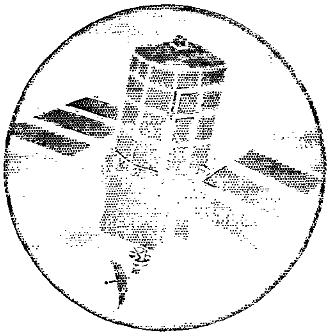
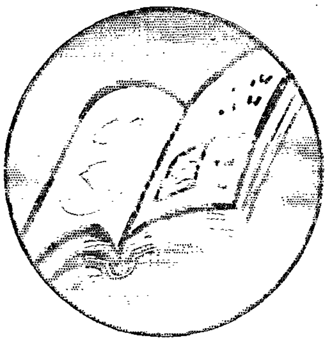
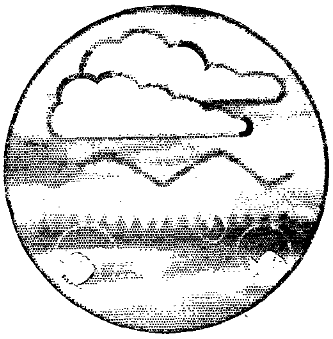
The Evaluation of FDMM







Research and Development

Technical Report
W134

ENVIRONMENT AGENCY

The Evaluation of FDMM

R&D Technical Report W134

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Research Contractor:

Silsoe College, Cranfield University

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Statement of use
This study uses the output from R&D Project 317, Guidelines for the Justification of river Maintenance (R&D Note 511) to evaluate the rural benefit assessment routines within the Flood Defence Management Manual (FDMM). Recommendations are made on ways in which FDMM might be modified and how it might be applied to complex catchments. These will be taken on board by the FDMM Project Board in the next stage of its development.

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NOTE

It is assumed that readers of this technical report have some working knowledge of the Flood Defence Management Manual (FDMM) and the Guidelines for the Justification of River Maintenance (Guidelines).

All references to FDMM relate to Volume 029, Version 1, which is dated 10/95.

All references to the Guidelines relate to R&D Note 511, Guidelines for the Justification of River Maintenance (Dunderdale and Morris, 1996, Cranfield University).

ABBREVIATIONS AND ACRONYMS

AD	Adopted Ditch
AAN	Annual Average Number
ATS	Above Target Standard
B	Bad drainage status
BA	Benefit Area
BTS	Below Target Standard
CCT	Compulsory Competitive Tender
CRIMS	Coastal and River Infrastructure Management System
EN	English Nature
FAO	Food and Agricultural Organisation
FCRN	Fisheries, Recreation, Conservation, Navigation
FDMM	Flood Defence Management Manual
FDMS	Flood Defence Management System
FHRC	Flood Hazard Research Centre
FRP	Flood Return Period
FSR	Flood Studies Report
FWR	Foundation for Water Research
G	Good drainage status
GR	Grid Reference
GRE	Gould Rural Environmental Ltd.
Guidelines	Guidelines for the Justification of River Maintenance
HE	Household Equivalent
HMIP	Her Majesties Inspectorate of Pollution
IDB	Internal Drainage Board
IDD	Internal Drainage District
LB	Left Bank
LOS	Levels of Service
LUT	Land Use Type
MAFF	Ministry of Agriculture, Fisheries and Food
NCC	Nature Conservancy Council
Nr	Number
NRA	National Rivers Authority
NRP	Non Residential Property
OTS	On Target Standard
PAGN	Project Appraisal Guidance Notes
R&D	Research and Development
RB	Right Bank
RIMS	River Information and Maintenance System
RPI	Retail Price Index
SCADE	Silsoe College Agricultural Drainage Evaluation Model
SoS	Standards of Service
SSEW	Soil Survey of England and Wales
SSLRC	Soil Survey and Land Research Centre
STWA	Severn-Trent Water Authority
VB	Very bad drainage status
WO	Welsh Office

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EXECUTIVE SUMMARY

Background

The Environment Agency are required to justify expenditure on river and watercourse maintenance and the Standards of Service provided. This requirement has prompted the development of a framework to improve the objective identification and justification of works. Research and development (R&D) work carried out under Topic C4-Operational Management have been drawn together in the Flood Defence Management Manual (FDMM) to fulfil this role. The Flood Defence Management Manual is supported by the Flood Defence Management System (FDMS).

While the Environment Agency are committed to the development and implementation of FDMM, there is some concern regarding the relevance and applicability of FDMM to all watercourses and circumstances. The North East Region of the Environment Agency piloted FDMM in 1996. During 1997, FDMM came on-line within all regions. All non-grant aided works with a value of less than £500 000 must now be justified using FDMM.

Guidelines for the Justification of River Maintenance (Dunderdale & Morris, 1996b, hereafter referred to as Guidelines) have been developed concurrently with FDMM and FDMM draws partly on their methodology. The Guidelines provide a routine for justifying maintenance activities in rural, predominantly agricultural areas. They may be used to support the agricultural benefit assessment routines within FDMM.

Given the commitment to FDMM, the need has arisen to evaluate and validate its performance through application to specific watercourses. This technical report addresses this issue. The performance of the Guidelines is also evaluated through application to the same case study watercourses. Ways in which the Guidelines may be used to support the agricultural component of FDMM are identified.

Study Aim

The broad aim of the study is to evaluate and validate the performance of FDMM through application to case study watercourses in predominantly rural areas, with reference to agricultural related benefit assessment.

Specific objectives are to:

1. apply FDMM and the Guidelines to case study watercourses which reflect a range of circumstances;
2. evaluate the performance of FDMM against agreed criteria;
3. suggest modifications to FDMM and the Guidelines in view of (1) and (2); and,
4. identify, if appropriate, ways in which the Guidelines can be used to support, and where relevant, extend the agricultural component of the FDMM methodology.

Benefit Assessment Systems

Throughout the history of the water authorities, the NRA and Environment Agency, numerous research and development (R&D) projects have developed methods to appraise the maintenance function. FDMM is based on elements of the appraisal systems listed here:

- The *'Blue Manual'* (Penning-Rowsell & Chatterton, 1977) and the *'Red' Manual* (Parker, Green & Thompson, 1987).

- *Drainage benefits and farmer uptake* (Silsoe College, 1980s).
- *House Equivalents* (developed by Chatterton & Green in the 1980s, modified by Robertson Gould Consultants).
- *River Information and Maintenance System* (RIMS) (Severn Trent Water Authority, Silsoe College & others, late 1980s).
- *River Maintenance Evaluation* (Sutherland & Morris, 1993, Dunderdale & Morris, 1996).
- *Guidelines for the Justification of River Maintenance* (Dunderdale & Morris, 1996).
- *Flood Defence Levels of Service* (Robertson Gould Consultants, 1990).
- The *Coastal and River Infrastructure Management System* (CRIMS) for Flood Defence (Howells, Haigh, Reaston, Taylor & Morris, 1992).
- The *Flood Defence Standards of Service (SoS) system* (Robertson Gould, 1992).
- *Economic appraisal of non-grant aided work (*Howells, Brown, Finney, & Morris, 1993).

FDMM is based on elements of all these systems, most notably, the economic appraisal of non-grant aided work and the SoS system.

Methodology

The Guidelines and FDMM have a similar methodological framework but differ in degrees of detail. To enable a comparative evaluation of FDMM and the Guidelines, criteria against which the systems may be assessed have been defined. The criteria encompass three fundamental aspects, namely:

operation of the system;
maintenance of the system; and,
time, costs and training.

To ensure that a range of watercourse which are broadly representative of the types found within England and Wales were identified, a simple river classification system was developed. This system classifies watercourses according to channel, floodplain and catchment character, land use and maintenance practice and was used to identify the case study watercourses.

Watercourses in the North East region were targeted as the FDMM pilot study was undertaken here and therefore some essential data were available. Environment Agency personnel within the Welsh region expressed concern that FDMM may not be applicable to many watercourses in the region due to their characteristics and the high incidence of Internal Drainage District (IDD) channels in the floodplain. For this reason, three sites were also selected within the Welsh region.

In order to enable the evaluation of FDMM under different circumstances, a highland carrier and pumped system were selected. Watercourses which have Internal Drainage Board (IDB) or IDD watercourse as tributaries also featured in the case studies.

Discussions with the Environment Agency, Internal Drainage Boards and farmers, and a visual survey of the floodplain and channel, were used to collect data relating to:

- channel parameters, floodplain topography and catchment characteristics;
- flood risk and drainage benefit areas and associated land use;
- flood return periods and associated flooded areas;
- drainage status; and,
- maintenance expenditure.

Results

FDMM and the Guidelines have been applied to the case study watercourses to demonstrate their application. A comparative analysis of the agricultural component of FDMM and the Guidelines has been undertaken. The two systems are similar in their methodological framework in that they both calculate benefits of flood alleviation and drainage in agricultural areas.

One major difference between the two systems is in the definition of the benefit area. FDMM identifies a flood risk area and within it a separate drainage benefit area for each bank. The Guidelines, however, identify an area of drainage influence which includes the area subject to flood risk. No distinction is made between the left and right bank.

The majority of data required by the Guidelines are also required by FDMM. Additional data which are required by the Guidelines relate mainly to general channel and catchment characteristics such as substrate and catchment size.

Results from the Application of FDMM

House Equivalents
FDMM uses the concept of House Equivalents (HE) which represent the value of assets and income earning potential which is placed at risk of flooding and inadequate drainage. The estimated potential cost of damage is expressed in terms of HEs, whereby one HE is equivalent to an annual cost of £1304 (in 1997/98 prices), this being the estimated cost of damage to a typical house exposed to flood risk.

HEs are accumulated by reach and expressed as HE/km of watercourse to indicate the scale of assets placed at risk, the status of the reach in terms of intensity of assets, and the existing Standard of Service (SoS) provided. The greater is the HE score (HE/km/yr), the greater are the asset values placed at risk. At present, a score of 0.5-1.0 HE/km/yr is regarded as 'on target'. A score greater than 1.0 HE/km/yr indicates a below target SoS, and less than 0.5 indicates that the SoS provided is above target.

Definition of Benefit Areas
The areas benefiting from maintenance were defined through a combination of field observations and discussions with the Environment Agency and IDBs.

Flood Risk and HE Scores
The flood risk areas and associated effective reach length (length of main river for which a flood risk area is defined) for each case study watercourse are shown in Table 1.

Table 1 Flood risk area and effective reach length, by watercourse

	Flood Risk Area (ha)		Effective Reach Length (km)	
Watercourse	Left Bank	Right Bank	Left Bank	Right Bank
Kelwell Stream	72	104	2.7	2.9
Watton Beck	210	250	1.0	1.0
Winestead Drain	460	269	7.3	7.3
Ffos Fawr	38	116	2.1	2.1
Abbey View AD	42	48	1.1	1.1
Ffynnon-y-ddol and tributaries	0	0	0	0

Note: Figures are subject to rounding.

The total number of HEs affected by flooding and the flood score (HE/effective reach length) are shown in Table 2. The Ffynnon-y-ddol and its tributaries are not subject to flooding. Channels have been designed to contain flood flows with a return period of over 100 years, hence no flood risk areas are defined. Assessment in thus based purely on drainage benefits.

Table 2 House Equivalents affected by flooding and flood score, by watercourse

	Total No. HEs affected by Flooding		Flood Score (HE/km) *	
Watercourse	Left Bank	Right Bank	Left Bank	Right Bank
Kelwell Stream	8.25	17.18	3.06	5.92
Watton Beck	110.87	128.85	110.87	128.85
Winestead Drain	190.91	20.64	26.15	2.83
Ffos Fawr	37.78	10.81	18.1	5.17
Abbey View AD	6.79	0.63	6.23	0.58
Ffynnon-y-ddol and tributaries	0.0	0.0	0.0	0.0

Note: Figures are subject to rounding. * HE divided by the effective reach length.

The total HE score for the flood risk area is divided by the effective reach length (HE/km) to reflect the intensity of land use and hence potential damage. Land use within the flood risk area is categorised into one of five bands (A=>50 HE/km/yr, B=25-50, C=5-24.99, D=1.25-4.99, E=>0.00-1.24 HE/km) according to this HE/km value per bank. Land use within the flood risk areas of the case study watercourses is predominantly classified as band 'C' and 'D' which is appropriate given the land use observed. These bands denote high grade or mixed agricultural land at risk of flooding and impeded drainage with some isolated properties also at risk.

Agricultural Drainage Benefits and HE Score

Due to the absence of documentation, it was necessary to define the drainage benefit areas in collaboration with the Environment Agency, based on local knowledge of the watercourse, drainage system, soil type and topography. Under the current maintenance regime, the drainage status of the whole flood risk area for each watercourse, is classed as 'good' (whereby drainage does not impose restrictions on land use), with the exception of the Ffynnon-y-ddol where approximately 82% of the drainage benefit area experiences bad drainage (where moderate restrictions on land use apply).

HE/ha values are derived to represent the monetary damages associated with inadequate drainage for different types of land use. These HE/ha values are multiplied by the areas affected to give a HE/km/yr drainage score.

Standards of Service

The flood and drainage scores (HE/km/yr) have been combined to determine the Standard of Service provided by the current maintenance regime. This is compared with the target score of 0.5-1.0 HE/km/yr which was set by the National Rivers Authority. Analysis shows that the SoS provided is below target for Kelwell Stream, Watton Beck and Winestead Drain and on target for the Ffos Fawr. Maintenance on the Abbey View AD and Ffynnon-y-ddol and tributaries is providing an above target SoS.

Estimates of the actual SoS provided are, however, sensitive to the effective reach length and the definition of the benefit area. Inclusion of IDB watercourses, highland carriers and embanked reaches within the effective reach length has an impact on the reach status as the HEs at risk are apportioned to a longer reach thereby lowering the HE/km/yr score. The flood risk and drainage benefit areas associated with these additional reaches should be identified and the HEs at risk included in the analysis.

