status factor
x grass use factor

Grass energy value (MJ/t DM) 11 200 grazed; 10 500 conserved (silage)

Grass utilisation factor (ie allowance for losses) 0.70 grazed; 0.80 conserved

For example, for good drainage, 100 kgN/ha, cut for silage

= 5.75 tDM/ha x 11 200 MJ/tDM x 0.7 x 1 x 1.08
= 48 712 MJ/ha

A2.4 Livestock Type and Energy Requirements

Energy requirements from grass per head of livestock depend on livestock type, age, size and output (liveweight gain or milk production) and the proportion of the diet coming from non-grass sources. Energy requirements per year are taken to be as follows:

Livestock type	MJ/head per year
24 month beef	28 350
Suckler beef	28 000
18 month beef	20 260
Dairy (5 350 litres milk)	37 400

As explained in Section 4.2.2 of the Main Report, the economic value of flood control and drainage for livestock production has been calculated in terms of beef rather than dairy production. Returns have been estimated for two 'extensive' systems (24 month beef and single suckler beef (lowland)) and one 'intensive' system (18 month beef), all derived from Nix. Basic characteristics of the Extensive Grass and Intensive Grass systems are as follows:

Extensive Grass: relatively low nitrogen use (<100 kg N/ha), often on heavy soils, without field drains, permanent pasture supporting grazing livestock such as 24 month beef, store cattle, suckler beef and sheep. Where conditions allow, silage/hay may be cut for winter feed.

Intensive Grass: relatively high nitrogen use (>200 kg N/ha), well-drained soils, temporary leys supporting dairy and/or intensive 18 month grass beef systems.

A2.5 Financial and Economic Returns from Grassland under Different Drainage Standards

Table A2.2 shows the calculation of the estimated returns from grassland under the three drainage conditions and three livestock enterprises. Explanations of the calculations are given below.

(a) Stocking Rate

Given by $\frac{\text{UME MJ/ha}}{\text{UME MJ/head}} = \text{head/ha}$

For example, for beef sucklers on a good site:

$$\frac{48\ 712 \text{ MJ/ha}}{28\ 000 \text{ MJ/head}} = 1.74 \text{ head/ha}$$

This is similar to the stocking rate reported in Nix 1992 for lowland sucklers.

TABLE A.2.2
ESTIMATED FINANCIAL AND ECONOMIC RETURNS TO GRASSLAND

		EXTENSIVE GRASS			EXTENSIVE GRASS			INTENSIVE GRASS		
Drainage status		Good	Bad	Very Bad	Good	Bad	Very Bad	Good	Bad	Very Bad
Grass type		Permanent			Permanent			Temporary Ley		
Nitrogen	kgN/ha	100	75	50	100	75	50	220	165	110
Conservation		sil/hay	hay/graze	graze	sil/hay	hay/graze	graze	silage	silage	silage 50%
UME Available	MJ/ha	48712	37715	25282	48712	37715	25282	73827	63212	49189
Livestock type		24 month beef			Single suckler beef(lowland)			18 month beef		
UME required	MJ/hd	28350	28350	28350	28000	28000	28000	20260	20260	20260
Stocking rate	hd/ha	1.7	1.3	0.9	1.7	1.3	0.9	3.6	3.1	2.4
Sales	£/hd	515.0	515.0	515.0	255.0	255.0	255.0	509.0	509.0	509.0
less calf or cow depr.	£/hd	140.0	140.0	140.0	50.0	50.0	50.0	140.0	140.0	140.0
Headage payments	£/hd	96.0	96.0	96.0	56.0	56.0	56.0	48.0	48.0	48.0
Financial gross output	£/hd	471.0	471.0	471.0	261.0	261.0	261.0	417.0	417.0	417.0
Economic gross output (Note 1)	£/hd	306.2	306.2	306.2	169.7	169.7	169.7	271.1	271.1	271.1
Variable costs	£/hd	235.0	235.0	235.0	81.0	81.0	81.0	190.0	190.0	190.0
GM before forage	£/hd	236.0	236.0	236.0	180.0	180.0	180.0	227.0	227.0	227.0
Semi fixed costs	£/hd	82.0	82.0	82.0	58.0	58.0	58.0	56.1	56.1	56.1
Financial net margin before forage	£/hd	154.0	154.0	154.0	122.0	122.0	122.0	170.9	170.9	170.9
Financial net margin before forage	£/ha	264.6	204.9	137.3	212.2	164.3	110.2	622.8	533.2	414.9
Economic net margin before forage	£/ha	-18.6	-14.4	-9.7	53.3	41.3	27.7	90.9	77.8	60.6
Forage costs										
grass production										
fert&chem	£/ha	63.0	49.0	35.0	63.0	49.0	35.0	140.4	115.3	90.2
application	£/ha	8.0	4.0	4.0	8.0	4.0	4.0	12.0	12.0	8.0
subtotal	£/ha	71.0	53.0	39.0	71.0	53.0	39.0	152.4	127.3	98.2
grass conservation	£/ha	42.3	32.7	21.9	28.0	21.7	14.5	92.2	78.9	61.4
Total forage costs	£/ha	113.3	85.7	60.9	99.0	74.7	53.5	244.6	206.2	159.6
Financial net margin after forage	£/ha	151.3	119.1	76.4	113.2	89.6	56.6	378.2	327.0	255.3
Economic net margin after forage	£/ha	-131.9	-100.2	-70.6	-45.7	-33.4	-25.9	-153.7	-128.4	-99.0
Grazing days penalty										
Grazing livestock equivalent	LU/hd	0.8	0.8	0.8	0.7	0.7	0.7	0.5	0.5	0.5
spring	days	0.0	7.0	28.0	0.0	7.0	28.0	0.0	0.0	14.0
autumn	days	0.0	14.0	28.0	0.0	14.0	28.0	0.0	14.0	28.0
winter	days	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
spring at	£/ha	0.0	8.2	22.0	0.0	8.2	22.0	0.0	0.0	21.4
autumn	£/ha	0.0	6.9	9.3	0.0	6.9	9.3	0.0	11.6	18.0
winter	£/ha	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total grazing penalty	£/ha	0.0	15.1	31.2	0.0	15.1	31.2	0.0	11.6	39.4
Financial net margin after graz.penalty	£/ha	151.3	104.0	45.2	113.2	74.5	25.4	378.2	315.4	215.9
Economic net margin after graz.penalty	£/ha	-131.9	-115.3	-101.9	-45.7	-48.5	-57.1	-153.7	-140.0	-138.5

Note: 1. The economic price of beef has been taken as 65% of the financial price, see Section A.2.3

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(b) Gross Output, Variable Costs and Gross Margin before Forage Costs

These financial estimates are derived from Nix, 1992 for the enterprises concerned. For suckler cows, variable costs include purchase bulk feeds (classified under forage costs in Nix 1992).

(c) Semi Fixed Costs

The conventional definition of agricultural gross margins in the UK omits a number of cost elements which are more or less constant per unit of activity and are therefore likely to vary with changes in enterprise size. These include direct labour, power and machinery running costs, and direct building costs. Contrary to what is implicitly assumed in standard UK gross margin analysis, such 'fixed' costs would be higher per hectare the more high-yielding and intensive the enterprise. Drawing on published sources (Meat and Livestock Commission, Milk Marketing Board, and Ministry of Agriculture, Fisheries and Food Farm Management Surveys reported by the University Departments of Agricultural Economics) the following estimates have been used:

Item	£/hd/year			
	24 month	Suckler	18 month	Dairy
Labour	35.6	21.3	24.9	148.5
Power and machinery	37.8	31.7	25.7	28.0
Buildings/shelter	8.3	4.7	5.5	19.5

Notes:

- Labour estimates are based on average labour requirements per head per year, modified to represent extra labour requirements at the margin of herd size. Dairy, 30 hours at £4.68/head. 24 month beef, sucklers and 18 month beef at 7.6 hours, 5.3 hours and 4.6 hours respectively. The latter fatstock extra labour requirements are based on about 38% of average requirements per head.

- Power and machinery costs based on tractor hour equivalents: dairy, 9 hours, 24 month beef, 6.25 hours, suckler 5.25 hours, 18 month beef 4.25 hours at £11/hour, of which 55% are running costs.

- Building costs based on average costs of housing per cow or livestock place, amortised over 20 years at 8% interest, plus 1.5% annual maintenance, all multiplied by 33% to reflect costs of buildings at the margin of herd size.

(d) Net Margin Before Forage

Per head: equals Gross Margin before Forage (£/head) less semi-fixed costs (£/head).

Per hectare: net margin (£/head) x stocking rate (head/ha) = £/ha.

(e) Forage Costs

The costs of grass production are estimated according to nitrogen use.

Fertiliser Costs

Up to 100 kg N/ha

Fertiliser placed as 20N : 10P : 10K compound
at £112.50/t

$$= \frac{£112.50/t}{200 \text{ kg N/t}}$$

= £0.56 kg N

Above 100 kg N/ha

Additional N as Nitram (35.4%N)

$$\text{at} \quad \frac{£110/t}{345 \text{ kgN/t}} = £0.32 \text{ kg N}$$

plus 50 kg K/ha

$$\text{at} \quad \frac{£105/t}{600 \text{ kgK/t}} = £0.18/\text{kg K} = £9.00/\text{ha}$$

Sprays

£7/ha + £0.052 N/ha

Other costs

Seeds and liming on intensive grass have been ignored

Fertiliser Application

Assuming tractor application of fertiliser at 75 kg N/application at £4.0/ha running costs.

Grass Conservation

The variable costs of conserving silage or hay are charged at £23/tDM.

Nix (1992) gives silage costs at £18.5/t wet matter. At 20% dry matter, this equals £92.5/tDM. 50% of costs are for harvesting and storage and 50% of the latter are variable costs such as labour and machinery running costs.

Therefore, 1 tDM = £92.5 x 0.5 x 0.5 = £23/tDM.

Winter conserved grass consumption by stock type.

	24 month beef	Suckler	18 month beef	Dairy
Tonnes DM/head	1.07	0.7	1.1	1.3

(f) Net Margin After Forage Costs

Net margin after forage costs (£/ha) = Net margin before forage (£/ha) less total forage costs (£/ha).

(g) Grazing Penalties

Loss of grazing days involves additional expense due to the need to feed conserved or purchased feed instead of grazed grass, and the extra cost of housing. The opportunity costs of spring grazing days are particularly high, owing to the flush of grass growth in this period.

Value of a grazing day (£ per livestock unit)*	Dairy	Beef and sheep
Spring	1.36	1.16
Autumn	0.52	0.49
Winter	0.32	0.32

Note: * Measured in terms of dairy cow equivalent.
Source: Based on Hess and Morris, 1986.

The loss of a spring grazing day in £ per hectare is given by:

Value of grazing day for stock type (£/ha) x grazing livestock unit equivalent (lu/head) x stocking rate (hd/ha)

(h) Financial Net Margins

Financial net margins show the benefits and costs to farmers. In Table A2.2 net margins per hectare are shown by grassland and livestock enterprise type for good, bad and very bad drainage conditions.

As would be expected, financial net margins per hectare improve with better drainage conditions and as the production system is intensified. Under extensive grass management systems net margins with good drainage are £88/ha to £106/ha better than with very bad drainage, and the intensive grass system under good drainage produces net margins 2.5 to 3.3 times higher than those from the two extensive systems.

(i) Economic Net Margins

Economic net margins represent the real benefits of the alternative systems of grassland production to the national economy, rather than just to the farmers and are thus the critical parameters for agricultural benefits under different drainage conditions.

Unfortunately, the analysis produces very different results for the economic net margins of grassland production than the financial net margins. Apart from the fact that all the systems show net economic losses in all three drainage conditions, there is also the peculiar situation whereby improved drainage within a production system produces negligible, or even negative, economic benefits and the intensification of production (the move to an intensive grass system) leads to increased, rather than reduced, economic losses.