As the reach status is used to prioritise maintenance activities, any changes to the maintenance programme on the basis of the reach status alone must be undertaken cautiously, especially as the reach status does not take into account monetary benefits and costs.

Benefits of Flood Alleviation
The benefits of flood alleviation are based on the difference between the 'with' and 'without' project (maintenance) situations.

The effect of flooding has been based upon the predictive technique whereby annual average flood damages are determined by assessing the HEs affected by floods of varying magnitude for the 'with' and 'without' maintenance situations as shown in Table 3.

Table 3 Example of the calculation of annual flood damages using the arithmetic method

Flood Return Period (years)	Probability	Nr. HEs Affected	Probability Interval (a)	Average Nr. HEs Affected (b)	(a) x (b)
Without Maintenance					
1	1	0.50			
			0.95	5.21	4.95
20	0.05	9.92			
			0.03	9.92	0.30
50	0.02	9.92			
	Annual Average Number HEs affected without maintenance (AAN $_{without}$)				5.25
With Maintenance					
1	1	0.00			
			0.95	1.49	1.41
20	0.05	2.98			
			0.03	6.45	0.19
50	0.02	9.92			
	Annual Average Number HEs affected with maintenance (AAN $_{with}$)				1.61

The difference in the $AAN_{without}$ and AAN_{with} is the flooding impact annual average benefit of the 'project' expressed in HEs. This figure is multiplied by the value of one HE to derive the annual average benefit expressed in monetary terms. Using the example in Table 3, the benefits of flood alleviation are therefore £4747 ((5.25-1.61) x £1304).

The annual benefits of flood alleviation over the whole flood risk area for each case study watercourse are shown in Table 4.

Benefits of Drainage
The predictive technique was used to determine differences in freeboard between the 'with' and 'without' maintenance situation to determine changes in drainage status which would occur in the absence of maintenance.

The annual benefit of preventing a deterioration in drainage status is calculated from the area affected (ha) multiplied by the annual benefit (£/ha) to be gained from preventing the deterioration. Total annual drainage benefits are shown in Table 4 for each case study watercourse.

Table 4 Annual benefits of flooding and drainage, by watercourse

Watercourse	Annual Benefit (£) of Flood Alleviation	Annual Benefit (£) of Preventing Deterioration in Drainage Status
Kelwell Stream	18523	11440
Watton Beck	43788	29329
Winestead Drain	128849	47213
Ffos Fawr	11443	4620
Abbey View AD	1846	2708
Ffynnon-y-ddol and tributaries	0	20411

Note: Figures are subject to rounding. 1997/98 economic prices are used.

Long Term Deterioration Without Maintenance

At present, on the watercourses studied, maintenance is undertaken annually. The without maintenance situation represents the base case best estimate of the likely conditions which will prevail if maintenance were discontinued. Without maintenance, however, over a period of years the channel capacity is likely to be reduced due to vegetation growth and siltation. Therefore, the impact of the annual flood after 10 years without maintenance, for example, is likely to be greater than its impact after one year without maintenance.

To test the sensitivity of FDMM to this, two without maintenance flooding scenarios were used for Kelwell Stream and Watton Beck. Scenario 1, the base case, is a typically representative best estimate and shows the likely number of HEs affected by flooding, and the deterioration in drainage status which may occur, if maintenance were discontinued. Scenario 2 represents the average annual loss of benefit assuming there are incremental losses due to a further deterioration in channel capacity over time due to lack of maintenance and consequently larger areas are flooded and drainage status deteriorates further.

The Scenario 2 benefits are an estimate of the losses which may occur if maintenance were discontinued for 10 years. These annual benefits are derived by discounting the average value of incremental losses over the period between Scenario 1 and year 10 to derive the present value of these average incremental losses, and adding this to the loss under Scenario 1. Table 5 shows an example of this and calculates losses due to flooding.

Table 5 Estimation of losses due to flooding (agricultural + urban), assuming further deterioration without maintenance, Kelwell Stream

		Left Bank	Right Bank
Benefit lost under Scenario 1 (£)	(a)	6533	11990
Benefit lost in year 10 (£)	(b)	9494	17424
Incremental loss over 10 years (£)	(b) - (a) = (c)	2961	5435
Average value of incremental loss (loss in year 5) (£)	(c) / 2 = (d)	1481	2717
Discount factor at 6 % (year 5)	(e) Appendix II	0.747	0.747
Present value of average incremental loss (£)	(d) x (e) = (f)	1106	2031
Average annual loss assuming further deterioration (£)	(f) + (a)	7639	14020
Total of both banks (£)		21659	

Note: Figures are subject to rounding. 1997/98 prices are used.

Justification

Justification of the maintenance scheme is undertaken through a comparison of the benefits and costs of maintenance in a simple benefit:cost ratio.

Total annual maintenance expenditure on each main river is summarised in Table 6. The combined annual flooding and drainage benefits and the benefit:cost ratio are also shown in Table 6. For the assumptions made, the current maintenance regimes appear to be justified in economic terms.

If the urban benefits are removed, the current maintenance regimes appear to be justified in economic terms for all the case study watercourses given the assumptions made.

Table 6 Justification of maintenance, by watercourse: FDMM

Watercourse	Annual Maintenance Expenditure (£)	Annual Benefits Lost Without Maintenance (£) (Urban and Agricultural)	Benefit:Cost Ratio (Urban and Agricultural)	Benefit:Cost Ratio (Agricultural Only)
Kelwell Stream	3713	29963	8.07	6.22
including cost for embanked reach	5300	29963	5.65	4.36
Watton Beck	1883	73117	38.83	21.15
including cost for highland carrier	6590	73117	11.10	6.04
Winestead Drain	42939	176062	4.10	2.24
Ffos Fawr	1428	16063	11.24	3.7
Abbey View AD	763	4554	5.96	4.1
Ffynnon-y-ddol and tributaries	9476	20411	2.15	2.2

Note:. Figures are subject to rounding. 1997/98 economic prices are used. Maintenance expenditure obtained from the Environment Agency and IDB/IDDs. Figures are taken from the Appendices.

Assessment of the benefits of maintenance on the Winestead Drain is complicated due to the fact that the watercourse is pumped and that an IDB watercourse which lies directly upstream of the main river is served by a pumping station which is sited on the main river.

In the previous analysis, the benefits of maintenance are derived by comparing the total benefits provided by channel maintenance and pumping with the 'do-nothing' option for the main river reach of Winestead Drain only. In accordance with FDMM, the IDB watercourse upstream of the main river has been excluded from the analysis. This IDB watercourse, however, benefits from maintenance and pumping on the main river and in order to determine total benefits and costs, this watercourse and associated benefit area should be included within the analysis. Sensitivity analysis to determine the impact of this and the benefits associated with (a) channel maintenance only and (b) pumping only has been carried out.

The sensitivity of the benefit:cost ratio to maintenance expenditure and definition of the benefit area has been assessed. In addition, the impact of including a proportion of the maintenance expenditure on the main rivers into which the case study watercourses discharge has been determined.

It is important that an integrated and comprehensive view of the river and drainage system is taken in order to capture all relevant costs and benefits. These should be identified for areas served by tributary IDB/IDD networks, for the areas served by pumping stations beyond the immediate maintained reach and low lying areas protected by embanked sections or highland carriers. This suggests a catchment based approach is more reliable than a reach based approach.

Comparison of Results from FDMM and the Guidelines

The benefit:cost ratios produced through application of FDMM to agricultural related benefits and the Guidelines are summarised in Table 7. Comparison shows that ratios produced by FDMM are generally higher than that from the Guidelines.

Table 7 Benefit:cost ratio, FDMM and Guidelines, by watercourse

Watercourse	FDMM (a) Annual Benefits (Agricultural Only) (£)	GUIDELINES (b) Annual Benefits (Agricultural Only) (£)	Ratio of (a)/(b)	FDMM Benefit:Cost Ratio (Agricultural + Urban)	GUIDELINES Benefit:Cost Ratio (Agricultural + Urban)
Kelwell Stream	23106	12945	1.78	8.1	5.3
Watton Beck	39826	30682	1.30	38.8	34.0
Winestead Drain	96036	49353	1.95	4.1	3.0
Ffos Fawr	5313	4004	1.33	11.2	10.3
Abbey View AD	3114	2347	1.33	6.0	4.9
Ffynnon-y-ddol and tributaries	20411	22981	0.89	2.2	2.4

Note: Figures are subject to rounding. 1997/98 economic prices are used.

The main reasons for the difference in agricultural benefit assessment relate to:

- differences in identification of benefit areas;
- differences due to use of standardised HE values based on 1991 relative prices;
- differences due to the use of HEs in FDMM to estimate flood costs;
- differences in the treatment of flood envelopes, which are assumed overlapping in FDMM and discrete in the Guidelines;
- differences in flood costs according to catchment size which are not identified in FDMM but which are identified in the Guidelines; and,
- differences in the identification of drainage related benefits which are more elaborate in the Guidelines.

Quality of Results

FDMM and the Guidelines are the products of extensive research and both systems are underpinned by some hydrological and agri-economic modelling. The accuracy of the results, however, is affected by the assumptions made for the particular circumstances of the watercourse and benefit areas, and the amount of detailed information available. Lack of data available at the present time creates the need to make estimates. As availability of data increases, fewer estimates will be necessary.

Standard data and default values are provided in the Guidelines and to a lesser extent in FDMM, which may be used in the absence of measured data in order to reduce the need for making estimates. This can reduce the possible sources of error which are introduced into the calculation.

User Confidence

At present, there seems to be limited understanding of, and linked to this, limited confidence in FDMM. Whilst this is mainly because FDMM is a new system and not very familiar to the users, it is also due to its 'black box' image. Clarification of various elements within FDMM is required and training needed to enable a thorough understanding of the system. In its present format, inconsistencies and anomalies in FDMM are a source of confusion and these need to be addressed. As familiarity with FDMM increases through application to more sites, confidence in it will increase.

The Guidelines can accommodate more variation in watercourses (for example, highland carriers and IDB/IDD channels) and benefit areas than FDMM and are therefore applicable to a wider variety of circumstances. This, coupled with the fact that the Guidelines are more transparent has lead to confidence being placed in them by users, especially those using RIMS which draws on a similar methodology and approach. In areas where land use is predominantly agricultural, and drainage rather than flood alleviation is the main concern, the Guidelines can help to underpin FDMM and demonstrate that FDMM can be used to accommodate agricultural interests.

Conclusions and Recommendations

The general conclusion of the study is that in the main, FDMM serves the purposes intended. It does provide an objective basis for deciding SoS and assessing benefit:cost performance of river maintenance works.

Problems lie in the use and interpretation of underlying data, assumptions and procedures. These can be addressed to improve its ease and accuracy of use.

Evaluation of FDMM and the Guidelines

Following the application and evaluation of FDMM and the Guidelines, suggestions for modifications have been made. These relate to:

1. modifications to FDMM to address site specific circumstances and peculiarities such as highland carriers, IDB/IDD watercourses and derivation of benefit areas;
2. guidance in the use of FDMM and in particular in the use of adjustment factors such as the areal drainage factor;
3. provision of information and clarification regarding assumptions and use of default values such as the drainage adjustment factors;
4. guidance in the use of the Guidelines and ways in which they may be used to support the agricultural component of FDMM; and,
5. modifications to the presentation of FDMM and the Guidelines and correction of errors.

Recommendations Regarding FDMM

The recommendation arising from the study which relate to FDMM are that:

- the modifications to FDMM which are discussed in Chapter 5 are implemented and the record sheets re-designed accordingly;
- attention is given to the definition of data requirements to enable FDMM to be used to its full potential;
- a catchment scale of analysis is adopted whereby benefits and costs of the whole watercourse system are studied, including IDB/IDD drainage networks, embanked reaches and highland carriers and costs associated with asset management;
- the derivation and application of the potential waterlogging damage factor as it applies to the estimation of agricultural drainage assessment is reviewed;
- default values are generated for use in cases where data are absent or limited;

- case studies are developed to show the application of FDMM. These would provide examples of their application to a range of circumstances;
- a case study is developed to demonstrate the integration of urban, semi-urban, rural and semi-rural benefit assessment;
- a training programme is devised and implemented throughout the Environment Agency to address needs which are specific to each user group;
- a summary version of FDMM is produced for use on site; and,
- a review of the Flood Defence Management System (FDMS) is undertaken through application to the same sites used in this study to enable a comparison with FDMM.

Use of the Guidelines to Support FDMM

The Guidelines may be used to support the agricultural component of FDMM. In particular, the Guidelines may be used to:

- justify maintenance on IDB/IDD watercourses which are tributaries of the main river. This would be particularly useful in areas of Wales such as in the Conwy Valley and in Lincolnshire where IDD/IDB watercourses are abundant;
- justify the flood protection provided by highland carriers and embankments. At present, flood risk areas associated with these are not defined using FDMM and their associated benefits are excluded from the analysis;
- justify to a third party, the rationale behind a decision to change the SoS provided. The concept of benefits in terms of £ is likely to be more familiar and meaningful than the use of HEs.
- determine the current drainage status and that which is likely to prevail in the absence of maintenance if measured data are not available. These drainage conditions may then be used in FDMM to reduce the number of estimations which are made and hence the potential sources of error.

Recommendations Regarding the Guidelines

The recommendation arising from the study which relate to the Guidelines are that:

- the modifications to the Guidelines which are discussed in Chapter 6 are implemented and the record sheets re-designed accordingly;
- case studies are developed to show the application of the Guidelines in support of FDMM to accommodate peculiar circumstances and different levels of detail;
- the training programme recommended in support of FDMM and implemented throughout the Environment Agency includes training in the use of the Guidelines in support of FDMM; and,
- a spreadsheet version of the Guidelines is developed for use by the Environment Agency.

KEY WORDS

FDMM, Flood Defence Management Manual

Guidelines, Guidelines for the Justification of River Maintenance

Benefit:Cost Ratio

Justification

River Maintenance

Economics

Drainage

Flooding

1. INTRODUCTION

1.1 Background

The primary aim of flood defence is to provide effective defences for people, property and agricultural land against flooding and waterlogging from rivers and sea (Birks, Pickles, Bray and Taylor, 1992). In order for rivers to perform this flood defence role efficiently, management of the watercourse is often necessary. In recent years greater emphasis has been placed on the need for objective methods for assessing the value and design of appropriate river maintenance programmes.

This requirement for justification of maintenance expenditure and Standards of Service provided has prompted the development of a support framework to improve the objective identification and justification of works. Strands of research and development (R&D) work carried out under Topic C4-Operational Management have been drawn together in the Flood Defence Management Manual (FDMM) to fulfil this role. The Flood Defence Management Manual is supported by the Flood Defence Management System (FDMS).

While the Environment Agency are committed to the development and implementation of FDMM, there is some concern regarding the relevance and applicability of FDMM to all watercourses and circumstances. The North East Region of the Environment Agency piloted FDMM in 1996. During 1997, FDMM came on-line within all regions. All non-grant aided works with a value of less than £500 000 must now be justified using FDMM.

Guidelines for the Justification of River Maintenance (Dunderdale & Morris, 1996b, hereafter referred to as Guidelines) have been developed concurrently with FDMM and FDMM draws partly on their methodology. The Guidelines provide a routine for justifying maintenance activities in agricultural areas.

Given the commitment to FDMM, the need has arisen to evaluate and validate its performance through application to specific watercourses. This report addresses this issue. The performance of the Guidelines is also evaluated through application to the same case study watercourses.. Ways in which the Guidelines may be used to support the agricultural benefit assessment component of FDMM are identified.

1.2 Aim and Objectives

The broad aim of the study is to evaluate and validate the performance of FDMM through application to case study watercourses in predominantly rural areas, with reference to agricultural related benefit assessment.

Specific objectives are to:

1. apply FDMM and the Guidelines to case study watercourses which reflect a range of circumstances;
2. evaluate the performance of FDMM against agreed criteria;
3. suggest modifications to FDMM and the Guidelines in view of (1) and (2); and,
4. identify, if appropriate, ways in which the Guidelines can be used to support, and where relevant, extend the agricultural component of the FDMM methodology.

1.3 Report Structure

This report summarises the objectives, methods, results and conclusions of the study. Chapter One summarises the background to the study and defines the aims and objectives. Chapter Two defines the study topic and issues relating to river maintenance and summarises the sequential development of maintenance appraisal systems. An overview of FDMM and the Guidelines is also provided in Chapter Two.

The methodology is outlined in Chapter Three. Results of the application of FDMM and the Guidelines to case study watercourses are presented and interpreted in Chapter Four. FDMM and the Guidelines are evaluated in Chapters Five and Six respectively. Chapter Seven contains conclusions and recommendations.

The report is supported by a full list of references and a series of appendices. The full results of the application of FDMM and the Guidelines to each case study watercourse are presented in separate Appendices.

2. RIVER MAINTENANCE: CONCEPTS, PRINCIPLES, APPRAISAL METHODS

This Chapter explains the need for maintenance and the requirement to justify maintenance expenditure. The sequential development of benefit assessment systems is outlined. The methodology of FDMM and the Guidelines for the Justification of River Maintenance are summarised.

2.1 Introduction

The floodplains of many rivers in England and Wales are used for agriculture which is sensitive to drainage conditions and flooding. The floodplain provides fertile land for agriculture, a flat environment for building and an obvious route for communications. Many conurbations in the UK such as London and Birmingham are established on floodplains.

Effective defence for people, property and agriculture from flooding and waterlogging (underground flooding) is necessary. Without flood defences, approximately 7% of the total land area of England and Wales (10 000 km^2) would be at risk from non-tidal fluvial flooding (Richardson, 1996). Flooding from coastal waters would affect 7000 km^2 . This total area includes approximately 55% of grade one agricultural land (Richardson, 1996) in England and Wales. Maintenance of flood alleviation measures therefore has a significant impact on the national economy.

2.2 River Management and Maintenance

The primary aim of flood defence is to provide effective defences for people, property and agricultural land against flooding and waterlogging from rivers and sea (Birks et al, 1992).

In order for rivers to perform this flood defence role efficiently, management of the watercourse is often necessary. The primary function of the river is to drain the land and the main purpose of watercourse maintenance is to enable the river to deliver a particular standard of flood protection and land drainage service. The standards to which the Environment Agency seeks to alleviate flooding and allow provision for adequate drainage of land are termed the Flood Defence Standards of Service (SoS).

By definition, maintenance is a repeat activity which through a 'single action or sequence of actions, serves to modify the flooding or drainage characteristics of the reach being considered' (Howells, Brown, Finney and Morris, 1993).

Maintenance influences the relationship between flows and levels in the river and drainage system. In rural, mainly agricultural areas, this relates to the control, within acceptable limits, of flooding and watertable levels. Maintenance affects the ability of the river to retain flows of a given magnitude, and thereby the risk of flooding. Similarly, maintenance affects the outfall for field drainage, whether by natural movement of water through soils or assisted by underground pipes.

Maintenance also affects environmental qualities, either directly through its impact on conditions within the channel, or indirectly through its impact on soil water regimes in the adjacent floodplain.

2.3 Maintenance Justification

The need for maintenance works has traditionally been based on the fact that the maintenance scheme is scheduled as part of an ongoing regular programme of work. The criteria for determining the degree to which these services are provided, and therefore standards of maintenance, have traditionally been based on local judgement, the current level of service provided and available funding. This judgement is subjective and substantial variation in approach exists between Environment Agency regions. This approach is unstructured and cannot be considered appropriate in a national context to determine the need for maintenance works, the level of service and value for money, as there is no link between the rationale for maintenance and the Standard of Service (SoS) provided.

Through commitment to the Citizen's Charter, public awareness has increasingly focused on the 'real world outcome' of the work of the National Rivers Authority (NRA) and now the Environment Agency. Resources provided by the tax payers and industry must be seen to be used in a cost-effective manner whilst effecting a discernible improvement on the quality of the water environment. In the year 1996/97, over £250 million was spent by Flood Defence nationally on maintaining and improving flood defences. This accounted for almost 50% of the core-function expenditure of the organisation (Environment Agency, 1996).

Prior to the launch of the Environment Agency, Flood Defence underwent a period of structural change. The business was divided into two sections - the Client and the Contractor - with the aim of improving efficiency. This led to a greater focus on the objective assessment of the need for and justification of maintenance works, especially regarding the estimation and comparison of benefits and costs.

This requirement for justification of maintenance expenditure and achieving Standards of Service provided has prompted the development of a framework to improve the objective identification and justification of works. This framework is FDMM, which draws together R&D work carried out in Topic C4 - Operational Management. FDMM is supported by FDMS.

Projects which are funded by grant aid provided by the Ministry of Agriculture, Fisheries and Food (MAFF) and the Welsh Office (WO) must be justified in accordance with the MAFF Project Appraisal Guidance Notes (PAGN, MAFF, 1993) which are in line with Treasury Guidelines. Non-grant aided works over £500 000 in value are also justified using the PAGN as these are also submitted to MAFF for approval. All other non-grant aided projects must be justified in accordance with FDMM.

2.4 Sequential Development of Benefit Assessment Systems

Throughout the history of the water authorities, the NRA and Environment Agency, numerous R&D projects have developed methods to appraise the maintenance function. A brief summary of some of these projects is presented here.

Early systems to facilitate and standardise the assessment of the benefits of flood alleviation and land drainage were provided in the *'Blue Manual'*, produced in 1977 (Penning-Rowsell and Chatterton, 1977). The manual simplified the assessment of benefits of protecting urban and agricultural land. It provided nationally applicable standardised flood damage data for a variety of urban land uses and computer based routines for the discounting of benefits. A similar manual produced in 1987 (the *'Red' Manual*) provides routines for the appraisal of urban benefits (Parker, Green and Thompson, 1987).

In the early 1980s, Silsoe College undertook a major study of *drainage benefits* and farmer uptake on behalf of Severn Trent Water Authority (STWA) and MAFF. This included a review of 22 agricultural drainage improvement projects throughout England and Wales. Subsequently, methods were developed for agricultural benefit assessment and drainage project appraisal.

The concept of *House Equivalents* (HEs) (often called Household Equivalents) was developed for Standards of Service during the 1980s by Chatterton and Green (1988). Under this concept, land use subject to flooding is recorded and evaluated using the common numeraire of the HE. A key factor in the use of the HE is the 'value' of one HE in economic terms. Chatterton and Green used the conventional annual average damage approach to derive an HE value of £153 (1988 price base). All other economic activities in the floodplain such as commercial and agricultural interests were then converted to their HE value.

This approach was adapted by Gould Consultants, now Gould Rural Environmental Ltd (GRE), who used the concept of the 'average cost of a flood', to derive an HE of £1135 (1993 price base). It is this interpretation of the HE which is usually used. The value of one HE may be updated annually by using the appropriate price index. In 1997/98 economic prices, the value of one HE is estimated to be £1304 (Environment Agency, 1997). It was only later that the concept of HEs was applied to justification.

The *River Information and Maintenance System* (RIMS) was developed during the late 1980s by the Severn Trent Water Authority (STWA) and others. This computer based application enables the justification of maintenance activities. RIMS performs benefit assessment for urban and infrastructural features such as commercial properties, housing, roads and railways and for agricultural land. Silsoe College built on their previous work to design the agricultural component of the system. The benefits of maintenance are estimated to be the value of damage to land and infrastructure without maintenance, less the value of damage with maintenance.

In 1989, the NRA, commissioned Silsoe College to undertake a study to *monitor and evaluate the impact of maintenance* on six main river sites within the Severn-Trent Region (Sutherland and Morris, 1993). The study developed methods for the technical and economic appraisal of river maintenance. Subsequent to this, the study was extended to incorporate other NRA Regions, and further develop methods to help design, justify and prioritise maintenance activities. This involved the monitoring of 12 sites in five NRA Regions during the period 1992 - 1996, and the development of guidelines for the management of the maintenance function. The output from this study included *Guidelines for the Justification of River Maintenance*. These provide a routine for the justification of maintenance regimes in terms of the impact on standards of land drainage service, flood risk and economic benefits and costs of maintenance.

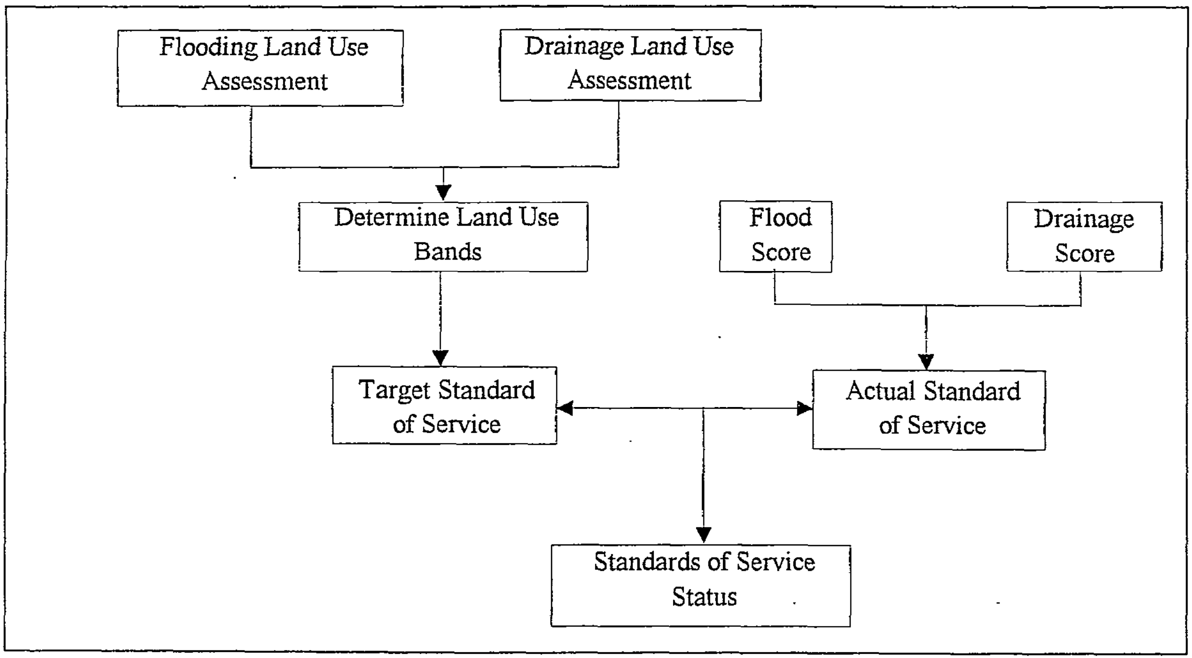
The NRA commissioned Robertson Gould Consultants in association with Sir William Halcrow and Partners to develop a system which could be applied nationally to define and monitor *Flood Defence Levels of Service* (LOS) (Robertson Gould Consultants, 1990). This system involves the identification of land use, in terms of HEs which is within the area at risk of flooding. Land use is classified into five bands according to the total number of HEs. The total number of agricultural HEs affected by flooding at various return periods are used as a measure of the adequacy of the level of service provided.

The *Coastal and River Infrastructure Management System* (CRIMS) for Flood Defence (Howells, Haigh, Reaston, Taylor and Morris, 1992), developed in the early 1990s, draws together various strands of research relating to the appraisal of maintenance. It draws largely on the flood defence Levels of Service work. CRIMS is a simpler, less precise method than RIMS for justifying maintenance. It uses the concept of HEs to calculate agricultural benefits which arise from changes in flood risk, land use and yield as a result of flood alleviation.