Though at first sight an anomalous and illogical result, it does, unfortunately, reflect economic reality. The reasons are the very high costs of livestock production as a percentage of gross output and the fact that the real (economic) value of this output is only 65% of the financial value, that which the farmer receives. Total variable and semi-fixed costs as a percentage of financial gross output under good drainage conditions are as follows (see Table A2.2):

System	Production costs as a proportion of financial gross output (%)
Extensive grass	
24 month beef	81
single suckler beef (lowland)	79
Intensive grass	75

Clearly, if production costs are 75% of financial gross output and the economic gross output is only 65% of the financial gross output the economic net margin is bound to be negative. The basic conclusion to be drawn is that beef production in the UK, except on a very low input low cost basis, is economically marginal, owing particularly to the low price of beef on the world market (the economic price of beef is based on the likely price of imported beef).

A2.4 Arable Crops

For the reasons given in Section 4.2.2 of the Main Report, for economic appraisal purposes flood control and drainage benefits for arable cropping have been estimated on the basis of cereals. Returns have been calculated for both winter wheat and spring barley. By definition, most of the land protected by flood protection works is low lying and usually of medium or heavy rather than light textures. Wheat, rather than barley is the preferred cereal crop on such land, often rotated with a periodic crop of oilseed rape. Thus the standard economic benefit estimates for project appraisal purposes have been based on wheat.

(a) Drainage Status and Crop Yields

Based on a review of literature (Hess and Morris, 1986) and farm surveys (Morris and Sutherland, 1992) the estimates of yield loss by drainage status are as follows:

Yield as percentage of good drainage	Drainage status		
	Good	Bad	Very bad
Winter cereals	100	80	50
Spring cereals	100	90	80
Oilseed rape	100	90	80
Root crops (and peas)	100	60	40

(b) Yields, Prices, Gross Outputs, Variable Costs and Gross Margins

These are taken from Nix 1992 for the 1993/4 harvest year. Yields for good drainage status are based on the averages quoted in Nix and are reduced according to drainage conditions. Prices are those paid to farmers, plus Area Compensation Payments.

(c) Semi-fixed Costs

Estimates for direct labour, farm power and machinery running costs and direct storage and drying costs (excluding depreciation) all of which vary between crops, are as follows:

Semi-fixed costs		Winter cereals	Spring cereals
Labour	£/ha	46.6	22.7
Power and machinery	£/ha	61.6	44.6
Storage and drying	£/ha	5.0	5.0

Labour and machinery costs are based on estimates of work rates for field operations (Morris, 1993).

(d) Financial and Economic Net Margins

Table A2.3 shows the calculation of the net margins for winter wheat and spring barley. As noted above, wheat has been taken as the standard cereal crop for benefit estimation purposes.

TABLE A.2.3
Estimated Financial and Economic Crop Returns by Drainage Condition
per hectare of Crop (1993 prices)

CROP Drainage Condition		WINTER WHEAT (FEED) good	 bad	 very bad	SPRING BARLEY (FEED) good	 bad	 very bad
Yield	t/ha	7.2	5.8	3.6	5.0	4.5	4.0
Price	£/t	90.0	90.0	90.0	87.0	87.0	87.0
Sale Revenue	£/ha	648.0	518.4	324.0	435.0	391.5	348.0
Area Payment	£/ha	115.0	115.0	115.0	115.0	115.0	115.0
Financial gross output	£/ha	763.0	633.4	439.0	550.0	506.5	463.0
Economic gross output *	£/ha	615.6	492.5	307.8	413.3	371.9	330.6
Financial variable costs	£/ha	260.0	260.0	260.0	150.0	150.0	150.0
Financial gross margin	£/ha	503.0	373.4	179.0	400.0	356.5	313.0
Economic gross margin	£/ha	355.6	232.5	47.8	263.3	221.9	180.6
Semi-fixed costs	£/ha	143.8	136.6	125.8	105.1	102.4	99.7
Financial net margin	£/ha	359.2	236.8	53.2	294.9	254.1	213.3
Economic net margin	£/ha	211.8	95.9	-78.0	158.2	119.5	80.9
Returns per ha of land							
Reduction of Economic Net Margin to allow for 15% Set Aside	£/ha	31.8	14.4	-11.7	23.7	17.9	12.1
Economic Net Margin/ha of land	£/ha	180.0	81.5	-66.3	134.4	101.6	68.8

Note:- * Area payment not included and 5% deduction applied to sales revenue price

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A3 Estimation of Agricultural Losses from Flooding

A3.1 General

The costs of a single flood depend on the crop flooded, the timing of the flood with respect to crop development and related field activities, the duration of the flood and, to a lesser extent, the depth of flooding.

Seasonality is a critical factor. A review of catchment hydrology within Severn Trent (Hess and Morris, 1986) showed that large catchments (above 25 km^2) are predominantly winter flooding, whereas small catchments (below 25 km^2) have more equal distribution of flooding in winter and summer (see Table 4.1 in the main report).

These seasonal distributions can be used to determine the expected cost of a single flood occurring within a year. The average annual cost of flooding can be derived by estimating the number of floods that are likely to occur within the year (the flooding frequency). These methods are incorporated below. They are explained in more detail in Hess and Morris (1986).

A3.2 Grassland

The cost of flooding on grassland is estimated in terms of:

$$D = GMJ \times RF +/- C$$

where	D	-	total damage (£/ha)
	GMJ	=	energy from grass lost due to flooding (MJ)
	RF	=	cost of replacement feed (£/MJ)
	C	=	other costs incurred or saved (£/ha)

The effect of a flood on energy lost depends on the normal yield of grass (as determined above) and the timing of the flood with respect to the cycle of grass growth. Flood impacts on grass are negligible during the winter grass dormancy period. During spring and summer, flood impacts vary according to whether the grass is grazed or conserved in the form of hay or silage. A flood just before a cut can result in substantial loss.

(a) Grass Energy Reduction

Table A3.1 contains estimates of the yield losses associated with floods which occur in particular months on grazed and conserved (single cut) grassland. For conserved systems, energy loss is partly in terms of a reduction in dry matter cut as hay or silage.

TABLE A3.1

Grass Energy Yield Losses owing to Flooding by Month

Month of flood	Loss in reduced grass conservation		Loss in grass yield grazed (%)
	Yield silage[1] (%)	DM silage[2] (%)	
January	0.0	0.0	0.0
February	0.6	0.6	0.0
March	7.6	7.6	3.5
April	29.0	27.8	8.6
May	55.0	35.2	6.4
June	39.3	17.6	4.8
July	5.2	0.0	4.6
August	3.8	0.0	3.3
September	1.8	0.0	1.7
October	0.3	0.0	0.4
November	0.4	0.0	0.0
December	0.0	0.0	0.0

Notes: (1) Percentage of total non-flooded crop used to estimate loss in value of grass energy production.

(2) Percentage reduction in the total amount of dry matter conserved, in order to estimate the saving in silage making and related cost.

(b) Value of Energy

Energy from grass is valued at the cost of replacing it with mineralised barley (85% barley at £85/t, 15% concentrate at £220/t = £105/t plus £6/t mixing = £111/t wet matter. At 88% dry matter = £126/t, at 12 500 MJ/tDM = 1.01 pence per MJ).

(c) Savings in Grass Conservation Costs

For one cut for grass conservation, approximately 80% of the total energy from an equivalent grazed sward is conserved and 20% is grazed later (aftermath grazing). Savings in conservation costs are valued at £23/t DM.

(d) Other Costs

Flooding may require relocation of stock during the grazing period. This is valued at an equivalent housing cost of £0.32/day per livestock unit. A flood is assumed to result in 10 days loss of access. The number of stock relocated depends on stocking rate as determined by total energy from grass (MJ/ha) divided by 37 400 MJ (the energy requirement of a cow at 5 350 litres of milk).

The cost of debris collection and minor fence repairs is estimated at £5 per hectare on grassland, equivalent to half an hour of a man, tractor and trailer at £10/hour.

Table A3.2 shows examples of the calculation of average annual costs of flooding for both conserved and grazed grassland under different assumptions for the seasonal distribution of floods. The table uses the scenarios described for drainage status in Section A2.2. This method was used to provide the values shown in Table A3.3, which summarises the grassland flood damage costs calculated.

TABLE A3.2

Examples of Calculation of Grassland Flood Costs

(a) Conserved Grass (Silage), Large Catchment

Grass	UME loss	Cost of replacement (£)	Reduction in dry matter conserved (t)	Savings in conservation costs (£)	Other costs (£)	Total loss (£)	Seasonal weighted (£)	
January	0	0.00	0.00	0.00	5.00	5.00	1.15	
February	443	4.56	0.03	0.73	5.00	8.83	1.68	
March	5 610	57.79	0.40	9.26	5.00	53.52	6.42	
April	21 408	220.50	1.47	33.89	5.00	191.62	7.66	
May	40 602	418.20	1.87	42.91	5.00	380.29	11.41	
June	29 012	298.82	0.93	21.45	5.00	282.37	2.82	
July	3 839	39.54	0.00	0.00	11.30	50.84	0.51	
August	2 805	28.89	0.00	0.00	11.30	40.19	0.40	
September	1 329	13.69	0.00	0.00	11.30	24.99	0.25	
October	221	2.28	0.00	0.00	11.30	13.58	0.41	
November	295	3.04	0.00	0.00	5.00	8.04	1.13	
December	0	0.00	0.00	0.00	5.00	5.00	0.90	
Seasonal UME yield (MJ/ha)			73 821	MJ/ha	Large catchment		1	Total
Replacement feed (£/MJ)			0.01	£/MJ	Loss of milk (£/ha)		0.00	£/ha
Conserved dry matter (t/ha)			5.3	t/ha	Clean up (£/ha)		5.00	34.74
Cost of silage making (£/t)			23.00	£/t	Relocation (£/ha)		6.30	

(b) Grazed Grassland, Large Catchment

Grass	UME loss	Cost of replacement (£)	Reduction in dry matter conserved (t)	Savings in conservation costs (£)	Other costs (£)	Total loss (£)	Seasonal weighted (£)	
January	0	0.00	0.00	0.00	5.00	5.00	1.15	
February	0	0.00	0.00	0.00	5.00	5.00	0.95	
March	885	9.11	0.00	0.00	5.00	14.11	1.69	
April	2 174	22.39	0.00	0.00	7.16	29.56	1.18	
May	1 618	16.67	0.00	0.00	7.16	23.83	0.71	
June	1 214	12.50	0.00	0.00	7.16	19.66	0.20	
July	1 163	11.98	0.00	0.00	7.16	19.14	0.19	
August	834	8.59	0.00	0.00	7.16	15.76	0.16	
September	430	4.43	0.00	0.00	7.16	11.59	0.12	
October	101	1.04	0.00	0.00	7.16	8.20	0.25	
November	0	0.00	0.00	0.00	5.00	5.00	0.70	
December	0	0.00	0.00	0.00	5.00	5.00	0.90	
Seasonal UME yield (MJ/ha)			25 282	MJ/ha	Large catchment		1	Total
Replacement feed (£/MJ)			0.01	£/MJ	Loss of milk (£/ha)		0.00	£/ha
Conserved dry matter (t/ha)			0	t/ha	Clean up (£/ha)		5.00	8.20
Cost of silage making (£/t)			23.00	£/t	Relocation (£/ha)		2.16	

TABLE A3.3

Flood Damage Costs: Average Economic Cost of a Single Flooding of Grassland Occurring in a Year (£/ha at 1993 Prices)

Drainage status and production system		Grass use as shown		Grazing only	
		Large catchment	Small catchment	Large catchment	Small catchment
Extensive Grass					
Good	Silage or hay	24.7	37.4	11.2	16.7
Bad	Hay/graze	15.0	17.0	9.8	14.1
Very bad	Graze	8.2	11.1	8.2	11.1
Intensive Grass					
Good	Silage	34.7	53.8	14.3	22.8
Bad	Silage	30.5	46.9	13.0	20.2
Very bad	Silage/graze	18.0	27.2	11.2	16.9

Source: Calculations by Dr.J Morris of Silsoe College, March/April 1993.

Flood damage costs on rough pasture would be about 50% of those for extensive grass, grazing only.