The *Flood Defence Standards of Service (SoS) system* was developed as a management tool, to provide a method for the definition and monitoring of Standards of Service on a consistent, non-subjective basis (Robertson Gould, 1992). This approach is based on the HE principle and is composed of two elements:

1. an assessment of current land use and definition of target SoS. The drainage and flooding land use assessments are used in conjunction to define land use bands and attribute target SoS; and,
2. monitoring of actual and estimation of the likely future impacts of flood incidents on the basis of the current maintenance strategy.

It draws together elements of the RIMS, CRIMS and the Flood Defence Levels of Service methodology. The methodology of the SoS system is illustrated in Figure 2.1.



Source: NRA, 1995, Figure 3.1

Figure 2.1 Standards of Service methodology

The *economic appraisal of non-grant aided work*, undertaken by Mott MacDonald Consultants and Silsoe College (1992-1993) drew together elements of this previous research. It provided a consistent appraisal method which could replace the varying regional practices which have developed over the years.

FDMM is based on elements of all these previous benefit assessment systems, most notably, the economic appraisal of non-grant aided work and the SoS system.

2.5 Derivation of House Equivalents

A House Equivalent (HE) is defined as the average financial cost of damage caused to an average house when flooded, by a single representative event (GRE methodology). This HE is used as a common unit to assess the intensity of land use within an area at risk of flooding. A house within the area being assessed registers as one HE and flood damage costs defined for all land use features identified as important to SoS are expressed in terms of this HE. HE values for various land use features are given in FDMM, Table 3.2, p3/7.

A key factor in the use of the HE is the 'value' of one HE in economic terms. This value is based on the average damage (£) caused by flooding of various depths (<0.1 m - >1.2 m) and return periods (<10 yrs, 10-50 yrs, >50 yrs) to an inventory of over 100 items and up to 400 building repair activities, in a sample of properties which represent 104 house types (Howells et al, 1992). In 1991 prices, an average value of this damage was estimated to be £1134. This is the value of one HE. Non-residential property is treated in a similar manner.

The average weighted damage (£) for each land use feature and associated HE are shown in Table 2.1. Further information on the derivation of the damage figures is presented in the following paragraphs.

Potential damage to communications is based on the duration of flooding (<, or >12 hours). Typical duration of road/railway closures and disruption costs were taken from case studies conducted by the Flood Hazard Research Centre (FHRC, 1988). The weighted average damage figure (£) assumes that 65% of events are of short duration and 35% of long duration. These costs were inflated in CRIMS (Howells et al, 1992) to 1991 values using the appropriate price indices, and are shown in Table 2.1.

The losses incurred by flooding of forestry (Table 2.1) are based on the probability of flooding after planting and the total cost of replacement planting after the event which is divided by 50 (planting is assumed to be on a 50 year cycle) to derive an annual cost. The impact of flooding on scrub is discounted on the assumption that no damage is incurred. Further details may be found within CRIMS (Howells et al, 1992).

Damage to extensive pasture is based on the assumption that on average, a flood lasts 7 days and a further 7 days will be required for the grass to recover. The loss of 0.5 month's growth is weighted by the probability of flood occurrence by month (Howells et al, 1992). Losses to intensive pasture are based on the probability of flooding by month and the energy which would be lost. Loss of grass conservation and grazing are taken into account (Howells et al, 1992).

Losses to extensive arable crops are based on winter wheat; the most commonly grown cereal in the floodplain. It is assumed that in a large catchment (>2500 ha), there is a 3% probability of total crop loss from a single event occurring at the drilling stage and a further 3% loss associated with additional floods. Losses during the growing period and at harvest are taken into account (Howells et al, 1992).

Potatoes and sugar beet are taken to be representative of intensive arable crops. Estimates of losses are based on a single flood in a large catchment (>2500 ha). The loss relates to the difference between the unaffected and affected gross margin, weighted by the probability of occurrence during the growing season, and during harvest. The cost of ploughing in the damaged remains of the crop is included in the calculation (Howells et al, 1992).

Table 2.1 Land use features and HE values

Land Use Feature	Average Weighted Damage (£ *) (a)	Unit	HE (b)
House	1134	Number	1
Garden	43	Number	** 0.04
NRP - Manufacturing	32.2	Area (m^2)	0.03
NRP - Distribution	60.6	Area (m^2)	0.054
NRP - Leisure	35.3	Area (m^2)	0.032
NRP - Offices	37.9	Area (m^2)	0.033
NRP - Retail	41.3	Area (m^2)	0.035
NRP - Agricultural	*0.4*	Area (m^2)	*0.001*
It was proposed in CRIMS to use a value of 0.001 HE to simplify the calculations undertaken			
C roads	3040	Number	2.7
B roads	7100	Number	6.3
A roads (non-trunk)	17740	Number	15.9
A roads (trunk)	35480	Number	31.7
Motorway	70960	Number	63.5
Railway	70960	Number	63.5
Forestry and scrub	0.21	Area (100 ha)	*** 0.02
Extensive pasture	14.29	Area (100 ha)	1.30
Intensive pasture	35.58	Area (100 ha)	3.00
Extensive arable	72.34	Area (100 ha)	6.30
Intensive arable	501.49	Area (100 ha)	44.1
Formal parks	720	Number	0.6
Golf/race courses	790	Number	0.7
Playing fields	90	Number	0.1
Special parks	10510	Number	9.3

Note: Figures are subject to rounding. * 1991 prices
** E.g. 43/1134 = 0.04, *** E.g. (0.21/1134)x100 = 0.02
Source: (a) CRIMS, R&D 373/1/T (1992) (b) NRA (1995)

Evaluation of damage to amenity activities relates to the marginal loss as a result of flooding over and above losses expected through bad weather. An additional factor to consider is the probability of a sporadic activity such as a cricket match or point-to-point coinciding with a flood event. The probability of this occurring is low. In some cases, for example, as in the case of a golf course, membership fees would still be due, even if flooding prevented full utilisation of the facilities. Losses from fees would therefore be minimal but repairs to greens, fairways and bunkers would be required following flooding.

2.6 Overview of FDMM

FDMM presents a step by step framework for the economic appraisal of non-grant aided work with a value of less than £500 000. An overview of FDMM is presented in the following sections.

2.6.1 Reach definition

Each river bank or flood defence system is divided into reaches of broadly similar length (ideally 4-7 km). Reaches broadly mark changes in land use or hydrological regimes and may be divided into sub-reaches with limits that coincide with easily identifiable features such as bridges or control structures. The reach limit defined on the channel is extended across the width of the flood risk area to define the assessment area for each reach. Left and right banks are treated separately, and if possible, the reaches on each bank should use the same demarcation points. The effective reach length is the 'length within the main channel of a SoS reach for which a flood risk area is defined (loops, spurs and lengths without an associated floodplain are excluded)' (FDMM, 1995). Figure 2.2 illustrates this diagramatically.

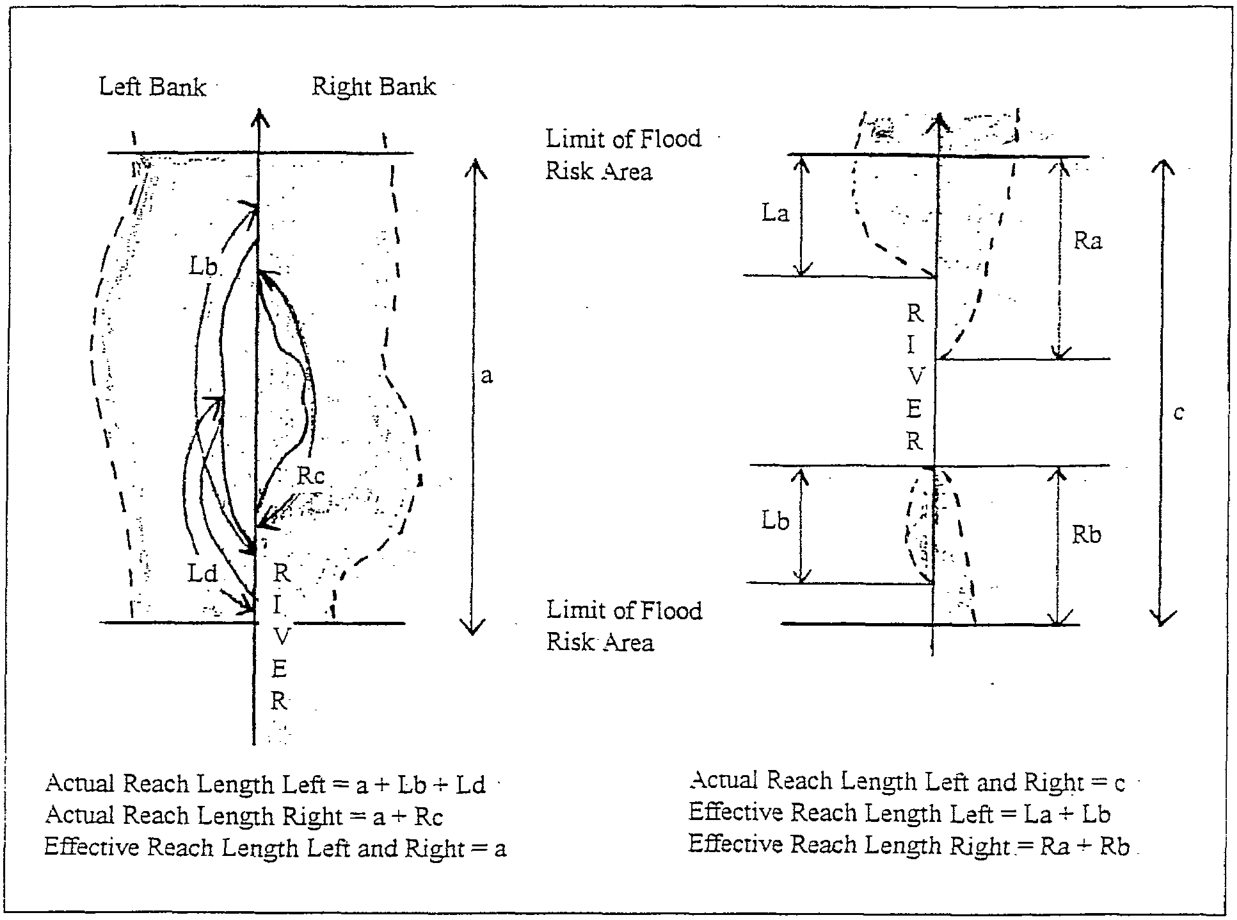
2.6.2 SoS assessment - flooding

Area of benefit

The area benefiting from the flood defence services provided is identified and termed the flood risk area. This area may equate to the maximum known flooding extent or the area protected by an existing flood defence scheme.

Land use assessment - flooding

The intensity of land use within this flood risk area is expressed in terms of House Equivalents (HE). Examples of HEs for various land use categories are shown in Table 2.1. The agricultural values exclude allowances for poor drainage as the flood risk and drainage benefit areas may differ.



Source: NRA, 1995, Figure 2.4

Figure 2.2 Calculation of reach lengths

The total HE score for the flood risk area is divided by the effective reach length, to derive an HE/km value. The land protected is categorised into one of five bands according to land use intensity and hence potential damage as shown in Table 2.2.

Table 2.2 Land use bands according to number of HE/km

Land Use Band	Range of HE/km (one bank only) *	Comment
A	> 50	Typically large urban areas at risk from flooding
B	25 - 50	Less extensive urban areas with some high grade agricultural land
C	5 - 24.99	High grade agricultural land at risk of flooding and impeded drainage and some properties at risk of flooding
D	1.25 - 4.99	Typically mixed agricultural land, prone to waterlogging or flooding, the occasional property at risk of flooding
E	0.01 - 1.24	Typical low grade agricultural land, often pasture, at risk of flooding and impeded drainage, isolated agricultural properties at risk of flooding
F	> 0 < 0.01	Typically small areas of low grade agricultural land or areas of forestry and scrub at risk from flooding or impeded land drainage
X	0	Little or no flooding occurs (E.g. upland watercourse), or culverted
Xld	0	The reach is within the floodplain of a larger river
Xest	0	The reach is within an estuary

Note: * Combined flooding/drainage value
Source: NRA, *1995*, Table 3.4

Effect of flooding

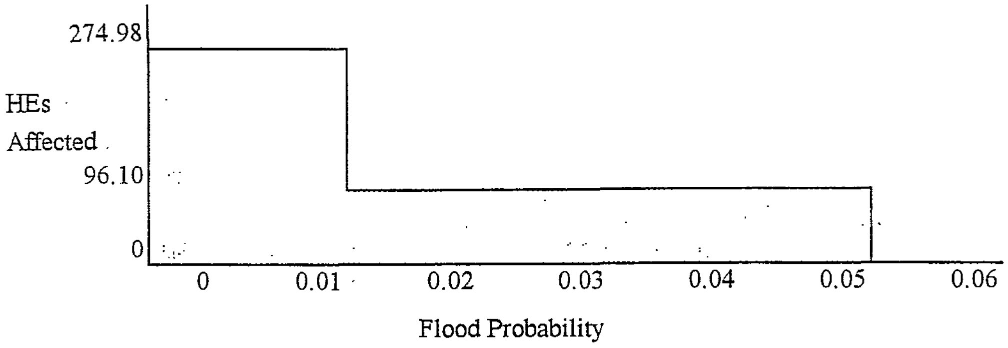
The effect of flooding is determined through the use of two complimentary techniques: the historical and predictive technique.