A3.3 Arable Cropping

The average annual cost of flooding on arable crops can be estimated as follows:

$$D = NM(Y) - NM(Y^1) + (RC \times R^1) + (MCXS^1) + (REM \times F)$$

where
- D = average annual loss £/ha per year
- $NM(X)$ = net margin £/ha per year at given yield (X)
- Y = normal yield £/ha per year
- Y^1 = yield after flooding £/ha per year
- RC = additional cost of reseeding with spring crops
- R^1 = percentage of years reseeding necessary
- MC = harvest costs saved if crop not harvested
- S^1 = percentage of years crop not harvested
- REM = remedial/debris collection costs
- F = number of floods per year

The cost of a single flood event (£/ha) on an arable crop depends on crop type, stage of crop development and duration of flooding. For the present analysis crop type and the time of year of flooding are the main variables.

The average expected cost of a single flood on a given crop can be assessed by estimating the cost of a single flood occurring in a given month weighted by the probability distribution of floods throughout the year. The seasonal distribution of flooding reflects the catchment characteristics, as previously discussed.

Based on methods described in Hess and Morris (1986), Table A3.4 estimates the cost of a single flood occurring on winter wheat within a year, weighted by seasonality of occurrence. The analysis is done for different yield levels (indicative of drainage status) and for large and small catchments. Explanations are given below.

TABLE A3.4

Average Economic Cost of a Single Flooding of Arable Land Occurring in a year (£/ha at 1993 prices)

Catchment size		Large			Small		
Crop type		Winter wheat	Winter wheat	Winter wheat	Winter wheat	Winter wheat	Winter wheat
Yield loss	%	6	6	6	24	24	24
Percentage reseeded	%	3	3	3	9	9	9
Percentage harvest loss	%	3	3	3	19	19	19
Yield	t/ha	7.2	5.76	3.6	7.2	5.76	3.6
Financial price	£/t	90	90	90	90	90	90
Economic price	£/t	85	85	85	85	85	85
Gross output	£/ha	612.0	489.6	306.0	612.0	489.6	306.0
Variable costs	£/ha	260	260	260	260	260	260
Gross margin (GM)	£/ha	352.0	229.6	46.0	352.0	229.6	46.0
Cost of reseeding	£/ha	179	179	179	179	179	179
Harvest costs	£/ha	50	50	50	50	50	50
Alternative crop (GM)	£/ha	258	215	173	258	215	173
Economic Cost of Flooding							
Loss of yield of harvested crop:							
- Financial							
- Economic	£/ha	38.9	31.1	19.5	155.5	124.4	77.7
Reseeding costs saved	£/ha	36.7	29.4	18.4	146.9	117.5	73.4
Harvest costs saved	£/ha	5.37	5.37	5.37	16.11	16.11	16.11
Other costs	£/ha	1.50	1.50	1.50	9.50	9.50	9.50
Total loss:	£/ha	10.00	10.00	10.00	10.00	10.00	10.00
- Financial							
- Economic	£/ha	55.8	47.9	36.3	194.1	160.0	113.3
	£/ha	53.6	46.2	35.2	185.5	153.1	109.0

Source: Based on calculations by J Morris, Silsoe College.

(a) Flood Impact

Example Calculation:

Catchment type:	large (mainly winter flooding)
Crop type:	winter wheat
Yield loss:	6%
Reseeded:	3%
Harvest loss:	3%

Overall, average expected reduction in yield loss is 6% for a single flood occurring within a year, assuming the seasonal distribution for a large catchment. This includes allowances for floods which result in zero, partial or complete loss in yield.

On average, there is a 3% chance that floods will kill the newly seeded crop (in October). Reseeding is assumed. The yield difference between original and reseeded spring crop is accommodated in the previous yield loss estimate. However, additional costs of reseeding are charged.

On average there is a 3% chance that floods will prevent harvest. The yield loss is included in the 6% loss above. However, there are some savings in harvesting costs.

(b) Yield, Price and Gross Margins

These are based on Nix (1992) for the 1993/94 harvest year.

Yield:	7.2 t/ha for good drainage conditions
Price:	economic price of £85/t for wheat
Gross output:	yield (t/ha) x price £/t = £/ha
Variable costs:	from Nix
Gross margin:	gross output - variable costs

(c) Cost of Reseeding

Winter sown crops damaged by flood are assumed to be replaced by spring sown crops.

Reseeding crops	=	seed costs + (0.3 x non-seed variable costs) + relevant machinery operating and labour costs
For winter wheat	=	£45 + 0.3 (£260 - £45) + £69.5
	=	£179/ha

(d) Cost of Harvesting

Complete loss results in savings in harvest and post-harvest costs. In the case of winter wheat these are:

Labour and machinery	=	£32.0/ha
Drying and storage	=	£4.9/t

For a 7.2 t/ha crop = £32.0/ha + 7.2 t/ha x £4.9/t
= £67.3/ha

(e) Other Costs

Costs of debris collection and minor repairs are charged at the equivalent of 1 h/ha of a man, tractor and trailer at £10/h; ie £10/ha.

(f) Total Losses

These are accumulated by drainage status and catchment (flood seasonality) characteristics.

A3.3 Flood Frequency

The average annual cost of flooding can be determined by dividing the cost of a single flood occurring within a year by the expected interval (expressed in years) between floods. Thus a flood event costing £30/ha occurring every 5 years costs an average £6/year. This method ignores the impact of multiple floods, whose effect can be greater than a simple sum of individual events.

A4 Drainage Standards

Drainage standards were described above in terms of good, bad and very bad. These relate to the depth of the watertable during the spring, when excess water in the soil profile can restrict crop growth and field access. Watertable depth in the field can be managed by the installation of field drains or, in relatively free-draining soils, natural movement of water into an adjacent watercourse or network of open ditches which feed into the latter.

The standards of service in the watercourses and ditches necessary to provide adequate drainage can be described in terms of the freeboard required for piped outfalls or natural drainage.

Table A4.1 shows the freeboard requirements for fields with piped underdrainage. These allow a 200 mm surcharge at the pipe outfall into the watercourse.

Table A4.2 shows the freeboard requirements for naturally drained soils. It can be seen that the heavier the soil, the greater the freeboard requirement. The table indicates the relative change in freeboard associated with given changes in drainage status.

The message is that underdrained and naturally well draining soils are likely to be sensitive to changes in river and watercourse levels, and therefore to changes in standards of drainage service. Undrained, heavy, soils are not.

In this respect, existing land use is a key indicator. Intensive grass and arable land use are likely to be on reasonably well drained land and are therefore sensitive to standards of service. Extensive grass is usually on undrained, heavy, soils where soil moisture is more affected by rainfall than watercourse levels. These latter sites are relatively insensitive to standards of drainage service.

TABLE A4.1

River Freeboard Requirements for Fields with Piped Underdrainage

Soil texture	Flat floodplain* (m)	Rising floodplain (m)
Clay	1.2	1.0
Silty clay	1.4	1.2
Sandy clay	1.4	1.2
Silty loam	1.6	1.4
Loamy sand	1.6	1.4
Coarse sand	1.6	1.4

Note: * add floodplain width (m)/500

TABLE A4.2

River Freeboard Requirements for Naturally Drained Soils

Depth (m) to watertable	Drainage status	Soil type	Flat floodplain	Rising floodplain (1% slope)
0.5)		Sand	0.9	0.6
)	Bad	Loam	1.3	1.0
)		Clay	2.1	2.0
0.3)		Sand	0.7	0.3
)		Loam	1.1	0.6
)		Clay	1.9	1.5
0.0)	Very bad	Sand	0.4	0.0
)		Loam	0.8	0.0
)		Clay	1.6	1.0

A5 Regional Differences in Agricultural Benefits

A5.1 Introduction

In Section 3.3 of the January 1993 Review of Literature the possibility was raised of there being substantial differences in the level of flood defence agricultural benefits per hectare within England and Wales. Owing to climatic, soil and other variations between regions, the differences in enterprise mixes, productivity and net returns could be sufficiently large to justify applying different per hectare agricultural benefit values by region rather than applying a single set of national values.

In the report it was proposed that an assessment of agricultural net returns per hectare by region would be made using the annual farm management survey reports produced for MAFF by eight universities and colleges. Between them these cover the whole of England and Wales. Copies of the 1898/90 and 1990/91 reports by Newcastle, Manchester, Cambridge, Exeter and Reading universities and by the University College of Wales (Aberystwyth) and Askham Bryan College in Yorkshire, were kindly provided on loan by Mr Michael Murphy of the Cambridge University Department of Land Economy, which carries out the East Anglia part of the survey.

Perusal of these reports indicated that a regional comparison of returns per hectare on a monetary basis would be difficult and time-consuming to make and could require numerous assumptions which might well weaken the validity of the results. Comparison on the basis of a more simple and readily available parameter, physical yield per hectare, was therefore preferred.

For any particular crop the level of yield is the single largest determinant of the crop's gross margin (output minus variable costs of production) per hectare. For major field crops the variable costs of production (inputs, machinery operations, casual labour etc) rarely exceed 50% of the gross output, and many, such as seed costs and land preparation, do not vary significantly with the level of yield. Thus, for example, if a crop in one region has a yield 10% higher than that in another region its gross margin per hectare is likely to be at least 20% higher.

Livestock returns and profitability vary more from farm to farm than is the case with major crops, management efficiency having a greater impact on productivity levels. Nevertheless, the productivity per hectare of the grassland, and also forage crop (eg kale and root crops) land, used to feed a farm's livestock is a critical factor affecting the net returns per hectare. The most convenient means of expressing the productivity of flood-prone land used for livestock is in terms of its stocking rate; that is, the number of Grazing Livestock Units (GLSU - one LSU is equivalent to an adult Friesian cow) per forage hectare. GLSU/ha has therefore been used as the parameter with which to compare grassland yields between regions.

A5.2 Crop Yields by Region

If there are substantial differences in crop yields between regions, adjustment factors for agricultural benefit levels around the national mean could be derived from regional crop yield statistics. An analysis of the yields of major field crops between regions was therefore undertaken.

This was somewhat hampered by the fact that MAFF no longer publishes, or even has available as internal information, county or regional crop yield statistics, except for cereals and some minor crops. Production of MAFF yield estimates by county was discontinued in 1982. Contact was made with the Potato Marketing Board, in an effort to obtain potato yield data, but the PMB produces yield data only on a national basis, by variety, with no regional breakdown. Sugar beet yield data could not be obtained from the British Sugar Corporation in the time available.

In view of the scarcity of up-to-date yield statistics by region for crops other than cereals recourse was made to county level historical data from the 1970s and early 1980s. As part of the Silsoe College Agricultural Drainage Evaluation Model, in 1987 Messrs T M Hess and J Morris carried out an analysis of regional variations in crop yields using MAFF statistics for the 1974 to 1982 period. Silsoe College kindly provided us with a copy of its Technical Paper 8, in which the analysis was presented.

Table A5.1 presents the results of the analysis, for wheat, barley, potatoes and oilseed rape. The detailed yield data are given at the end of this appendix. The figures for oilseed rape may be of less validity than for the other crops, because they exist for only a relatively short period in the 1970s when, moreover, oilseed rape was still a fairly new and therefore not well established crop.

For each crop the national (England) yield for the period is given in tonnes/ha and then for each region the percentage variation from this national average is shown.

The main conclusion to be drawn from Table A5.1 is that, considering the variations in climate and soils within England, the differences in major crop yields between regions are remarkably small. The inference is that standards of crop management (ie farming standards) are sufficiently high to overcome the variations in climatic and other conditions between regions. Farmers have adapted their crop production technologies to their local environment sufficiently well to compensate for and overcome climatic constraints such as drought periods in eastern England and the danger of excessive rainfall during the growing season in the west of the country.

It should be noted that the yield figures do not, of course, take account of quality differences, which may have a significant influence on farmgate prices, and thus gross margins. For example, barley grown for malting fetches a higher price than that grown for feed. We are not, however, aware of major regional quality differences for the crops analysed here.

In the case of cereals the variation around the national average in Table A5.1 is generally less than 5% in the main producing regions (the North and the North West are not major cereal growing regions). York and Humberside had the largest consistent difference, with yields 2% to 8% higher. In East Anglia, the 4% to 6% yield difference in the 1974 to 1982 period had almost disappeared by the 1986 to 1992 period.

In all regions the 1974 to 1982 potato yields did not vary by more than 5% from the national average. Except for East Anglia, the regions with higher potato yields were not those with higher cereal yields; ie there was no consistent pattern of regions having consistently higher major crop yields except, to a very limited extent, in East Anglia.

A5.3 Grassland Yields (Stocking Rates) by Region

Table A5.2 presents stocking rate data extracted from annual farm management survey reports for 1989/90 and 1990/91. Unfortunately, regional survey reports from Wye were not available. The figures for dairying provide a more reliable and consistent basis for regional comparison than do those for cattle and sheep farms because there are greater differences in enterprise mix in this latter category. For both dairying and cattle and sheep farms only the lowland category has been taken.

TABLE A5.1

Regional[1] Differences in Crop Yields in England (% variation from national average)

Crop	National (t/ha)	North	Yorks and Humberside	North West	West Midlands	East Midlands	East Anglia	South East	South West
Wheat									
1974 - 1982	5.0	+1	+2	+3	-2	-2	+6	0	-1
1986 - 1992	6.64	+4[2]	+8	-10[2]	-3	+3	+2	-4	-5
Barley									
1974 - 1982	4.0	+3	+5	-4	+1	0	+4	+1	-1
1986 - 1992	5.14	+1[2]	+7	-11[2]	-2	0	0	+1	-4
Potatoes									
1974 - 1982	33.2	-2	-4	+5	+1	-5	+5	+1	-1
Oilseed rape									
1974 - 1979	2.74	+3	+8	+7	+2	+1	+10	-5	-8

Sources: (a) 1974 - 1982 data were by county, from Technical Paper 8, Silsoe College Agricultural Drainage Evaluation Model, T M Hess and J Morris, 1987
(b) 1986 - 1992 data from Home Grown Cereals Authority.

Notes: (1) North = Cleveland, Cumbria, Durham, Northumberland, Tyne and Wear
North West = Cheshire, Greater Manchester, Lancs, Merseyside
West Midlands = Hereford and Worcester, Salop, Staffs, Warwick, W Midlands
East Midlands = Derby, Leics, Lincs, Northants, Notts
East Anglia = Cambs, Norfolk, Suffolk
South East = Beds, Berks, Bucks, Essex, Greater London, Herts, Hants, Kent, Oxon, Surrey, Sussex, Isle of Wight
South West = Avon, Cornwall, Devon, Dorset, Glos, Somerset, Wilts.

(2) Relatively small hectarages

TABLE A5.2

Livestock Stocking Rates Recorded in the Annual Farm Management Survey, 1989/90 to 1990/91
Grazing Livestock Units (GLSU) per hectare

Region/survey institution	Dairying	Cattle and sheep farms
North (Newcastle University)	2.2 - 2.4	1.4 - 1.6
North West (Manchester University)	1.9 - 2.0	1.0 - 1.1
Yorkshire and Humberside (Askham Bryan College)	2.1	1.3 - 1.4
South West (Exeter University)	1.9 - 2.0	1.7
Part of South East (Reading University)	1.9	1.5 - 1.6
Wales (Aberystwyth)	1.8 - 2.2	1.5 - 1.6
Wye Farm Management Pocketbook (national figures)	1.9	NA

Source: Annual Farm Management Survey reports, loaned to Mott MacDonald by the Department of Land Economy, University of Cambridge.

As for crop yields, there is surprisingly little variation in dairying stocking rates between regions. The only region which differs significantly from the national average of 1.9 GLSU per ha (the figure in the Wye Farm Management Pocketbook) is the North, which has a significantly higher stocking rate on the sample farms of 2.2 to 2.4 GLSU/ha. Logically, one would expect the South West to have the highest rate, because of its longer grass-growing period (milder winters) and high rainfall. It is possible that other factors such as higher concentrate feeding rates are distorting the comparison in the case of the North. Since the difference is anyway not that large, we do not consider any specific adjustment for livestock production benefits per hectare should be made.

A5.4 Conclusions

Agriculture in flood-risk areas is likely to vary substantially from scheme to scheme. Livestock production is the predominant enterprise in many floodplain areas but, where drainage is adequate, arable cropping is also widespread. Whichever type of farming predominates, however, the analyses presented in Sections A5.2 and A5.3 indicate clearly that there are no substantial grounds for introducing regional adjustment factors for agricultural benefits. This conclusion is applicable to project appraisals carried out for CRIMS and for the Prioritisation and Programming of Flood Defence Works as well as for the appraisal of projects costing under £500 000. In all cases the degree of approximation (margin of error) inherent in the benefit assessment is such that making adjustments for regional differences in crop and grassland yields of less than 10%, and generally much less than this (see Tables A5.1 and A5.2), would not be justified.

REFERENCES

Hess T M & Morris J	1986	Agricultural Land Drainage Benefit Assessment Methods: Technical Papers in Support of SCADE Model, Silsoe College.
Morris J & Sutherland D C	1992	The Evaluation of River Maintenance. Report to NRA. Silsoe College.

REGIONAL CROP YIELD DATA

The following are copies of the original yield data and are included herewith for easy reference.

Average Yields and Ranking of Counties

AVERAGE WHEAT YIELD BY COUNTY (t/Ha)

Region	1974	1975	1976	1977	1978	1979	1980	1981	1982	
Bedford	5.380	4.410	3.290	5.170	4.930	5.060	6.130	5.990	5.640	5.1
Cambs.	5.260	4.410	3.790	5.050	5.170	4.990	5.950	6.210	6.230	5.2
Essex	5.040	4.210	4.010	5.260	5.640	4.950	6.180	6.140	6.600	5.3
G.Lon.E	4.830	4.410	3.570	5.100	5.440	5.190	6.180	6.060	6.340	5.2
Herts.	4.760	4.410	3.230	4.530	5.720	4.940	6.180	6.030	6.060	5.0
Norfolk	4.790	4.350	4.020	4.880	5.140	5.330	6.000	6.210	6.350	5.2
Suffolk	5.230	4.430	4.160	5.350	5.450	5.700	6.540	6.260	6.860	5.5
Berks.	4.530	4.830	3.930	4.590	5.630	5.160	5.830	6.210	5.970	5.1
Bucks.	4.500	4.260	3.830	4.570	5.250	4.840	5.600	5.650	5.970	4.9
E.Suss.	4.330	3.650	4.260	4.520	4.980	4.970	6.010	5.010	6.400	4.9
G.Lon.	4.340	4.060	3.720	4.610	5.480	5.050	5.810	5.510	6.300	4.9
Hants.	5.150	4.490	3.920	5.040	6.200	6.000	6.120	5.480	6.950	.4
Wight	4.820	4.110	3.930	4.690	5.270	5.480	5.850	5.510	6.300	5.1
Kent	4.360	3.660	3.850	4.320	5.110	4.660	5.250	5.260	5.910	4.7
Oxon	4.530	4.150	3.590	4.520	5.520	4.810	6.160	5.530	6.490	5.0
Surrey	4.300	3.390	3.700	4.210	4.560	4.700	5.030	5.510	5.650	4.5
W.Suss.	4.530	3.910	3.640	4.800	5.480	5.010	6.420	5.770	6.200	5.0
Derbys.	5.380	3.660	3.000	4.410	5.150	5.190	5.550	5.500	6.460	4.9
Leics.	4.740	3.710	3.520	4.640	4.630	4.700	5.550	5.440	5.740	4.7
Lincs.	4.930	4.410	4.120	4.980	5.090	5.340	5.850	5.950	6.380	5.2
N'hants	4.970	4.260	3.430	4.740	5.200	5.000	5.550	5.320	5.570	4.8
Notts.	5.150	3.870	3.200	4.940	5.500	4.870	5.550	5.380	5.810	4.9
Ches're	4.360	4.100	3.460	4.670	5.330	4.910	6.970	5.500	5.750	5.0
Her & W	4.700	4.150	3.520	4.750	5.310	4.860	5.730	5.550	5.920	4.9
Salop	4.650	4.270	3.770	4.740	5.050	5.630	5.650	5.230	5.610	4.9
Staffs.	5.030	4.060	3.120	4.880	5.600	5.510	5.280	5.590	4.900	4.3
Warwick	4.660	3.950	3.430	4.630	5.280	4.880	5.730	5.700	5.810	4.8
W.Mids.	4.750	4.100	3.130	4.670	5.040	5.100	5.690	5.500	5.750	4.8
Avon	4.460	4.010	3.160	5.180	4.510	5.370	6.420	5.720	5.330	4.9
Cornw'l	4.550	4.050	3.110	4.830	5.370	5.350	5.930	5.720	6.020	.9
Devon	3.790	3.890	3.170	4.370	4.810	4.850	4.870	4.900	4.460	4.3
Dorset	4.310	3.830	3.380	4.550	5.200	5.120	5.940	5.460	6.200	4.8
Gloucs.	4.740	4.030	3.290	4.940	5.330	5.470	5.770	5.900	6.200	5.0
Som'set	4.680	3.750	3.440	4.840	5.490	5.550	6.290	6.180	6.160	5.0
Wilts.	4.610	4.240	3.760	4.390	5.610	5.380	6.060	5.720	6.260	5.9
Cl'land	5.210	4.560	4.440	3.860	4.560	5.100	4.980	5.750	6.050	4.8
Cumbria	5.330	4.560	4.060	4.740	4.660	5.100	5.060	5.750	6.050	5.0
Durham	5.160	4.400	4.270	3.900	4.680	4.960	5.360	5.890	6.260	4.8
N.Yorks	5.200	4.490	4.270	4.690	4.620	4.930	5.200	5.540	5.610	4.9
N'land	5.800	4.710	4.640	5.460	4.710	5.410	4.670	6.030	5.860	5.8
Tyne+W	5.350	4.560	3.930	4.740	4.660	5.100	5.050	5.750	6.050	5.0
G.Man.	5.200	4.210	4.070	4.840	5.220	5.670	5.860	5.500	5.750	5.1
Humbs.	5.190	4.350	4.380	4.830	5.310	5.770	5.980	5.940	6.310	5.8
Lancs.	4.790	4.210	3.960	4.840	5.220	5.670	5.900	5.500	5.750	5.0
Merseys	5.200	4.210	4.010	4.840	5.220	5.670	5.870	5.500	5.750	5.4
N.Yorks	5.360	4.280	3.940	4.920	5.030	5.370	5.770	5.180	6.060	5.6
S.Yorks	5.290	3.850	3.260	4.890	5.110	5.700	5.460	5.380	6.080	5.0
W.Yorks	4.950	4.050	3.540	4.600	4.630	5.220	5.350	5.750	6.050	4.0
MEAN	4.859	4.165	3.713	4.750	5.169	5.201	5.754	5.658	6.004	5.0

Source:- Hess T.M and Morris J (1987), "Silsoe College Agricultural Drainage Evaluation Model - Technical Papers, Silsoe College, Bedford

AVERAGE BARLEY YIELD BY COUNTY (t/Ha)