The historical technique uses information gathered on flood events that have occurred on each bank of the river reach over a period of five years (the monitoring period). Information on the areas flooded, date of the event, duration and nature of flooding (freshwater or saline) is required. The total number of HEs affected by each event is calculated using the following formula:

HE score =
(urban HE affected x salinity weighting) + (agricultural HE affected x severity x salinity weighting)

The severity weighting takes account of the effect of flood duration and seasonality on agricultural losses. The salinity weighting allows for the more severe effects of saline flooding as opposed to freshwater flooding. Scores for each event on each bank are calculated, and yearly scores averaged over the monitoring period on a rolling basis to reduce seasonal variation and to give the average annual value of HE/km affected (flood score, HE/km/yr).

The predictive technique builds on the historical technique by taking account of the flood return period at which different land uses are inundated. It seeks to identify an estimated long-term average annual value for HE affected. A severity weighting is applied to take account of the timing and flood duration. A graph is plotted of the number of HE affected at a particular return period within the reach, an example of which is shown in Figure 2.3. The area under the curve represents the Annual Average Damage measured in HEs. Division of this value by the reach length, provides the annual HE/km likely to be affected by flooding (flood score, HE/km/yr). Alternatively, the process used in calculating the area under the curve can be carried out arithmetically without the need to draw the graph, using the 'benefit assessment sheet' contained within FDMM (FDMM, Section G, Sheet 5).



Total HEs affected (area under graph)	6.59
Effective reach length (km)	3.60
HEs affected/km/yr (Flood score)	1.83

Source: Supplement to the Summary Guidance for the FDMM, Summer 1997, p2/7

Figure 2.3 Example of the use of the predictive technique to calculate the flood score

If a large discrepancy between the two techniques is identified, the results should be investigated. Poor data sets for the historical flood events means that the predictive score will generally provide the most reliable indicator.

2.6.3 SoS assessment - agricultural land drainage

Using local knowledge and existing records, the areas within the flood risk area which are subject to drainage problems are identified and the agricultural HE score is adjusted accordingly. The adjustment is calculated using the potential waterlogging damage value which varies according to land use. This factor takes account of inadequate drainage and reflects the monetary loss (£/ha) associated with a deterioration in drainage status from good to very bad, irrespective of the drainage system.

If the drainage benefit area is not known, an areal drainage factor is applied to the flood risk area. This factor 'reflects the fact that the area affected by inadequate drainage will vary depending on soil type and the type of drainage system' (FDMM p3/21 paragraph 69).

Effect of inadequate drainage

Two techniques are used to determine the effects, if any, of inadequate drainage on land use in the area at risk. The historical technique is the same as that used for the flood assessment. Areas subject to inadequate drainage are identified visually and from local knowledge over a rolling five year period (monitoring period).

The predictive technique involves the setting of a drainage standard in terms of a theoretical freeboard which can be compared with the actual freeboard at times of dominant discharge (discharge which occurs most frequently). In naturally drained land, freeboard may be described as the vertical distance (m) between the water surface in the watercourse and field level. If land is artificially drained, freeboard relates to the distance between field level and 0.1 m below the field drainage pipe outfall. This is illustrated in Figure 2.4.

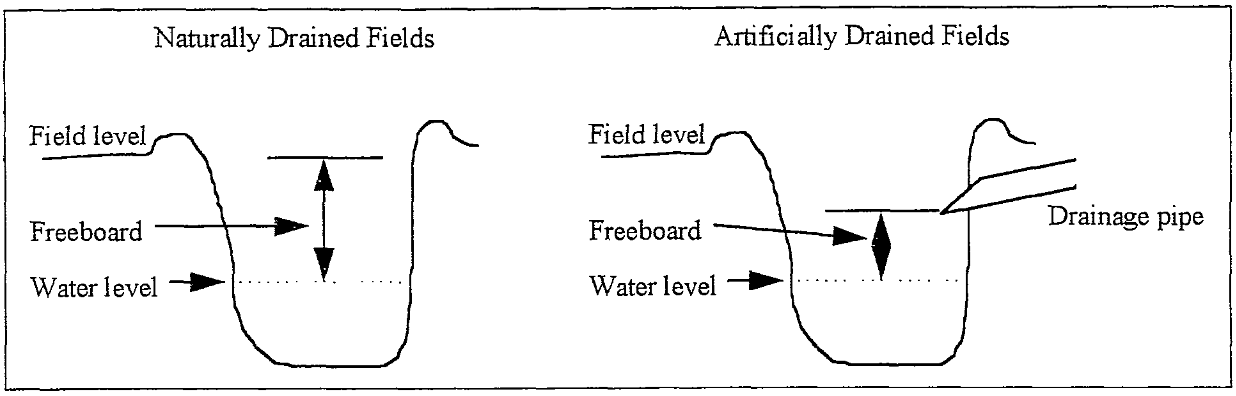


Figure 2.4 Diagrammatic illustration of freeboard

The historical and predictive scores are combined using the following formula:

Combined drainage score = ((Historical score x 1) + (Predictive score x 2)) / 3

This drainage score represents the level of damage caused by waterlogging. If a large discrepancy between the two techniques is identified, the results should be investigated.

2.6.4 Actual SoS

The combined flooding and drainage score provides an indication of total damage. By comparing the Standard of Service provided with a pre-defined target standard, the performance of the current maintenance regime can be assessed (Table 2.3).

Table 2.3 Standard of Service rating bands

HE/km/yr	Rating	Description	Action - maintenance regime urgency rating
> 2.0	1	Well below target	Significant increase in maintenance required
1.0 - 2.0	2	Below target	Increase in maintenance regime required
0.75 - 1.0	3	On target	Maintenance regime appropriate
0.5 - 0.75	4	On target	Maintenance regime appropriate, some reduction possible
0.25 - 0.5	5	Above target	Reduction in maintenance regime required
0.0 - 0.25	6	Well above target	Significant reduction in maintenance regime required

Source: NRA, 1995, Table 6.2 and 6.3

Based on an analysis of existing Standards of Service in 489 examples from the Wessex region of the NRA, a target SoS of 0.5-1.0 HE/km/yr for each bank has been set by the Environment Agency. A score of less than 0.5 indicates an above target standard (ATS). A score greater than 1.0 indicates a below target standard (BTS).

These rating bands are used to prioritise maintenance activities and to enable resources to be targeted on specific watercourses. Watercourses receiving a low rating (1-2) in which the SoS provided is below target are identified as a priority.

Once the SoS has been determined using the methodology of the SoS system, and the order in which watercourses are to be maintained has been established, procedures are identified in FDMM to enable the flood defence works to be justified.

2.6.5 Justification

Justification may be undertaken for a particular reach, asset or system and relates to the comparison of the benefits and costs associated with the alleviation of flood and waterlogging damage. Maintenance is justified if the benefit:cost ratio is greater than 1. FDMM is used for justification if total expenditure is less than £500,000, otherwise a full MAFF appraisal is required using the PAGN.

Benefit assessment - flooding

The benefits of flood alleviation are based on the difference between the 'with' and 'without' project (maintenance) situations.

Annual average flood damages are determined by assessing the House Equivalents (HEs) affected by floods of varying magnitude. Firstly, the flood extent for the 'without' project situation is calculated for a range of flood return periods and the number of HEs affected by each return period determined. The Annual Average Number ($AAN_{without}$) of HEs affected under the 'without' project situation are then calculated arithmetically or by plotting a graph of the number of HEs affected against the probability of flooding. An example of the arithmetic method is shown in Figure 2.5. The flood extent is then established for the 'with' project situation for the same range of flood return periods. The HEs affected within the flood extent for each return period are calculated and the Annual Average Number (AAN_{with}) of HEs affected 'with' project is determined in the same way as for the 'without' project situation.

Flood Return Period (years)	Probability	Nr. HEs Affected	Probability Interval (a)	Average Nr. HEs Affected (b)	(a) x (b)
Without Maintenance					
1	1	0.50			
			0.95	5.21	4.95
20	0.05	9.92			
			0.03	9.92	0.30
50	0.02	9.92			
Annual Average Number HEs affected without maintenance ($AAN_{without}$)					5.25
With Maintenance					
1	1	0.00			
			0.95	1.49	1.41
20	0.05	2.98			
			0.03	6.45	0.19
50	0.02	9.92			
Annual Average Number HEs affected with maintenance (AAN_{with})					1.61

Figure 2.5 Example calculation of annual average flood damages using the arithmetic method

The difference in the $AAN_{without}$ and AAN_{with} is the flooding impact annual average benefit of the 'project' expressed in HEs. This figure is multiplied by the average damage caused to one HE by a flood (£1304, 1997/98 prices) to derive the annual average benefit expressed in monetary terms. This procedure is shown by the equation in the following box. Using the example in Figure 2.5, the benefits are therefore £4747 ((5.25-1.61) x £1304).

$$(AAN_{without} - AAN_{with}) \times \text{Value of one HE}$$

Benefit assessment - drainage
Where maintenance works cause the river water levels to be lowered, benefits of improved drainage may result. To determine the benefits of drainage, the critical river level for drainage is determined and the average freeboard estimated.

The freeboard requirement for drainage is determined from the information given in Table 2.4 according to the drainage system, soil type and floodplain slope. For example, a freeboard of greater than 0.8 m is required to deliver good drainage for a rising floodplain with a light soil. This approach is based on methods developed by Silsoe College for the Severn Trent Water Authority (STWA) in the 1980s, and subsequently for the NRA (Hess, Leeds-Harrison, and Morris, 1989).

Table 2.4 Drainage status assessment according to system, soil type, floodplain slope and freeboard

Drainage System	Soil Type	Floodplain Slope	Freeboard Requirement for Drainage (m)		
			Good Drainage	Bad Drainage	Very Bad Drainage
Natural drainage	Heavy	Flat (< 0.5 %)	> 1.7	1.4 - 1.7	< 1.4
		Rising (> 0.5 %)	> 1.5	1.2 - 1.5	< 1.2
	Light	Flat (< 0.5 %)	> 1.2	0.9 - 1.2	< 0.9
		Rising (> 0.5 %)	> 0.8	0.5 - 0.8	< 0.5
			Clearance for Pipe Outlet for Drainage (m)		
			Good	Bad	Very Bad
Piped drainage	All	All	> 0.1	0.0 to 0.1	< 0.0

Source: NRA, 1995, Table 5.11

The economic benefits per unit area according to land use and change in drainage status are calculated, based on the extra net return per hectare to be obtained on extensive pasture, intensive pasture or arable land from improvements in drainage condition.

The benefits of flood alleviation and drainage are aggregated to determine the total benefit of the maintenance works. These benefits are compared with the costs to determine whether the maintenance programme is justified in economic terms.

Benefit assessment - other
Environmental and social benefits are difficult to quantify and in general, only rough indicators of recreational and amenity facilities are available. Increasingly, attention is being focused on methods to quantify these benefits. Within the context of low flows Silsoe College have developed a system for the economic evaluation and risk assessment of environmental quality. This system combines information on incidence of characteristics, unit value, degree of sensitivity and a measure of risk which can be evaluated in terms of significance and tolerance. Standard monetary estimates are used for valuing the consequences of low flows to water users and the environment and estimates of the probability that the consequences will occur (Morris, Weatherhead, Mills, Dunderdale, Hess, Gowing, Sanders, Knox, 1997). Other work by the Foundation for Water Research has led to the production of a manual to assess the benefits of surface water quality improvements (FWR, 1996). Within this manual, attention is also given to associated recreational benefits.

Further research is required in order to develop reliable systems for the quantification of these benefits which are supported by scientific study.

2.7 Guidelines for the Justification of River Maintenance

The Guidelines for the Justification of River Maintenance which formed the output of a recently completed NRA R&D study (Dunderdale and Morris, 1996b), comprise routines for the justification of maintenance regimes in terms of the impact on standards of land drainage service, flood risk and financial/economic benefits and costs of maintenance.

The methods in the Guidelines are similar in principle to those contained in the agricultural component of FDMM, but they differ in degrees of detail and in particular, in the way flood costs are identified. The Guidelines provide a broad brush approach to determining a maintenance benefit:cost ratio. They are based on the difference in benefits 'with' and 'without' maintenance.

Full details of the methodology are contained within R&D Notes 511 and 456 (Dunderdale and Morris, 1996a,b). A full comparison of the FDMM and Guideline methodology is presented in Chapter 4.

2.7.1 Benefit area

As in the FDMM, the starting point of the Guidelines is the definition of the area which derives benefit from the maintenance regime in terms of its impact on flooding and prevention of a deterioration in the standard of drainage service. Urban areas are not included in the benefit area as they receive different levels of flood protection and higher levels of service than rural areas.

2.7.2 Catchment characteristics

The dominant substrate influences the impact and longevity of maintenance (Fisher, 1995, Dunderdale and Morris, 1996) and floodplain topography influences the drainage of the floodplain. Catchment size affects the seasonal distribution of flooding. Large catchments experience predominantly winter flooding (80% winter floods, 20% summer floods), whereas smaller catchments (<2500 ha) contain a relatively higher incidence of summer floods (60% winter flooding, 40% summer flooding) (Hess and Morris, 1986). The distribution of flooding therefore influences the costs associated with the flood event.

Maintenance benefits vary according to land use within the benefit area. For consistency, the same land use types (LUT) are used as in RIMS and the Economic Appraisal of Non-Grant Aided Work for determining maintenance benefits (Table 2.5).

Table 2.5 Land use type

Land Use Type (LUT)		Main Crops
1	Extensive Pasture	Grass, poorly drained, uneven grass sward, sheep grazing, some hay
2	Intensive Pasture	Grass, well drained, field pipes, beef, dairy, even sward, clover, silage, reseeded
3	Pasture/Arable	Grass, wheat, barley, oats
4	All Cereals	Wheat, barley, oats
5	Cereal/Oil Seeds	Wheat, barley, oats, oilseed rape, linseed oil (peas, field beans)
6	Cereal/Root Crops	Wheat, barley, oats, potatoes, sugar beet (turnips, swedes)
7	Horticulture	Cabbage, carrot, broccoli, leek, onion, cauliflower, salad vegetables, orchard/soft fruit
8	Other	Woodland, paddock, wasteland, turf production, set aside, crops not shown above

Source: Sutherland et al, 1993b.