Region	1974	1975	1976	1977	1978	1979	1980	1981	1982	
Bedford	4.100	3.287	3.220	4.190	4.240	4.030	4.750	4.440	4.980	4.1
Cambs.	4.006	3.287	3.420	4.450	4.250	4.120	4.950	4.890	5.330	4.3
Essex	3.725	3.213	3.870	4.660	4.380	4.310	4.750	4.830	5.700	4.4
G.Lon.E	3.662	3.287	2.880	4.230	4.300	4.170	4.750	4.590	5.320	4.1
Herts.	3.713	3.287	3.260	4.100	4.240	3.640	4.750	4.300	5.320	4.1
Norfolk	3.687	3.475	3.240	4.000	4.330	4.040	4.530	4.420	5.270	4.1
Suffolk	3.537	3.437	3.490	4.010	4.170	3.980	4.570	4.500	5.040	4.1
Berks.	3.737	3.412	3.550	3.930	4.190	3.700	4.310	3.890	4.960	4.0
Bucks.	3.763	2.737	3.430	4.230	4.090	3.900	4.510	4.340	5.260	4.0
E.Suss.	3.737	3.075	3.500	4.070	3.860	3.950	4.040	3.850	4.730	3.9
G.Lon.	3.625	3.100	3.020	4.090	4.180	4.060	4.400	4.340	5.210	4.0
Hants.	4.113	3.450	3.190	4.570	4.590	4.190	4.580	4.300	5.700	4.3
Wight	4.250	2.950	3.740	4.040	4.090	4.000	4.370	4.340	5.180	4.1
Kent	3.675	2.975	2.990	3.550	3.820	4.160	3.950	4.560	5.000	3.8
Oxon	3.687	3.187	3.180	4.100	4.410	4.050	4.860	4.640	5.050	4.1
Surrey	3.575	2.525	2.550	3.500	3.570	3.850	3.990	4.340	4.750	3.6
W.Suss.	3.575	2.963	3.190	4.010	3.870	4.050	4.380	3.930	5.330	3.9
Derbys.	4.238	3.325	3.090	4.030	4.310	3.770	4.380	3.700	4.690	3.9
Leics.	3.875	2.937	3.780	4.100	4.300	3.530	4.380	4.200	5.000	4.0
Lincs.	4.369	3.425	3.630	4.320	4.120	4.020	4.610	4.340	5.360	4.2
N'hants	4.088	3.150	3.410	4.060	4.330	3.760	4.380	3.800	4.850	4.0
Notts.	3.963	2.838	3.130	4.200	4.320	3.540	4.380	4.040	4.680	3.9
Ches're	4.100	3.300	3.140	4.340	4.200	3.550	4.090	4.030	4.520	3.9
Her & W	3.963	2.987	2.950	4.280	4.510	4.060	4.380	4.160	4.820	4.0
Salop	4.050	3.525	3.590	4.070	4.230	4.200	4.470	4.100	4.260	4.1
Staffs.	4.312	3.338	2.940	4.390	4.650	3.800	4.360	3.670	4.630	4.0
Warwick	3.750	3.187	3.090	4.050	4.490	4.150	4.740	4.270	5.040	4.1
W.Mids.	3.937	3.263	2.620	4.210	4.200	4.060	4.760	4.020	4.680	4.0
Avon	3.900	2.662	3.130	4.310	4.330	4.220	4.380	4.130	4.860	4.0
Cornw'l	3.025	2.825	2.910	3.760	3.780	3.460	3.990	4.000	4.440	3.6
Devon	3.325	2.883	2.510	3.850	3.810	3.830	4.050	3.700	4.040	3.6
Dorset	3.437	3.487	2.900	4.080	4.260	4.200	4.420	3.870	4.950	4.0
Gloucs.	3.900	3.088	3.190	4.420	4.530	4.190	4.670	4.590	5.470	4.2
Som'set	3.737	2.862	2.750	4.360	4.620	4.430	4.790	4.280	5.050	4.1
Wilts.	3.900	3.412	3.170	4.440	4.590	4.620	4.710	4.440	5.180	4.3
Cl'land	4.275	3.662	3.670	4.360	4.110	3.850	4.020	4.280	4.930	4.1
Cumbria	4.187	4.450	3.710	4.520	4.160	4.160	4.220	4.250	4.570	4.2
Durham	4.312	3.500	3.490	4.240	3.900	3.680	3.900	4.430	4.630	4.0
N.Yorks	4.312	3.850	3.680	4.320	4.070	3.910	4.230	4.460	4.740	4.2
N'land	4.700	3.763	3.880	4.790	3.740	4.220	4.030	4.670	4.700	4.3
Tyne+W	4.537	2.900	3.520	4.340	3.530	3.700	4.090	4.530	4.680	4.0
G.Man.	3.463	3.150	2.400	4.050	4.080	3.250	3.940	3.860	4.360	3.6
Humbs.	4.375	3.862	4.260	4.460	4.380	4.400	4.690	4.280	5.110	4.4
Lancs.	4.100	3.513	2.960	4.540	4.140	3.650	4.290	3.630	4.320	3.9
Merseys	4.275	3.362	2.680	4.270	4.230	3.510	4.340	3.860	4.720	3.9
N.Yorks	4.300	3.888	3.590	4.500	4.280	4.090	4.600	4.380	4.710	4.3
S.Yorks	4.187	3.362	3.040	4.490	4.440	4.230	4.470	4.500	4.360	4.1
W.Yorks	4.175	3.350	2.950	4.310	3.980	3.870	4.400	4.220	4.360	4.0
MEAN	3.942	3.267	3.239	4.212	4.193	3.961	4.408	4.233	4.871	4.0

Source:- Hess T.M and Morris J (1987), "Silsoe College Agricultural Drainage Evaluation Model - Technical Papers, Silsoe College, Bedford

AVERAGE POTATO YIELD BY COUNTY (t/Ha)

Region	1975	1977	1978	1979	1980	1981	1982	MEAN	
Bedford	19.250	28.500	33.300	32.500	36.680	33.220	36.880	31.476	+
Cambs.	22.250	31.500	39.000	33.300	38.010	39.400	40.820	34.897	
Essex	17.750	29.400	33.200	32.100	34.920	33.380	35.810	31.080	+
G.Lon.E	17.500	31.200	37.900	34.400	37.930	31.700	38.110	32.677	
Herts.	17.500	26.700	35.300	31.800	35.110	32.620	36.800	31.119	+
Norfolk	21.500	32.000	39.100	36.600	39.220	35.290	36.700	34.344	
Suffolk	28.000	32.500	40.300	36.600	38.730	35.190	39.460	35.826	*
Berks.	21.750	23.000	31.200	28.000	38.840	39.380	40.540	31.816	+
Bucks.	22.750	33.700	33.800	31.500	38.840	39.180	40.620	34.341	
E.Suss.	18.750	26.600	31.200	31.200	37.880	37.370	40.640	31.949	
G.Lon.	21.500	32.200	33.700	33.900	38.840	39.980	40.680	34.400	
Hants.	19.750	29.400	32.200	31.100	44.420	37.120	42.090	33.726	
Wight	12.750	45.900	29.400	34.600	36.100	37.460	40.660	33.839	
Kent	23.500	32.700	32.700	34.300	36.520	34.490	36.070	32.900	
Oxon	20.750	31.000	36.600	33.500	43.450	44.650	48.360	36.901	*
Surrey	19.750	26.900	32.600	29.300	38.840	39.290	40.630	32.473	
W.Suss.	22.000	36.200	40.600	40.600	42.430	45.100	50.540	39.639	*+
Derbys.	19.250	24.000	38.600	31.000	33.540	32.770	40.840	31.429	+
Leics.	16.750	27.300	36.300	31.900	33.610	33.020	37.580	30.923	*+
Lincs.	19.250	30.100	35.200	32.600	37.810	34.610	38.290	32.551	
N'hants	16.000	25.800	32.700	32.800	37.720	29.450	32.970	29.634	*+
Notts.	17.500	28.400	42.100	34.400	36.840	33.850	41.500	33.513	
Ches're	27.000	29.800	38.400	34.300	36.600	34.520	37.300	34.060	
Her & W	27.000	29.900	39.300	35.700	37.180	35.140	40.880	35.014	
Salop	24.500	28.600	36.500	37.400	38.140	36.780	40.860	34.683	
Staffs.	19.000	28.100	39.500	33.200	36.780	34.770	42.960	33.473	
Warwick	19.250	23.440	35.100	35.400	40.330	37.800	42.860	33.454	
W.Mids.	17.750	25.600	35.700	29.500	36.110	35.800	40.620	31.583	+
Avon	20.000	25.300	30.300	30.400	31.790	35.760	38.900	30.349	*+
Cornw'l	26.750	29.100	34.700	39.100	33.850	31.820	37.710	33.290	
Devon	22.500	30.400	42.600	35.300	34.630	29.680	38.250	33.337	
Dorset	20.000	30.200	37.400	32.600	29.220	34.920	39.000	31.906	
Gloucs.	19.000	28.600	40.600	32.900	36.110	36.660	32.910	32.397	
Som'set	28.500	34.200	36.700	38.200	38.980	39.330	44.630	37.220	*+
Wilts.	22.750	30.200	33.500	30.500	34.450	37.150	41.320	32.839	
Cl'land	24.500	21.100	33.100	27.000	33.500	35.440	37.010	30.236	*+
Cumbria	30.500	31.700	36.700	37.700	35.520	36.620	35.080	34.831	
Durham	25.750	23.500	33.600	27.200	32.780	33.500	32.380	29.816	*+
N.Yorks	24.000	25.600	39.400	35.000	37.710	38.170	39.260	34.020	
N'land	29.500	28.400	35.400	34.100	34.210	35.500	35.440	33.650	
Tyne+W	29.750	27.900	34.000	31.400	29.880	35.640	37.070	32.234	
G.Man.	21.500	30.300	38.600	36.100	39.230	33.910	37.560	33.886	
Humbs.	20.000	28.800	37.500	32.700	33.670	32.700	36.410	31.683	
Lancs.	26.750	31.900	41.800	38.000	40.900	36.220	41.000	36.653	*+
Merseys	24.500	30.000	38.700	35.800	39.800	36.560	38.970	34.904	
N.Yorks	27.500	27.100	39.000	34.500	36.980	36.310	38.270	34.237	
S.Yorks	20.500	24.000	39.500	28.400	34.000	32.700	33.260	30.337	*+
W.Yorks	21.500	24.100	36.600	30.100	34.200	32.620	36.160	30.754	+
MEAN	22.000	29.059	36.254	33.354	36.725	35.782	39.075	33.173	

Source:- Hess T.M and Morris J (1987), "Silsoe College Agricultural Drainage Evaluation Model - Technical Papers, Silsoe College, Bedford

AVERAGE RAPE YIELD BY COUNTY (t/Ha)

Region	1974	1975	1976	1977	1978	1979	MEAN
Bedford	2.830	2.490	2.570	3.370	2.300	3.200	2.797
Cambs.	2.750	2.360	2.760	4.800	2.500	3.300	3.078 *
Essex	2.900	2.360	2.720	3.210	2.610	3.300	2.833
G.Lon.E	2.310	2.500	2.750	3.110	2.610	3.800	2.847
Herts.	1.470	2.280	2.330	2.830	2.420	3.200	2.433 **
Norfolk	2.870	2.730	2.890	3.260	2.450	3.600	2.967 *
Suffolk	2.680	2.690	3.130	3.320	2.560	3.480	3.010 *
Berks.	2.330	2.310	2.380	2.980	2.570	3.110	2.613 +
Bucks.	2.520	2.350	2.590	3.420	2.130	3.250	2.710
E.Suss.	2.270	2.120	2.380	2.920	2.350	3.100	2.533 **
G.Lon.	2.270	2.120	2.380	2.980	2.340	2.500	2.432 **
Hants.	2.170	1.760	2.170	3.150	2.500	3.000	2.458 **
Wight	2.270	2.120	2.330	2.980	2.800	3.000	2.592 +
Kent	2.270	2.700	2.520	2.760	2.340	3.250	2.640
Oxon	2.240	1.960	2.340	2.880	2.100	3.180	2.450 **
Surrey	2.270	2.120	2.380	2.980	2.300	2.600	2.442 **
W.Suss.	2.270	2.120	2.450	2.980	2.750	3.800	2.728
Derbys.	2.630	2.370	2.690	3.130	2.340	3.330	2.748
Leics.	2.620	2.240	2.580	2.930	2.400	2.970	2.623
Lincs.	2.850	2.420	2.910	3.160	3.000	3.580	2.987 *
N'hants	2.480	2.240	2.550	3.280	2.300	3.150	2.667
Notts.	2.590	2.620	2.540	3.010	2.640	3.370	2.795
Ches're	2.550	2.330	2.550	3.100	2.640	2.700	2.653
Her & W	2.550	2.380	2.550	3.100	2.960	3.150	2.782
Salop	2.550	2.380	2.550	3.100	2.100	3.620	2.717
Staffs.	2.550	2.380	2.550	3.100	2.750	3.430	2.793
Warwick	2.470	2.150	2.190	3.320	2.250	4.500	2.813
W.Mids.	2.550	2.380	2.550	3.100	2.100	4.500	2.863
Avon	2.240	2.350	2.260	2.740	2.200	3.450	2.542 *+
Cornw'l	2.240	2.350	2.260	2.740	2.480	3.200	2.545 +
Devon	2.240	2.350	2.260	2.740	2.480	3.700	2.628 +
Dorset	2.240	2.350	2.260	2.740	2.100	2.600	2.382 *+
Gloucs.	2.420	2.350	2.440	2.470	2.500	3.000	2.530 +
Som'set	2.240	2.350	2.260	2.740	2.200	3.200	2.493 **
Wilts.	2.100	2.340	2.060	2.970	2.600	2.900	2.478 *+
Cl'land	2.550	2.380	2.640	3.100	3.250	3.620	2.923
Cumbria	2.550	2.540	2.660	2.990	2.600	2.200	2.590 +
Durham	2.550	2.380	2.640	3.100	3.250	3.400	2.887
N.Yorks	2.720	2.600	2.660	2.940	2.640	3.010	2.762
N'land	2.550	2.380	2.640	3.100	3.210	3.520	2.900
Tyne+W	2.690	2.540	2.660	3.100	3.250	3.050	2.882
G.Man.	2.550	2.700	3.010	3.280	3.100	3.500	3.023 *
Humbs.	2.870	2.720	3.150	3.090	2.890	3.010	2.955 *
Lancs.	2.550	2.700	3.010	3.280	3.200	3.330	3.012 *
Merseys	2.550	2.700	3.010	3.280	3.300	3.700	3.090 **
N.Yorks	2.550	2.600	2.600	3.430	2.400	3.500	2.847
S.Yorks	2.550	2.700	2.670	4.090	2.800	3.650	3.077 ++
W.Yorks	2.550	2.700	3.010	3.280	2.800	3.340	2.947 *
MEAN	2.475	2.402	2.573	3.116	2.591	3.239	2.741

Source:- Hess T.M and Morris J (1987), "Silsoe College Agricultural Drainage Evaluation Model - Technical Papers, Silsoe College, Bedford

GB WHEAT AND BARLEY PRODUCTION BY REGIONS (a)

'000 hectares; tonnes per hectare; '000 tonnes

WHEAT	AREA			YIELD			PRODUCTION		
	1986/87	1987/88	1988/89	1986/87	1987/88	1988/89	1986/87	1987/88	1988/89
North	58	61	53	7.32	6.07	6.57	420	370	350
Yorkshire and Humberside	223	231	218	7.54	6.49	6.63	1,680	1,490	1,440
East Midlands	390	389	372	7.19	5.95	6.11	2,800	2,310	2,280
East Anglia	353	343	314	6.63	5.74	6.23	2,340	1,970	1,960
South East	510	492	456	6.78	5.80	6.01	3,460	2,850	2,740
South West	195	194	198	6.64	6.26	5.94	1,290	1,210	1,180
West Midlands	146	143	142	6.89	6.05	6.05	1,010	870	860
North West	18	19	16	6.64	5.11	5.67	120	100	90
England	1,892	1,872	1,770	6.93	5.97	6.15	13,120	11,180	10,910
Wales	10	11	10	6.27	5.96	5.78	70	60	60
England and Wales	1,902	1,883	1,780	6.93	5.96	6.15	13,200	11,240	10,960
Scotland	89	104	98	7.77	6.45	7.64	690	670	750

BARLEY	AREA			YIELD			PRODUCTION		
	1986/87	1987/88	1988/89	1986/87	1987/88	1988/89	1986/87	1987/88	1988/89
North	99	93	100	5.33	4.93	4.84	530	460	480
Yorkshire and Humberside	206	196	205	5.61	5.40	4.83	1,160	1,060	990
East Midlands	201	188	193	5.39	5.19	4.36	1,080	980	840
East Anglia	211	204	220	5.06	4.87	4.36	1,070	990	960
South East	274	262	276	5.43	5.17	4.86	1,490	1,350	1,340
South West	219	219	214	5.07	5.13	4.84	1,110	1,120	1,040
West Midlands	142	137	137	5.72	5.37	4.79	810	730	660
North West	45	46	47	4.85	4.36	4.29	220	190	200
England	1,397	1,344	1,392	5.34	5.13	4.68	7,460	6,910	6,520
Wales	50	51	51	4.87	4.69	4.33	250	240	220
England and Wales	1,447	1,395	1,444	5.33	5.12	4.68	7,720	7,160	6,760
Scotland	418	387	389	5.02	4.82	4.71	2,100	1,860	1,830

(a) *Standard Statistical Regions.*
Totals may differ from those in Table B2 because of rounding.

SOURCE: MINISTRY OF AGRICULTURE, FISHERIES AND FOOD [4].

R&D 435/2/NW

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GB WHEAT AND BARLEY PRODUCTION BY REGIONS (a)

'000 hectares; tonnes per hectare; '000 tonnes

WHEAT	AREA			YIELD			PRODUCTION		
	1989/90	1990/91	1991/92	1989/90	1990/91	1991/92	1989/90	1990/91	1991/92
North	66	66	67	6.44	7.68	7.56	430	500	510
Yorkshire and Humberside	250	248	248	6.99	7.55	7.74	1,740	1,870	1,920
East Midlands	410	389	388	7.16	7.01	7.57	2,930	2,730	2,940
East Anglia	349	345	342	7.25	7.44	7.42	2,530	2,570	2,540
South East	498	474	451	6.43	6.46	6.72	3,200	3,060	3,030
South West	205	191	183	6.08	6.12	6.67	1,250	1,170	1,220
West Midlands	157	147	149	5.78	6.40	7.39	910	940	1,100
North West	22	24	25	5.43	6.37	6.74	120	150	160
England	1,956	1,884	1,864	6.70	6.90	7.20	13,130	13,010	13,420
Wales	11	11	11	5.96	5.79	6.23	70	70	70
England and Wales	1,987	1,895	1,865	6.70	6.89	7.24	13,190	13,070	13,500
Scotland	108	111	123	7.51	8.32	7.94	810	920	980

BARLEY	AREA			YIELD			PRODUCTION		
	1989/90	1990/91	1991/92	1989/90	1990/91	1991/92	1989/90	1990/91	1991/92
North	86	76	72	4.43	5.74	5.83	380	440	420
Yorkshire and Humberside	178	161	149	5.45	5.70	5.97	930	920	890
East Midlands	163	152	132	5.20	5.06	5.77	850	770	760
East Anglia	188	179	168	5.41	5.36	5.76	1,010	960	970
South East	233	214	188	4.97	5.03	5.76	1,160	1,070	1,080
South West	192	173	151	4.56	4.62	5.36	880	800	810
West Midlands	123	112	98	4.49	4.86	5.11	550	540	500
North West	39	32	29	3.93	4.85	5.53	150	150	160
England	1,202	1,099	991	4.92	5.14	5.66	5,930	5,670	5,610
Wales	45	39	38	3.59	4.38	4.74	160	170	170
England and Wales	1,247	1,138	1,027	4.87	5.12	5.63	6,090	5,840	5,780
Scotland	362	338	313	4.99	5.58	5.49	1,810	1,890	1,720

(a) Standard Statistical Regions.
Totals may differ from those in Table B2 because of rounding.

SOURCE: MINISTRY OF AGRICULTURE, FISHERIES AND FOOD [4].

1992 HARVEST

TABLE 4 PRODUCTION AND YIELD BY REGION - see notes (a) to (c)

Standard Statistical Region	Wheat		Total Barley		Winter Barley		Spring Barley		Oats		Rye		Triticale	
	Production	Yield	Production	Yield	Production	Yield	Production	Yield	Production	Yield	Production	Yield	Production	Yield
	thousand tonnes	tonnes per hectare	thousand tonnes	tonnes per hectare	thousand tonnes	tonnes per hectare	thousand tonnes	tonnes per hectare	thousand tonnes	tonnes per hectare	thousand tonnes	tonnes per hectare	thousand tonnes	tonnes per hectare
ENGLAND & WALES	13,010	6.72	5,430	5.72	4,380	6.11	1,050	4.51	375	5.25	41	5.08	43	4.5
England	12,930	6.72	5,250	5.75	4,280	6.11	960	4.53	355	5.31	41	5.09	42	4.5
North	570	7.60	400	5.72	290	6.42	110	4.49	35	5.88	..	4.64	3	5.2
Yorks & Humberside	1,890	7.06	820	6.08	710	6.37	110	4.62	25	5.41	3	4.52	6	4.9
East Midlands	2,720	6.66	690	5.83	590	6.07	110	4.74	45	5.54	5	4.95	3	3.6
East Anglia	2,470	7.11	920	5.80	710	6.10	210	4.97	20	5.04	13	5.21	3	4.9
South East	2,980	6.55	980	5.77	820	6.04	160	4.70	90	5.06	13	5.17	10	4.6
South West	1,110	5.93	780	5.50	630	6.03	150	4.04	60	4.95	6	5.28	13	4.1
West Midlands	1,030	6.41	520	5.70	450	6.05	70	4.23	75	5.63	2	4.86	2	4.3
North West	170	6.63	130	4.89	90	5.38	40	4.00	10	4.97	..	3.32	1	5.3
Wales	80	6.48	180	4.96	90	5.80	80	4.27	20	4.45	..	3.82	1	4.4

Notes

(a) The figures for England regions exclude estimates for minor holdings.
(b) The figures for England and for Wales include estimates for minor holdings.
(c) Production figures for wheat and barley have been rounded to the nearest 10,000 tonnes, oats to the nearest 5,000 tonnes and rye and triticale to the nearest 1,000 tonnes.
.. Less than half the final digit shown.
Totals may not necessarily agree with the sum of their components due to rounding.

APPENDIX B

ENVIRONMENTAL ASSESSMENT

APPENDIX B

ENVIRONMENTAL ASSESSMENT

B.1 Introduction

The preparation of guidelines for the assessment of environmental impacts of projects is beyond the scope of the present study. However draft NRA guidelines have recently been prepared for the NRA by M. Postle and the main content of these are included below for easy comparison:-

Source: Extracted from M. Postle's contribution to the Draft NRA Guidelines on Environmental Assessment

B.2 Use Values versus Non-Use Values

B.2.1 Economists have defined two basic categories of value which individuals hold towards the environment.[1] The first category is that of *use values*. These are values associated with the benefits gained from direct use (or "consumption") of the environment, and may include recreation benefits (from fishing, hiking, bird watching, photography, etc.), educational and scientific benefits, and general amenity benefits.

The second category of values are those referred to as *non-use values*. Two types of non-use values have been defined: *option values* and *existence values*.[2] Option values relate to the desire of an individual to maintain the ability to use the environment at some time in the future (for example, the desire to visit the Norfolk Broads). They reflect an individual's willingness to pay to secure the future of a good and thus express the potential benefits of that good. Option values also represent the benefits attached to preservation or conservation of the environment so that future generations may also have the option of use.

Existence values form the last type of non-use value and are defined as those values which result from an individual's altruistic desire to ensure that an environmental asset is preserved and continues to exist into the future. These values are not associated with actual or potential use, but solely with the knowledge that the asset is there (with the continued existence of whales being a good example).

B.2.2 Both of these categories of value may be important in determining the benefits associated with different programme or project level actions, and their importance will vary over different situations. Use related values are more easily measured than non-use values.

Research undertaken by Middlesex (Green and Tunstall, 1991) has indicated the importance of non-use values. Key conclusions include:

- that a diffuse population may hold non-use values for a particular site; yet
- non-use values are not likely to be site specific; instead they will relate to the whole stock of the resource in question.

Indeed there is currently some debate as to whether or not any attempts should be made to measure non-use values at this point in time. Those opposing valuation of non-use values argue that little is known about the motivations underlying non-use values and the extent to which moral and altruistic concerns are involved. Because such motives may be inconsistent with neo-classical economics (which is based on "self-interest") such considerations cannot be encompassed within economic analysis. This has led to recommendations that no attempt be made to directly evaluate non-use values separately from use values (the Yellow Manual (Penning-Rowsell et al, 1992).