Land use on the left and right banks is not classified separately. If the land use is similar throughout the benefit area, or if a rapid assessment is required, the dominant land use type is identified. If land use is variable, or if a more detailed assessment is required, the percentage of the benefit area under each land use type is identified.

2.7.3 Design standard (maintained condition)

The benefits of maintenance are based on changes in channel capacity and drainage status 'with' and 'without' maintenance. Such change is dependent on the type and level of maintenance undertaken. In order for these benefits to be identified, information relating to channel parameters and drainage condition is required.

Influence of river conditions on freeboard

The drainage system, soil type and therefore hydraulic conductivity (the ability of the soil to transmit water through its pores) and river levels, influence the potential benefits of maintenance.

Where land adjacent to the watercourse may be subject to temporary high watertables, a distinction may be made between areas which are drained by underground field drains which outfall into the river or tributary ditch system and areas where field drainage is by natural movement through the soil.

In artificially drained areas, the requirement for freeboard is set by the drain outfalls, based on soil type and floodplain topography. Minimum acceptable freeboard requirements for piped field drainage in different soil types are shown in Table 2.6. In naturally draining fields, watertable levels are influenced by soil hydraulic conductivity, land slope and rainfall rate (Table 2.7).

Table 2.6 Freeboard requirements: fields with piped drainage

	Freeboard Requirement		
Soil Type	Flat Floodplain (m) *	Rising Floodplain (m)	Default Values (m) **
Sand	1.6	1.4	1.5
Silt	1.6	1.4	1.5
Loam	1.6	1.4	1.5
Clay	1.2	1.0	1.1

* For 100 m floodplain, add 0.2 m pro rata per additional 100 m

** Default values are typical freeboard requirements for land with piped drainage

Source: Morris, 1990

Table 2.7 Freeboard requirements: natural drainage

		Freeboard Requirement (m)		
Drainage Status	Soil Type	Flat Floodplain	Rising Floodplain	Default Values (m)
Good	Sand	1.0	0.7	0.85
	Loam *	1.3	1.0	1.15
	Clay	2.1	2.0	2.05
Bad	Sand	0.7	0.3	0.5
	Loam	1.1	0.6	0.9
	Clay	1.9	1.5	1.7
Very Bad	Sand	0.4	0.0	0.2
	Loam	0.8	0.0	0.4
	Clay	1.6	1.0	1.3

* E.g. 1.3 m freeboard is necessary to deliver a good drainage on a loam soil on a flat floodplain

Source: Hess et al, 1989

Influence of freeboard on watertable depth and drainage status
The relationship between freeboard and watertable depth is estimated for given site conditions using a steady state model (Youngs et al, 1989). The model is used to estimate watertable depth in the benefit area associated with the floodplain topography, soil hydraulic conductivity and freeboard.

The watertable depth determines the drainage status of the land. Drainage status of the benefit area is classed as good (G, drainage does not impose restrictions on land use), bad (B, moderate restrictions on land use) or very bad (VB, drainage imposes severe limitations on land use) respectively according to watertable depth (Dunderdale and Morris, 1996a).

Flooding
Flood costs are identified for the benefit area, based on land use, flood return period and area inundated. These flood costs are weighted by the percentage area of each LUT inundated to provide an average total flood cost for the benefit area.

Maintenance benefits
The flood costs are subtracted from the net return to provide a measure of the benefit of maintenance under the current regime.

2.7.4 Maintenance regime

The maintenance regime influences the impact of maintenance and the level of benefits obtained. The impact of maintenance on channel width, depth and the percentage channel vegetation cover that is to be removed is identified. Morphological modelling (Fisher, 1995) has produced routines which allow these data to be used to determine the impact of maintenance on freeboard and channel capacity. The percentage change in width, depth or vegetation cover removed are related to a percentage change in bankfull discharge and freeboard (Table 2.8).

If a detailed assessment is required, the equation $y = a + bx$ may be used to determine the relationship between the type of maintenance and its impact on bankfull discharge and freeboard. The a and b values are presented in Table 2.9. The parameter x is the percentage widening, deepening or vegetation cover removed and y is the impact of maintenance in terms of changes in bankfull discharge and freeboard. This detailed approach is illustrated by the example shown in Box 2.1.

Table 2.8 Impact of maintenance on bankfull discharge and freeboard

% Deepened	% Change in Bankfull Discharge	% Change in Freeboard	*% Widened*	% Change in Bankfull Discharge	% Change in Freeboard
Silt / clay bed channel					
5	5	2.5	5	2	1
10	9	4.5	10	4	2
20	15	7.6	50	18	9
25	17	8			
40	29.5	15			
Sand bed channel					
5	5.5	2	5	2.5	1
10	10	5	10	4.5	2
20	17.5	8	50	19	11
25	20	11			
40	25	17.5			

% Vegetation Cover Removed	% Change in Bankfull Discharge	% Change in Freeboard
Sand bed channel:	**Original vegetation cover 10%**	
40	2	1
60	2	1
80	3	1
100	3	2
Sand bed channel:	**Original vegetation cover 30%**	
40	5	3
60	7	4
80	10	5
100	12	6
Sand bed channel:	**Original vegetation cover 50%**	
40	8	5
60	13	7
80	17.5	9
100	22	11
Silt bed channel:	**Original vegetation cover 20%**	
40	15	5
60	23	7
80	30	9
100	37	11
Silt bed channel:	**Original vegetation cover 50%**	
40	19	6
60	28	9
80	37	11
100	42.5	13
Silt bed channel:	**Original vegetation cover 80%**	
40	17	6
60	25	9
80	30	11
100	33	13

Source: Dunderdale and Morris, 1996b, after Fisher 1995

Table 2.9 Impact of maintenance on bankfull discharge and freeboard, detailed information

Silt / Clay Bed Channel Maintenance Type	Change in Bankfull Discharge a	Change in Bankfull Discharge b	Change in Freeboard a	Change in Freeboard b
Deepen	1.50	0.68	0.65	0.34
Widen	0.34	0.35	0.17	0.18
Vegetation cutting				
Original vegetation cover 20%	0.70	0.37	1.00	0.10
Original vegetation cover 50%	3.80	0.39	1.70	0.12
Original vegetation cover 80%	7.70	0.27	1.70	0.12

Source: Dunderdale and Morris, 1996b, after Fisher 1995

Box 2.1 Impact of maintenance: detailed assessment, worked example

Example	
Question:	What is the impact on <u>freeboard</u> of deepening a <u>clay</u> bed channel by <u>15%</u> ?
Step 1	Select the appropriate a and b coefficients from Table 2.9.
Step 2	Substitute these coefficients into the equation: $y = a + bx$ $y = 0.65 + 0.34 \times 15$ $y = 5.75$
Answer	The increase in freeboard as a result of maintenance is 5.75%

2.7.5 Do nothing (without maintenance)

The changes in channel width, depth and freeboard as a consequence of maintenance are used to determine the watertable depth in the absence of maintenance. Using a steady state model for a rising or flat floodplain (Figure 2.6, Youngs et al, 1989), the watertable which would prevail in the absence of maintenance is identified and the drainage status of the floodplain associated with this watertable depth determined.

Flooding

The change in bankfull discharge, due to maintenance, is used to determine the bankfull discharge in the absence of maintenance and therefore the flood return period which would prevail in the without maintenance situation.

Flood costs are again calculated according to flood return period, floodplain topography, drainage status and land use.

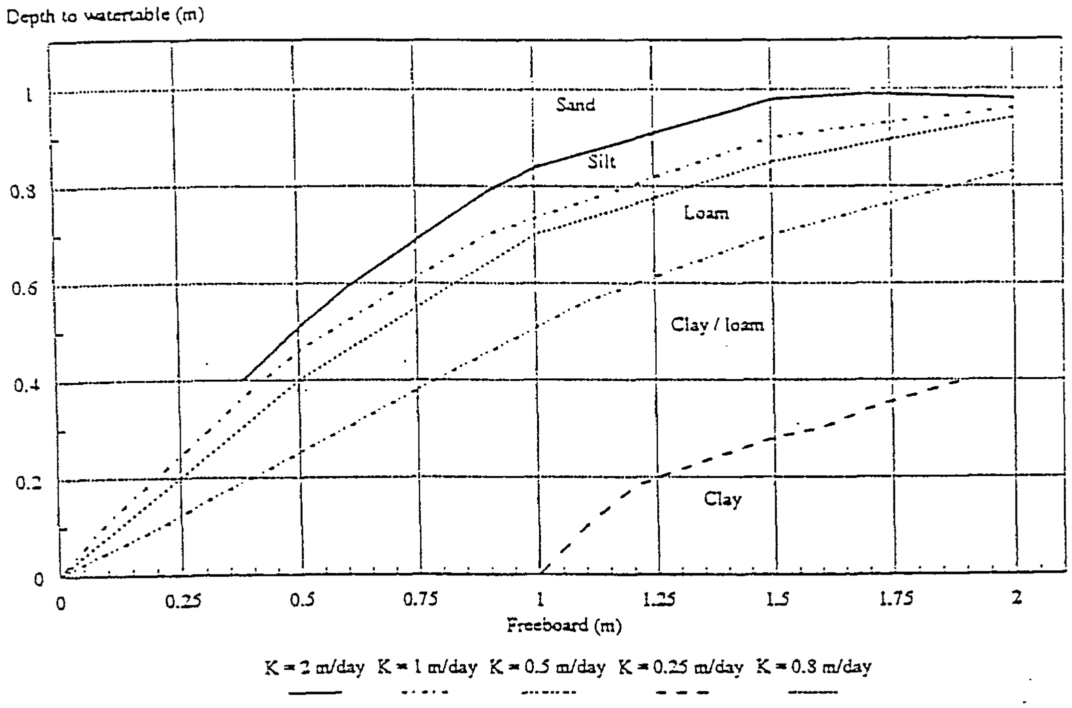
Maintenance benefits

The total flood costs are subtracted from the net return to provide a measure of the 'without maintenance' value of the benefit area if the current maintenance regime were not carried out.

2.7.6 Scheme justification

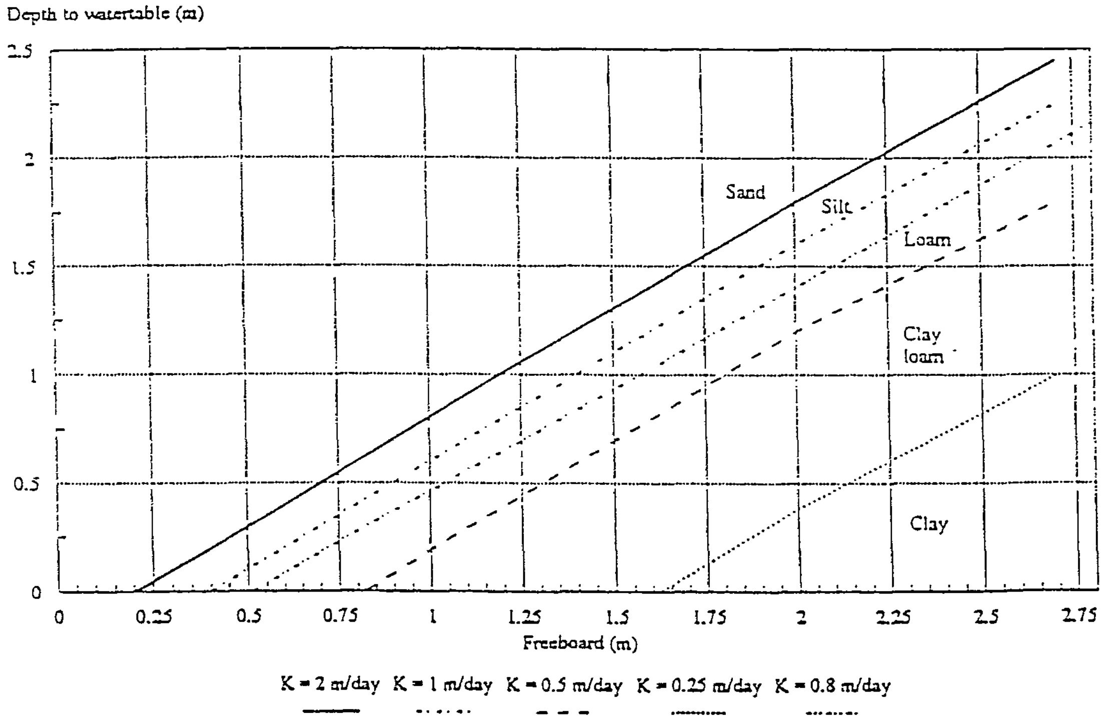
In general terms, maintenance works are justified if the associated benefits exceed costs by a sufficient margin. Because maintenance is usually a frequent, predominantly annual task which for the most part involves annual costs and benefits, it is appropriate to express these for a typical single year. The extra benefits 'with' maintenance comprise the average annual value of the avoidance of loss in income or damage to asset values if maintenance is not carried out, that is 'without' maintenance. The extra costs of maintenance are those associated with doing the works, expressed as equivalent annual costs. These comprise the cost of annual activities such as weed cutting, plus the cost of non-annual activities such as dredging amortised over the relevant period to give an annual cost.

Rising Floodplain (> 1 % slope)



Flat Floodplain (< 1 % slope)

(Coastal, ditch control or IDB/IDD area)



Source: Youngs et al, 1989

Figure 2.6 Freeboard : watertable relationship

2.8 Study Rationale

This Chapter has identified the main issues surrounding river maintenance and summarised methods for appraisal of the maintenance function. Changing circumstances have placed greater emphasis on the need for objective methods for assessing the value and design of appropriate river maintenance programmes. FDMM has been developed by the Environment Agency for the appraisal of all maintenance projects with a value of less than £500 000.