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1 Another type of environmental value has been defined. Sometimes referred to as *intrinsic* or *inherent* values (related to *existence*), these are the values which are said to reside in non-human biota and which are not related to any form of human satisfaction.

2 Option values are classified by some as falling under the heading of *use value*, as they refer to maintaining the potential for future use.

Source: Extracted from M. Postle's contribution to the Draft NRA Guidelines on Environmental Assessment

Such views contrast to the recent findings of a special "Blue Ribbon Panel" established specifically to look at use of the contingent valuation method (CVM) for developing use and non-use values. This panel has come out with a qualified acceptance of the use of CVM for non-use valuation contexts (Arrow et al, 1993). The qualifications relate to the need for an adequate testing protocol of the survey instrument used in the CVM. See Section 7.9 for a further discussion on this and guidelines on an appropriate protocol.

It should be remembered that the distinction between the two types of values can be important. If an analysis only catches the values related to direct use of the environment, it may result in a gross underestimation of the total environmental benefits that would be gained by an action. Indeed several studies have found that benefits related to option and intrinsic values may be greater than those related to direct use (for example, Loomis and Walsh, 1986). Although, some practitioners consider that one reason for the high values obtained when measuring non-use is due to people expressing a willingness to pay that reflects charitable concern, rather than a real non-use value (Bateman and Turner, 1992).

B.3 The Different Types of Environmental Costs and Benefits

There are a wide range of environmental costs and benefits that might result from NRA activities. In general, however, these can be grouped under the following headings:

- impacts on educational and scientific activities;
- impacts on recreation activities;
- impacts on amenity;
- impacts on landscape and countryside characteristics;
- impacts on the aquatic ecosystem; and
- impacts on conservation, geology and heritage sites.

There is, of course, overlap between the above groupings, with impacts on one being directly or indirectly related to impacts on another. Impacts on landscape and countryside characteristics, for example, may have amenity effects. Similarly, impacts on the aquatic ecosystem may have implications for specialised recreation activities such as bird watching, or for educational and scientific activities.

Education, recreation and amenity effects fall into the category of use-related values. Landscape and countryside characteristics will have use related values, where these refer to amenity. Although the aquatic ecosystem, conservation, geologic and heritage sites may have use-related values in terms or tourism or recreation, non-use values may be more significant.

When identifying the environmental costs and benefits arising from a given activity, it is important to ensure that the effects would actually occur. For example, for recreation benefits stemming from water quality improvements (e.g. boating) to be included in an appraisal, some evidence is required that boating would actually take place. Furthermore, if there would be costs involved in the establishment of facilities for boating activities, those costs must be netted from the estimate of recreation benefits.

Source: Extracted from M. Postle's contribution to the Draft NRA Guidelines on Environmental Assessment

It is also useful to distinguish between activities which lead to true benefits and those which result in the avoidance of damage costs. For example, improvements in water quality can result in true recreation benefits, but as discussed in earlier chapters they may also reduce expenditure towards averting damages such as water treatment by industry. In other cases an activity may result in the protection of an area, thus averting damages. As will be seen in the next section, the different valuation techniques vary in terms of whether they value true gains or whether they measure gains in terms of damage costs avoided.

Finally, as discussed earlier , care should be taken to ensure that double counting of costs and benefits does not occur. Such problems may arise where:

- a number of different types of effects will result from an activity; or
- the same group of individuals will be affected by more than one effect; and
- more than one valuation technique is used to measure the effects.

B.4 ENVIRONMENTAL VALUATION TECHNIQUES

B.4.1 Overview of Techniques

A range of techniques have been developed to assist in the valuation of environmental costs and benefits. These include techniques which are based on: the use of market information; inferring values through examining individuals' behaviour; and deriving values through direct questioning of individuals.

Four broad categories of techniques can be defined:

- **Market price approaches:** where environmental effects result in changes in the quantity or price of marketed goods, the value of such changes can be used to estimate welfare gains or losses. The two techniques which fall under this category are: the **dose-response approach** which links changes in the environment to changes in productivity ; and the **replacement costs approach (and related shadow project approach)** which uses the costs of restoring or recreating an environmental asset as a measure of its value (for a shadow project, such action is required by a standard or sustainability constraint).

- **Household production function approaches:** the price paid for a complimentary or substitute good is assumed to reflect an individual's willingness to pay for an environmental good or service. The techniques in this category include: the **avertive expenditure approach** which relies on information concerning expenditure for substitute goods (bottled water for tap water); and the **travel cost method** which values a given site in terms of the costs incurred in travelling to that site for recreation purposes.

- **Hedonic pricing methods:** the implicit value placed on an environmental good is estimated by looking at the price paid for the good in the real markets in which it is effectively traded. For environmental effects, the approach focuses on the property (houses or land) market, where it is assumed that environmental attributes affect property prices.

Source: Extracted from M. Postle's contribution to the Draft NRA Guidelines on Environmental Assessment

- **Experimental markets**: social survey methods are used to determine individual's preferences for changes in the environment. Two basic approaches exist: the **contingent valuation method** which asks people their willingness to pay (or to be compensated) for environmental gains (or losses); and the **contingent ranking method** which derives a monetary value for an environmental asset by linking it to rankings given to marketed goods.

Note that the above categorisation corresponds to that used in *Policy Appraisal and the Environment* (DoE, 1991). Other categorisations also exist, such as that used in the Yellow Manual (Penning-Rowsell, 1992) which groups avertive expenditure and replacement costs together under the heading of the "least cost alternative" because both of these approaches value a good in terms of the costs of providing it through another means. In addition, the Yellow Manual notes that there is a range of case specific approaches which can be used in monetary valuation. The example cited is the use of financial payments (such as payments under the Environmentally Sensitive Area scheme), as a means of setting lower bound estimates on the value of the associated environmental asset (habitat in the case of ESA payments).

Relevant NRA references include two R&D documents. The first is the final report for R&D Project No. 253 on the "*Economic Value of Changes to the Water Environment*" (CNS Scientific and Engineering Services, 1992). This provides a summary of many of the principles underlying economic appraisal, identifies key issues and reviews the above techniques. The second document is the *R&D Series Report on Environmental Economics* (NRA, 1993) which provides a review of previous work undertaken by the NRA in this area.

B.4.2 General Applicability

Selecting the technique which is most appropriate to the monetary valuation of a particular environmental or natural resource effect will be influenced by several factors. These include:

- the nature of the policy/project decision;
- the types of impact to be valued;
- data availability; and
- time and financial resource constraints.

With regard to the types of impacts to be valued, the techniques vary in terms of the range of environmental benefits or damages to which they can be applied. Table B.1 provides a general summary of the types of environmental issues which can be addressed by the different techniques. Note that some techniques, such as the contingent valuation method, are more flexible than others, such as the travel cost technique which has been developed specifically to address recreation related costs and benefits.

The ability of the different techniques to capture user, option and existence values is limited. Only contingent valuation methods provide a means of valuing both use and non-use values. The replacement costs (or shadow project) technique can be said to place an overall value on a site, but this value does not necessarily reflect individuals' use or non-use values for that site. The other techniques can only be used to value use related costs and benefits. A judgement will have to be made, therefore, as to how important option and existence values are likely to be, and thus the valuation approach most likely to address the significant economic effects.

Source: Extracted from M. Postle's contribution to the Draft NRA Guidelines on Environmental Assessment

TABLE B.1 (a): APPLICABILITY OF VALUATION TECHNIQUES

QUANTITY	WATER QUALITY/	RECREATION	AMENITY	LANDSCAPE/ COUNTRYSIDE CHARACTERISTICS	GEOLOGY/ PALAEONTOLOGY	HERITAGE	HABITAT/ ECOLOGICAL SIGNIFICANCE	WILDLIFE
Financial Payments		■					■	
Dose-Response Technique	■							
Replacement Costs/Shadow Projects						■	■	■
Avertive Expenditure	■							
Travel Costs		■				■		
Hedonic Pricing	■		■	■				
Contingent Valuation/ Ranking	■	■	■	■	■	■	■	■

Source: Extracted from M. Postle's contribution to the Draft NRA Guidelines on Environmental Assessment

R&D 435/2/NW

Given the current debate over non-use values, it is recommended that:

- consideration is first given to use related values; if these are likely to be significant and high enough to justify a proposed action, no attempt should be made to derive non-use values. Instead, the relative importance of the related effects should be reported in a quantitative or qualitative manner;

- only if the use values are not expected to provide economic justification (or are found not to do so following analysis) should action be taken to value non-use related values. If applicable and appropriate, the replacement costs method should be used first to provide an estimate of the physical costs of recreating the asset. Where this technique is not thought to give reliable or valid results, consideration may be given to the use of contingent valuation This is particularly true where the environmental resource at risk is irreplaceable. In cases where an attempt is made at valuing non-use, then there is a need to rigorously follow the testing protocol. Values developed through the use of contingent valuation should be considered to provide an indication of order-of-magnitude only and not true or precise values.

B.3 Validity and Acceptability

B.3.1 In selecting and applying the different techniques, careful thought will need to be given to their advantages and disadvantages and to the validity of the results. Table B.2 summarises some of the key considerations for each of the aforementioned techniques.

With regard to validity, this can be assessed in terms of four criteria (DoE, 1991):

- **theoretical validity:** is the technique consistent with economic theory?

- **convergent validity:** are the results of studies using one technique similar to the results of studies using other techniques? If so, this increases the credibility of the results. When comparing the results obtained from differing techniques, consideration must be given to the differences between the techniques. For example, comparison of the results of a travel cost and a contingent valuation study must bear in mind the fact that the former is valuing only use values while the latter is valuing both use and non-use. In addition, the travel cost method values a real experience while the contingent valuation study is predictive (Bateman and Turner, 1992).

- **repetitive validity:** does the same technique yield similar results when applied to similar problems?

- **criterion validity:** does the technique give results which are consistent with real behaviour?

Although the above criteria determine the technical acceptability of the various techniques, it is also important to consider the acceptability of the technique to relevant government agencies, environmental/nature conservation agencies and other interest groups (Turner et al, 1992).

Source: Extracted from M. Postle's contribution to the Draft NRA Guidelines on Environmental Assessment

TABLE

TECHNIQUE	BASIS OF VALUATION
Dose-Response Technique	Market prices.
Replacement Costs	Potential expenditures to prevent, avoid or compensate for an impact by replacing the service provided.
Avertive Expenditure	Actual expenditure on mitigating environmental effects.

Source: Extracted from M. Postle's contribution to the Draft NRA Guidelines on Environmental Assessment

B.2 (a) : SUMMARY OF TECHNIQUES

ADVANTAGES	DISADVANTAGES	RELIABILITY
Straightforward method when markets for goods exist. Values may be more acceptable than those derived through other techniques as based on "hard" data.	Problems when cause and effect relationships are uncertain. Changes in productivity may lead to changes in supply and price, complicating valuation process.	Generally good, but fails to capture non-market benefits.
Easily applied.	Assumes the existing system is optimal. Not based on individual's willingness-to-pay.	Does not value environmental good; cannot be assumed to provide reliable estimates.
Easily applied. Data may be readily available.	Cannot be used when mitigation measure involves secondary benefits. Assumes current levels of expenditure are "correct". Does not address question of optimal level of environmental quality.	Validity depends upon situation. Generally, considered to provide a lower bounds estimate.

TECHNIQUE	BASIS OF VALUATION
Travel Cost Approach	Valuation based on determining costs incurred in visiting (a site)/ undertaking an activity.
Hedonic Pricing Methods	Differences in property values given varying levels of environmental quality.
Contingent Valuation/ Ranking Methods	Individuals surveyed to determine willingness-to-pay or willingness-to-accept compensation.