Given the commitment of the Environment Agency to FDMM, the need has arisen to validate its performance and test its applicability to a variety of site specific circumstances. In particular circumstances, the agricultural component of FDMM may be supported by the Guidelines.

The following Chapter describes the methodology through which FDMM and the Guidelines are compared and evaluated with respect to agricultural benefit:cost assessment.

3. METHODOLOGY

3.1 Introduction

The methodology through which FDMM and the Guidelines are evaluated and compared with respect to benefit:cost assessment in agricultural areas, is presented in this Chapter.

3.2 Performance Assessment Criteria

The Guidelines and FDMM have a similar methodological framework but differ in degrees of detail. To enable a comparative evaluation of FDMM and the Guidelines, criteria against which the systems may be assessed have been defined. These criteria were drawn up in collaboration with officers from the North East and Welsh regions of the Environment Agency. The criteria encompass three fundamental aspects, namely:

Operation of the system
- data required
- availability of data
- the need to acquire specific data to enable use of the system

Maintenance of the system
- data to be updated
- need for updating
- dependency

Time, costs and training
- system installation
- updating the system
- system maintenance
- training
- manuals required
- data collection
- skill/knowledge required by user

3.3 Channel Classification

To ensure that FDMM was applied to a range of watercourses which were broadly representative of the types found within England and Wales, a simple river classification system was developed. This system classifies watercourses according to channel, floodplain and catchment character, land use and maintenance practice. The parameters selected were: dominant substrate; channel bed width; floodplain topography, catchment size; land use; and, maintenance practices.

3.3.1 Dominant substrate

Dominant channel substrates were classified as gravel, sand, silt or clay, according to particle size. Particles of diameter 2-60 mm are classed as gravel, sand particles are 0.06-2 mm in diameter, silts are 0.002-0.06 mm in diameter and clay 0.002 mm in diameter (British Standards Classification of particle size). Substrate influences the type of maintenance required and the longevity of its impacts.

In watercourses with a gravel substrate, the mobile nature of the bed makes it difficult for aquatic vegetation to gain a root hold and to colonise the channel sediments. The need for widening, deepening and vegetation removal may thus be limited and consequently the impacts of maintenance are short lived. For this reason, gravel substrates were excluded from this classification system.

3.3.2 Channel width

Channel width is a critical indicator of channel size and may constrain the options for river maintenance. For example, it is likely to be inappropriate to leave a substantial fringe of emergent vegetation un-cut on a channel 2 m in width due to the significant reduction in channel capacity which would result, therefore 100% of the channel vegetation may have to be removed. In a channel 10 m wide, however, this may be acceptable as flow and channel capacity would not be impeded to such a degree.

Four channel width bands were identified: <2 m, 2-5 m, 5-10 m and >10 m. These width bands encompass the range of channel sizes on which maintenance is performed in England and Wales (Ward, Holmes, Andrews, Gowing and Kirby, 1996).

3.3.3 Floodplain topography

Floodplains are classed as rising (>1%) or flat (<1%), according to their slope (Dunderdale and Morris, 1996a). Floodplain topography influences land drainage and hence the benefits of maintenance.

3.3.4 Catchment size

As discussed in Section 2.7.2, catchment size affects the seasonal distribution of flooding. Large catchments experience predominantly winter flooding whereas smaller catchments contain a relatively higher incidence of summer floods. This seasonal distribution of flooding influences flood costs.

3.3.5 Land use

Maintenance benefits vary according to the type and intensity of land use affected. Land use was divided into four main types, namely: extensive pasture; intensive pasture; extensive arable; and, intensive arable.

Extensive pasture is characterised by poorly drained grass which provides rough grazing for sheep and heavy cattle. Nettles, rushes and weeds are usually present. Intensive pasture is usually well drained with an even sward which is managed. There may be evidence of reseeding and silage cutting. An all cereal or cereal and oilseed rotation are classed as extensive arable land use. Intensive arable land consists of a rotation containing root crops.

3.3.6 Maintenance activities

Channel and bank maintenance activities were classified into five broad types, namely: weed cutting; grass cutting; dredging/desilting; tree and bush work; and, vermin control.

3.4 Site Selection

The channel classification system presented in the previous section provided criteria which were used in the identification of the case study watercourses. Watercourses with different substrates and bed widths, with rising and flat floodplains in large and small catchments were selected. Land use encompassed the four types and each of the five major maintenance activities were featured. The main characteristics of each watercourse are summarised in Figure 3.1.

In order to enable the evaluation of FDMM under different circumstances, a highland carrier and pumped system were selected. Watercourses which have Internal Drainage Board (IDB) or Internal Drainage District (IDD) watercourse as tributaries also featured in the case studies.

Three watercourses were selected within the North East region of the Environment Agency. This region was targeted due to the fact that the North East piloted FDMM and therefore some essential data were available. Environment Agency personnel within the Welsh region expressed concern that FDMM may not be applicable to many watercourses in the region due to their characteristics and the high incidence of IDD channels. For this reason, three sites were also selected within the Welsh region. A summary of each site is presented in Chapter 4 Section 4.3. Full details on each site are presented in the Appendices.

Watercourse	KELWELL STREAM	WATTON BECK	WINESTEAD DRAIN	FFOS FAWR	ABBEY VIEW AD	FFYNNON-Y-DDOL & tributaries
Watercourse type	**Lowland**	**Highland Carrier**	**Pumped System**	**Lowland**	**Lowland**	**Lowland**
Dominant substrate						
Sand						
Silt				X	X	
Clay	X	X	X			X
Channel bed width						
< 2 m	X			X	X	X
2-5 m		X				X
5-10 m			X			
Floodplain slope						
Rising > 1 %	X	X				
Flat < 1 %			X	X	X	X
Catchment size						
Large (> 2500 ha)		X	X			
Small (< 2500 ha)	X			X	X	X
Land Use						
Extensive pasture		X		X	X	X
Intensive pasture	X					X
Extensive arable	X	X	X			X
Intensive arable		X				
Maintenance						
Weed cutting	X	X	X	X	X	X
Grass cutting	X	X	X			
Dredging/desilting	X	X	X			
Tree and bush work		X				
Vermin control	X	X				

Figure 3.1 Summary of the characteristics of the case study watercourses

3.5 Data Collection

Within the North East region, some data required by FDMM were collected by RUST Environmental Consultants on behalf of the Environment Agency. Within the Welsh region, WS Atkins undertook a similar task. These data were collected on a reach specific basis. Unfortunately these data could not be used for *the purpose of this study* for the reasons listed here:

- reaches of different delineation were required;
- some of the required data were absent;
- data were found to be of insufficient detail;
- interpretation of the data was unclear; or,
- data were found to be incorrect.

The majority of the required data were therefore collected by Silsoe College through discussions with the Environment Agency, IDB and IDD personnel and farmers and from records held by the Environment Agency. A visual survey of each watercourse was also undertaken.

Data collected by Silsoe College related to:

- channel parameters, floodplain topography and catchment characteristics;
- flood risk and drainage benefit areas and associated land use;
- flood return periods and associated flooded areas;
- drainage status; and,
- maintenance expenditure.

3.6 System Application

FDMM was applied to the watercourses identified in Section 3.4 to demonstrate its application. Analysis was undertaken to determine the sensitivity of FDMM to parameters such as effective reach length, drainage benefit area and maintenance expenditure. The impacts of including and excluding IDB and IDD watercourses, embanked sections and a highland carrier were also assessed.

The Guidelines were applied to the same watercourses using the same data as FDMM. Analysis was also undertaken to determine the sensitivity of the Guidelines to the assumptions made.

In order to enable a direct comparison between results obtained from FDMM and the Guidelines, which assess agricultural benefits only, the urban benefits were added to the Guidelines. The results of both systems were then compared and evaluated.

3.7 Suggested Modifications

Following the application and evaluation of the two systems, suggestions for modifications to FDMM and the Guidelines have been made. These relate to

- modifications to FDMM to address site specific circumstances and peculiarities;
- guidance in the use of FDMM and in particular in the use of the adjustment factors;
- provision of information and clarification as to the derivation of adjustment factors;
- guidance in the use of the Guidelines;
- provision of additional explanation and clarification of terminology; and,
- the presentation of FDMM and the Guidelines and correction of errors.

Guidance has been provided as to the interpretation of the use of FDMM and the Guidelines with particular respect to area circumstance and wider lessons which may be applied elsewhere. Ways in which the Guidelines can be used to support, and where relevant, extend the agricultural component of the FDMM methodology have been presented.

3.8 Summary

The methodology followed has been presented in this Chapter. Results of the study are presented and interpreted in the following Chapter.

4. RESULTS

4.1 Introduction

FDMM and the Guidelines are compared in this Chapter. A summary of the results from the application of FDMM and the Guidelines to the six case study watercourses is also presented. Differences in results obtained through using FDMM and the Guidelines are explained. Full details and the completed record sheets are presented in the Appendices. Each watercourse is the subject of a separate Appendix.

4.2 Comparison of FDMM and the Guidelines

A comparative analysis of the agricultural component of FDMM and the Guidelines has been undertaken. Box 4.1 summarises the data required by FDMM and the Guidelines; maintenance of the system; the need for and frequency of updating data; the dependency of the systems on these data; and, the time and costs involved and training required to enable efficient use of the systems.

The two systems are similar in their methodological framework in that they both calculate benefits of flood alleviation and drainage in agricultural areas. The differences lie in the degrees of detail and in some data which are required.

One major difference between the two systems is in the definition of the benefit area. FDMM identifies a flood risk area and within it a separate drainage benefit area for each bank. The Guidelines, however, identify an area of drainage influence which includes the area subject to flood risk. No distinction is made between the left and right bank.

The majority of data required by the Guidelines are also required by FDMM. Additional data which are required by the Guidelines relate mainly to general channel and catchment characteristics such as substrate, and catchment size.

Box 4.1 Comparative analysis of FDMM and the Guidelines

OPERATION	FDMM	GUIDELINES
Data required		
Reach length (km)	Total length of study watercourse allocated to each bank.	Total length of study watercourse.
Flood risk area (ha)	Maximum known flooding extent or area protected by existing flood defence scheme.	*This term is not used*
Benefit area (ha)	*This term is not used*	Area affected by impact of maintenance on flooding and land drainage. (Taken to be same as FDMM flood risk area)
Effective reach length flooding (km)	Length of main channel for which flood risk area is defined (km).	*This term is not used*
Land use (ha)	Agricultural land use	Agricultural land use
Flood return periods (years)	Return periods of events at which particular land use interests are affected by flooding.	Return periods of events at which particular land use interests are affected by flooding.
Flooding	For previous 5 yrs, date of onset, duration (days), nature (fluvial/saline), area (ha), land use features affected.	% of each land use type that floods under the various specified flood return periods

Drainage benefit area (ha)	Area known to be subject to or liable to drainage problems (ha).	Same as benefit area.
Soil type	Heavy or light.	Sand, silt, loam, clay.
Drainage system	Natural, piped, limited or developed ditch system.	Natural, piped.
Floodplain topography	Rising (> 0.5 %), flat (< 0.5 %).	Rising (> 1%), flat (< 1%).
Dominant water level	Dominant water level.	*This term is not used*
Drainage status	Good, bad or very bad.	Good, bad or very bad.
Actual freeboard (m)	Actual freeboard at times of dominant discharge.	Average freeboard under mean spring flow conditions (m).
Effective reach length drainage (km)	Length of the reach within the drainage benefit area.	*This term is not used*
Deterioration in drainage	Drainage status which would prevail in absence of maintenance.	Drainage status which would prevail in absence of maintenance.
Maintenance costs (£/yr)	Total annual maintenance costs for the total length of watercourse under consideration.	Total annual maintenance costs for the total length of watercourse under consideration.
Substrate	*This term is not used*	Dominant substrate in channel.
Catchment size	*This term is not used*	Large (>2500 ha), small (<2500 ha).
Channel parameters (m)	*This term is not used*	Average bed width and channel depth.
Vegetation cover	*This term is not used*	% cover of submerged/floating vegetation immediately prior to maintenance.
Discharge (cumecs)	*This term is not used*	Bankfull discharge, representative of the channel.
Flooding (cumecs)	*This term is not used*	Mean annual flood.
Maintenance regime (m, %)	*This term is not used*	Change in bed width and depth due to maintenance.
Vegetation	*This term is not used*	% cover of submerged/floating vegetation removed.
Benefits	Benefits related to: flood relief and drainage.	Benefits related to: flood relief and drainage.
MAINTENANCE OF SYSTEM		
Data to be updated and frequency		
Value of one HE (£)	Updated annually.	*HEs are not used*
HE/unit	Currently at 1991 base. Updated every 4 - 5 yrs or more frequently according to circumstances.	*This term is not used*
Agricultural financial and economic data	Currently at 1993 base. Update annually.	Currently at 1997/98 base. Update annually.
Average annual cost of a single flood	Currently at 1993 base. Update annually.	Flood costs according to land use, drainage, catchment size and flood return period. Currently at 1997/98 base. Update annually.
HE depth damage data	Currently at 1993 base. Update annually.	*This term is not used*
Need for updating	It is not necessary to update all the databases annually, providing that all the monetary databases are kept at the same year base. Maintenance costs would need to be adjusted to reflect the same year base.	
Dependency	FDMM and the Guidelines are totally dependent on these databases.	