Source: Extracted from M. Postle's contribution to the Draft NRA Guidelines on Environmental Assessment

TABLE B.2 (a) Continued

ADVANTAGES	DISADVANTAGES	RELIABILITY
Extensive application to the valuation of recreation benefits.	Large data requirements and potential difficulties in modelling demand function. Requires site-specific surveys of visitors. Method does not reflect quality of experience. Difficulties in dealing with multi-purpose visits.	Where data is available and modelling concerns addressed then results considered reasonably reliable. Values use related benefits only so may underestimate true value. Results should be validated against those of other studies.
Useful for valuing change in quality between residential areas. Relies on use of market data which may be readily available. Data may also be less prone to bias than more hypothetical techniques.	Individuals must be able to distinguish small changes in quality and understand implications. Difficulties in developing model: independent variables, functional form. Requires a number of assumptions concerning housing market which may not hold.	Only measures values to land-owners. Fails to capture values of other groups or those related to non-use benefits.
Based on individual preferences. Flexible. Can be used to derive use and non-use values.	Requires surveying of individuals to elicit values. Potential biases in results due to nature of questionnaire.	When biases are controlled for, should provide reliable estimates. Validation can be carried out by comparing results to other studies.

The greatest resistance to environmental valuation is likely to focus on its application to non-use related values and to conservation related activities. Conservation agencies are resistant to the economic versus environmental "trade-off" approach adopted by government departments, and instead attempt to retain, protect or improve existing environmental assets. Such agencies have expressed a number of concerns regarding monetary valuation:

- ecological and landscape/amenity assets need to be viewed in a holistic manner and the total value of the whole stock of assets is greater than the sum of the parts;

- the current planning system provides a means for establishing preliminary (non-monetary values) for sites through the site designation process; these designations and site ownership considerations could be used to develop rankings for use in evaluations; and

- there are practical limitations to monetary valuation.

Source: Extracted from M. Postle's contribution to the Draft NRA Guidelines on Environmental Assessment

APPENDIX C

Sample Completed Appraisal Sheets

Cover Sheet

Region	District
NORTH WEST	SOUTH CUMBRIA

River Name	Catchment Name/Number
COASTAL	—

River Ref	SoS Reach	Left/Right Bank	Tidal/Non-Tidal	Channel Width
—	—	—	TIDAL	—

Project Name

BOLTON-LE-SANDS SEA DEFENCES -

Brief Project Description

COASTAL DEFENCE SCHEME TO PROTECT 36 DOMESTIC PROPERTIES, 1 FARM, 4 CARAVAN PARKS, 1 ELECTRICAL SUB-STATION, 1 EFFLUENT TREATMENT WORKS, 1 SEWAGE PUMPING STATION AND 53 hectares of AGRICULTURAL LAND FROM INUNDATION FROM STORM TIDES.
CONSISTS OF HEIGHTENING/STRENGTHENING EXISTING EMBANKMENTS.

Prepared by:	Date
DONALD A BROWN	14.06.93

Checked by:	Date

Sheet 1 of 13

N.B. FOR THIS EXAMPLE ONLY A SELECTION OF SHEETS HAVE BEEN INCLUDED.

Step 8. Quantify benefits identified in relation to the "do nothing/without project" case.

Summary of Benefits

Option Nr	Flood Mitigation Benefits (£ pa)				Other Benefits (£ pa)		Total (£ pa)
	Property	Agric.	Traffic	Sub-total	Drainage	Other	
1	27126	1866	–	28992	–	–	28992
2							
3							
4							
5							
Base date for estimates							

Step 9. Discount benefits and costs

Option Nr	Discounted Benefits	Discounted Costs	NPV	B/C Ratio
1	456 914	107 000	349914	4.3
2				
3				
4				
5				

Step 10. Compare options and make a provisional selection of best option

Option Nr	Rank	Reason for Decision, including other factors considered
1		ONLY 1 OPTION CONSIDERED
2		
3		
4		
5		

Option Nr	1

Return Period and Duration of Flooding	Depth Category	Nr HEs in Depth Category	Damage per HE		Aggregate Damage
			< 12 hrs	> 12 hrs	
1 : 10 years (short duration)	< 0.10	129.1	576	1166	74362
	0.11-0.20		1683	4143	
	0.21-0.30		4412	8549	
	0.31-0.60		5953	10889	
	0.61-0.90		7227	12656	
	0.91-1.20		8287	15244	
Emergency services	Nr Properties	107	240	420	25680
			Total for this return period		100042

Return Period and Duration of Flooding	Depth Category	Nr HEs in Depth Category	Damage per HE		Aggregate Damage
			< 12 hrs	> 12 hrs	
1:20 years (short duration)	< 0.10	123.5	576	1166	71136
	0.11-0.20	10.2	1683	4143	17167
	0.21-0.30	1.3	4412	8549	5736
	0.31-0.60	12	5953	10889	71436
	0.61-0.90	–	7227	12656	–
	0.91-1.20	–	8287	15244	–
Emergency services	Nr Properties	121	240	420	29040
			Total for this return period		194514

Note
Complete separate tables for each return period for each option

Option Nr	1

Return Period and Duration of Flooding	Depth Category	Nr HEs in Depth Category	Damage per HE		Aggregate Damage
			< 12 hrs	> 12 hrs	
1:40 years (short duration)	< 0.10	19.1	576	1166	11002
	0.11-0.20	8.9	1683	4143	14979
	0.21-0.30	91.6	4412	8549	404139
	0.31-0.60	29.3	5953	10889	174423
	0.61-0.90	15.8	7227	12656	114187
	0.91-1.20	–	8287	15244	0
Emergency services	Nr Properties	142	240	420	34080
			Total for this return period		752809

Return Period and Duration of Flooding	Depth Category	Nr HEs in Depth Category	Damage per HE		Aggregate Damage
			< 12 hrs	> 12 hrs	
1:50 years (short duration)	< 0.10	16.1	576	1166	9274
	0.11-0.20	–	1683	4143	–
	0.21-0.30	2.5	4412	8549	11030
	0.31-0.60	96.7	5953	10889	575655
	0.61-0.90	33.1	7227	12656	239214
	0.91-1.20	15.8	8287	15244	130935
Emergency services	Nr Properties	142	240	420	34080
			Total for this return period		1000187

Note
Complete separate tables for each return period for each option

Summary

Option Nr	Annual Benefit (£)	Adjustment Factors		Adjusted Benefit (£ pa)
		Saline Flooding	Flood Warning[1]	
1	23588	1.15	—	27126
2		1.15		
3		1.15		
4		1.15		
5		1.15		

Notes

1. See Table 3.6
2. Use annual average damage calculation sheets to compute annual benefits for each option

Option Nr	1	Catchment Size	~~Large~~/Small	Flooding	~~Fresh~~/Saline

Return Period of Flooding	Land Use Category	Drainage Status	Area (ha)	Damage (£) per ha L	Damage (£) per ha S	Saline Factor	Aggregate Damage
1:10 years	Extensive Pasture (Silage)	Good		24.7	37.4	44.9	
		Bad		15.0	22.1		
		Very Bad		-	-		
	Extensive Pasture (Grass)	Good		11.1	16.7	44.9	
		Bad	12.1	9.8	14.1		7660
		Very Bad		8.2	11.1		
	Intensive Pasture (Sileage)	Good		34.7	53.8	20.1	
		Bad		30.5	46.9		
		Very Bad		18.0	27.2		
	Intensive Pasture (Grass)	Good	20.25	14.3	22.8	20.1	9280
		Bad		13.0	20.2		
		Very Bad		11.2	16.9		
	Arable	Good		46.0	158.0	11.4	
		Bad		39.0	130.0		
		Very Bad		30.0	93.0		
Total for this return period							16940

Notes:

L = Large catchment, S = Small catchment

Complete separate sheets for each return period for each option

Option Nr	1	Catchment Size	~~Large~~/Small	Flooding	~~Fresh~~/Saline

Return Period of Flooding	Land Use Category	Drainage Status	Area (ha)	Damage (£) per ha L	Damage (£) per ha S	Saline Factor	Aggregate Damage
1:20 years	Extensive Pasture (Silage)	Good		24.7	37.4	44.9	
		Bad		15.0	22.1		
		Very Bad		-	-		
	Extensive Pasture (Grass)	Good		11.1	16.7	44.9	
		Bad	12.1	9.8	14.1		7660
		Very Bad		8.2	11.1		
	Intensive Pasture (Sileage)	Good		34.7	53.8	20.1	
		Bad		30.5	46.9		
		Very Bad		18.0	27.2		
	Intensive Pasture (Grass)	Good	40.5	14.3	22.8	20.1	18560
		Bad		13.0	20.2		
		Very Bad		11.2	16.9		
	Arable	Good		46.0	158.0	11.4	
		Bad		39.0	130.0		
		Very Bad		30.0	93.0		
						Total for this return period	26220

Notes:

L = Large catchment, S = Small catchment

Complete separate sheets for each return period for each option

Option Nr	1	Catchment Size	~~Large~~/Small	Flooding	~~Fresh~~/Saline

Return Period of Flooding	Land Use Category	Drainage Status	Area (ha)	Damage (£) per ha L	Damage (£) per ha S	Saline Factor	Aggregate Damage
1:40 ✓ years	Extensive Pasture (Silage)	Good		24.7	37.4	44.9	
		Bad		15.0	22.1		
		Very Bad		-	-		
	Extensive Pasture (Grass)	Good		11.1	16.7	44.9	
		Bad	12.1	9.8	14.1		7660
		Very Bad		8.2	11.1		
	Intensive Pasture (Sileage)	Good		34.7	53.8	20.1	
		Bad		30.5	46.9		
		Very Bad		18.0	27.2		
	Intensive Pasture (Grass)	Good	40.5	14.3	22.8	20.1	18560
		Bad		13.0	20.2		
		Very Bad		11.2	16.9		
	Arable	Good		46.0	158.0	11.4	
		Bad		39.0	130.0		
		Very Bad		30.0	93.0		
						Total for this return period	26220

Notes:

L = Large catchment, S = Small catchment

Complete separate sheets for each return period for each option

Note:- 1. 1:50 years damages are the same.

Without Project					
Flood Return Period (yrs)	Probab -ility	Damage (£)	Probability Interval (a)	Average Damage (b)	(a) x (b)
10	0.1	16940			
			0.05	21580	1079
20	0.05	26220			
			0.025	26220	655.5
40	0.025	26220			
			0.005	26220	131.1
50	0.02	26220			
Annual Average Damage **without** project ($AAD_{without}$)					1865.6

With Project					**Option Nr 1**
Flood Return Period (yrs)	Probab -ility	Damage (£)	Probability Interval (a)	Average Damage (b)	(a) x (b)
Annual Average Damage with project (AAD_{with})					—
Annual Benefit = ($AAD_{without}$ - AAD_{with})					1865.6

Summary

Option Nr	Annual Benefit (£)
1	1865·6
2	
3	
4	
5	
Note Use annual average damage calculation sheets to compute annual benefits for each option	

Without Project							
Roads Affected		Return Period					
Road Nr	Location(s) Flooded and Diversion Routes	Road Type	D/L	Vd/Vn	Cost/ hr	Duration of Flooding	Total Cost
						Total Cost for this Return Period	

INFORMATION NOT AVAILABLE

Notes

Road Types: Motorways (MW), Built-up Trunk (BT), Built-up Principal (BP),Non Built-up Trunk (NBT), Non Built-up Principal (NBP), Minor (MN)

D/L : Diversion Length/Normal Route Length

Sd/Sn: Diversion Speed/Normal Route Speed

Cost/Hr: From Table 3.9

Duration of Flooding taken from flood hydrographs or estimated

Without Project					
Flood Return Period (yrs)	Probab -ility	Damage (£)	Probability Interval (a)	Average Damage (b)	(a) x (b)
10	0.1	100042			
			0.05	147278	7363.9
20	0.05	194514			
			0.025	473661.5	11841.5
40	0.025	752809			
			0.005	876498	4382.5
50	0.02	1000187			
Annual Average Damage without project ($AAD_{without}$)					23588

With Project					Option Nr 1
Flood Return Period (yrs)	Probab -ility	Damage (£)	Probability Interval (a)	Average Damage (b)	(a) x (b)
Annual Average Damage with project (AAD_{with})					—
Annual Benefit = ($AAD_{without}$ - AAD_{with})					23588