TIME, COSTS AND TRAINING		
System installation	The installation and set up costs are minimal and relate to the cost of copying and distribution of the FDMM/Guidelines and ensuring an adequate supply of record sheets for use by the users.	
Updating the system	Initially, it may take considerable time to update all the data in FDMM. However, once the procedures have been set up, updating in subsequent years should be a straightforward, simple process. An ongoing resource commitment is required to allow in particular, periodic validation of land use predictive flooding score and to maintain a record of flood events.	The data which require updating are minimal (agricultural financial/economic data). These data are updated annually by Silsoe College, Cranfield University using agri-economic databases and models and relevant price indices.
Training	5 day course provided by external trainer. Course covers practical and theoretical aspects of FDMM and FDMS.	2 day course is recommended. Course would cover theoretical and practical aspects using case studies.
System maintenance	System maintenance is minimal for the user. Updated information is circulated on sheets which are filed at the front of the FDMM and a record sheet completed to show the originator of amendment, amendment date and the name of the person who incorporated the amendment into FDMM.	Maintenance takes the form of inserting amendment sheets in the Guidelines.
Manuals required	FDMM and 2 supplementary documents: Managing Flood Defences: Summary Guidance for the FDMM and Managing Flood Defences: Supplement to the Summary Guidance for the FDMM.	A copy of the Guidelines is required (R&D Note 511). R&D Note 456 contains supporting information but is not necessary to be able to use the Guidelines.
Data collection	Some data are already held by the Environment Agency. Data collection is time-consuming and costly.	Most of the data are already held by the Environment Agency as they are needed for FDMM. Some basic data, however, are not always documented, for example, catchment size or bankfull discharge.
	Once these basic data are collected, however, the need for further data collection will be minimal and will relate for example to the regular monitoring of flooded areas and freeboards. Other data such as land use, may be updated for example, every 5 years (unless a major change occurs when it should be updated more frequently).	
Skill/knowledge required by user	A general knowledge of cost:benefit concepts, a basic understanding of drainage, an appreciation of links between maintenance, drainage, land use, productivity and related costs and benefits is required. The greater this knowledge and the greater the awareness of the watercourse, the more straightforward the application.	

4.3 Site Summary

Through collaboration with the Environment Agency, six watercourses were selected as case studies. The classification system identified in Chapter 3 was used to ensure that a range of channel types were selected in order to reflect a wide range of circumstances. A summary of each case study site is presented in the following sections. Full details are presented in the Appendices.

4.3.1 Kelwell Stream

Kelwell Stream and its feeder streams North Kelwell and South Kelwell rise near Old Ellerby approximately 4 km north east of Kingston upon Hull. The study reach extends from the upstream limit of main river on North Kelwell (GR. TA 51543 43729) and South Kelwell (GR. TA 51560 43680) to the confluence of Kelwell Stream with Foredyke Stream (GR. TA 51145 43730). A map showing the study area and watercourse system is presented in Appendix I. A schematic map is shown in Figure 4.1.

The catchment area of Kelwell Stream, North Kelwell and South Kelwell (Kelwell System), is estimated to be 16.7 km^2 (1670 ha) and is intensively drained both through field drains and the natural ditch system. The Environment Agency 'main' river total reach length is 5.2 km. The Beverly and Holderness IDB also maintain two watercourses within the catchment, with a total reach length of 1.1 km. These discharge into Kelwell Stream. Kelwell Stream and its tributaries discharge under gravity into Foredyke Stream and then into the Holderness Drain and finally into the River Humber through two sets of doors.

The Kelwell System is subject to annual weedcutting. The embankments are flail mown and subject to vermin control. The channel is subject to dredging approximately every 10 years during which approximately 0.15 m of silt is removed. Total annual maintenance costs for Kelwell Stream, including the embanked section, North Kelwell and South Kelwell are estimated to be £5300 (1997/98 prices).

The IDB channels are also subject to annual weedcutting. Tree and bush maintenance is carried out as required and dredging of the channel takes place on average every 10 years. Approximately 0.2 m of silt is removed. Total annual maintenance cost for 1997/98 are estimated to be £550.

4.3.2 Watton Beck

Watton Beck is a spring fed river which rises in the chalk wolds to the East of Middleton-on-the-Wolds approximately 16 km north of Kingston upon Hull. The catchment area of Watton Beck, is estimated to be 27 km^2 (2700 ha). The area downstream of the spring line is estimated to cover 13.75 km^2 (1375 ha). It is this intensively drained area; both through field drains and the natural ditch system, which benefits from maintenance.

The Environment Agency 'main' river total reach length is 4.5 km. Above main river there is a Beverly and Holderness IDB watercourse of approximately 2.9 km in length.. The study reach extends from the upstream limit of the main river (GR. TA 502860 449490) to the confluence of Watton Beck with the River Hull (GR. TA 506380 447300). Two other IDB watercourses discharge into Watton Beck on the right bank. A map showing the study area and watercourse system is presented in Appendix IV. A schematic map is shown in Figure 4.1.

Watton Beck discharges under gravity into the tidal River Hull on its upper reach through two flapped outfalls. The River Hull flows out into the River Humber estuary.

Watton Beck is embanked for a length of approximately 2.5 km upstream from the confluence with the River Hull and is described as a highland carrier. This section of Watton Beck does not provide a drainage function for the lowland area over which it flows. This lowland area is served by a network of IDB drains which run broadly parallel to Watton Beck and discharge into the Beverly and Barmstron Drain which is pumped into the River Hull at Wifholme Landing.

Watton Beck is subject to weedcutting twice a year and the banks are flail mown three times a year. Vermin which inhabit the embankment are controlled. The channel is subject to dredging approximately once every 10 years. A depth of approximately 0.15 m of silt is removed. Total annual maintenance expenditure by the Environment Agency on Watton Beck, including the highland carrier section, is estimated to be £6590 (1997/98 prices).

The IDB channels are also subject to annual weedcutting. Tree and bush maintenance is carried out as required. Desilting of the channel takes place on average every 10 years during which approximately 0.2 m of silt is removed. Total annual maintenance expenditure on the IDB watercourses is estimated to be £167 (1997/98 prices).

4.3.3 Winestead Drain

Winestead Drain rises to the east of Withernsea, approximately 17 km east of Kingston upon Hull. The catchment area of Winestead Drain is estimated to be 54 km^2 (5400 ha). This lowland catchment is intensively drained both through field drains and the natural ditch system.

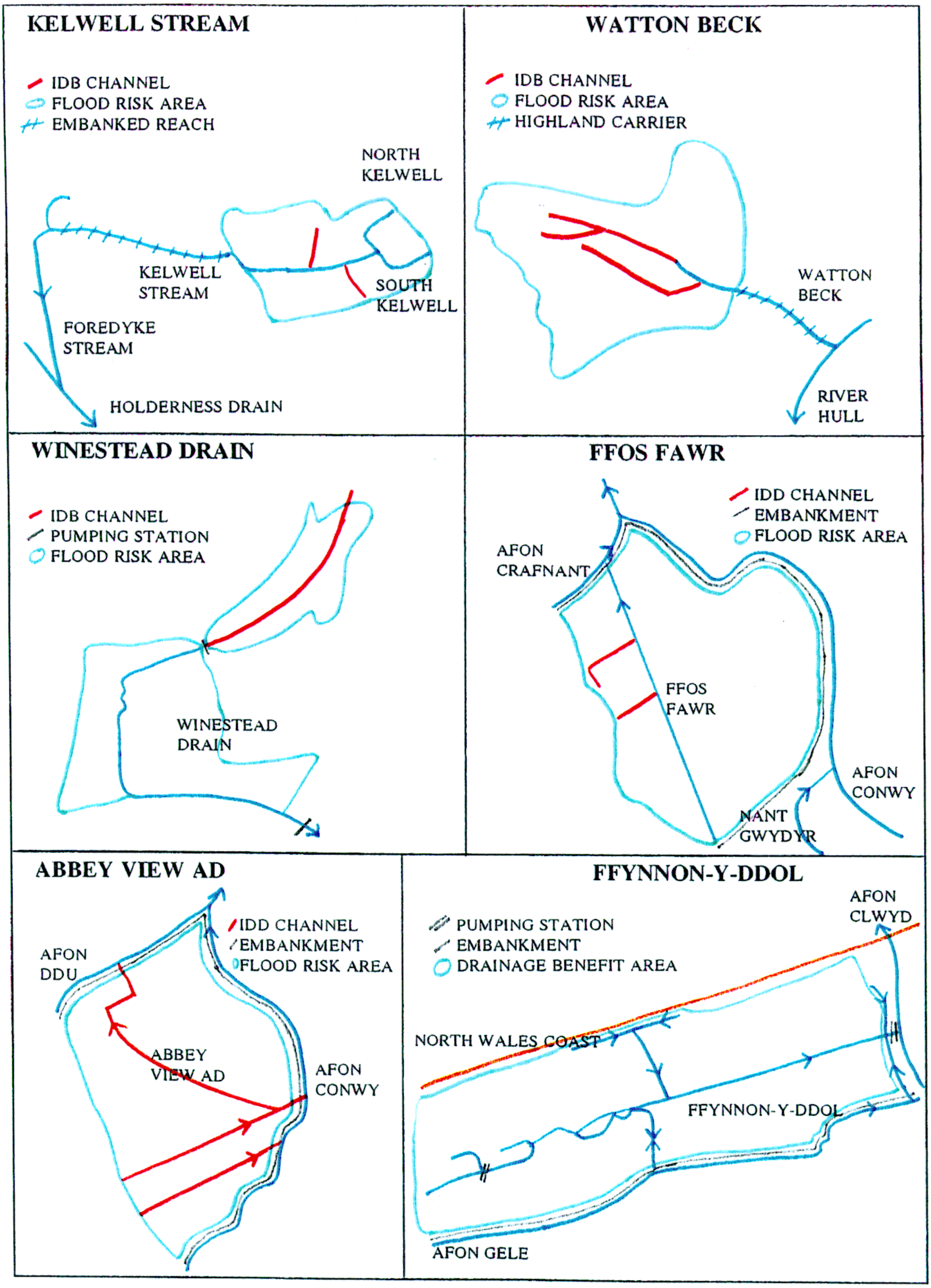
The Environment Agency 'main' river reach length is 7.3 km. Above main river is an IDB watercourse of approximately 6.1 km in length. Two pumping stations control water levels in the main river and IDB watercourse, both owned and operated by the Environment Agency. The Booster Pumping Station at the head of main river (GR. TA 530050 423400) pumps land drainage water from the IDB watercourse up into the main river which is at a higher level. The Outstrays Pumping Station provides the outfall of Winestead Drain into the estuary of the River Humber.

The study reach extends from the upstream limit of the main river to the pumped outfall of Winestead Drain into the Humber Estuary at Outstrays Pumping Station (TA 533500 418495). A map showing the study area and watercourse system is presented in Appendix V. A schematic map is shown in Figure 4.1.

Winestead Drain is subject to annual weedcutting twice a year. The banks are also flail mown twice a year. The channel has been subject to dredging approximately once every 10 years. A depth of between 0.15 and 0.3 m of silt is removed to reach hard bed level.

Total annual maintenance expenditure by the Environment Agency on Winestead Drain is estimated to be £42939 (1997/98 prices). This includes a charge for maintenance of the pumps and electricity running costs. No allowance is made for the annual depreciation of the initial capital costs. The benefits identified are therefore the returns associated with continuing maintenance only. Channel maintenance costs are £6075 (1997/98 prices).

The IDB channel is subject to annual weedcutting. Dredging of the channel takes place on average every 10 years to remove 0.3-0.6 m of silt. Total annual maintenance expenditure on the IDB watercourse is estimated to be £3433 (1997/98 prices).



Note: Detailed maps are presented in the Appendices

Figure 4.1 Schematic maps of the case study watercourses showing the main features

4.3.4 Afon Conwy

The Afon Conwy rises from Llyn Conwy in the Migneint Moor, Snowdonia. The catchment area is estimated to be 590 km^2 (59000 ha).

The river is a highland carrier which conveys water from the upland catchment through the flat valley floor to the outfall into Liverpool Bay at Conwy. The Afon Conwy does not provide a land drainage function for the lowland part of the catchment through which it flows. This lowland area protected from flooding by the Afon Conwy by flood banks. It is served by an intensive network of channels and is designated as an IDD which is run and managed by the Environment Agency. In affect, these IDD watercourses are 'main' rivers in all but name. Many of the IDD watercourses discharge into the Afon Conwy through the floodbanks via flapped outfalls.

Two discrete areas of the Conwy floodplain were selected for study following discussions with the Environment Agency, namely: the Ffos Fawr and the Abbey View AD.

Ffos Fawr

The area served by the Ffos Fawr covers 154 ha on the left bank of the Afon Conwy, to the east of Trefriw. This area is bounded on three sides by the floodbanks of the Afon Conwy, Nant Gwydyr and Afon Crafnant. The western boundary follows the natural limit of the floodplain which is determined by geology and topography. A map showing the Ffos Fawr study area and watercourse system is presented in Appendix VI. A schematic map is shown in Figure 4.1.

The Ffos Fawr drains this area and is fed by two IDD watercourses; the Ffos Fawr AD Number 1 and 2. The Ffos Fawr discharges into the Afon Crafnant through the floodbank and into the Afon Conwy. The whole area is naturally drained by an intensive network of ditches.

The Ffos Fawr and Ffos Fawr AD Number 1 and 2 are all subject to annual weedcutting. Annual maintenance expenditure on the Ffos Fawr main river is calculated to be £1428 (1997/98 prices). Annual expenditure on AD Number 1 and 2 is calculated to be £294 and £380 respectively (1997/98 prices).

Abbey View AD

The area served by the Abbey View AD lies on the left bank of the Afon Conwy, to the south of Dolgarrog. The floodbanks of the Afon Conwy and Afon Ddu form the boundaries of the area to the north, east and south. The B5106 road forms the western boundary. A map showing the Abbey View AD study area and watercourse system is presented in Appendix VII. A schematic map is shown in Figure 4.1.

The Abbey View AD discharges through the floodbank into the Afon Ddu via a flapped outfall. Dolgarrog AD Number 5 drains the northern area and also discharges into the Afon Ddu. Two adopted ditches (Cae Coch AD Number 1 and 2) flow over the southern end of the study area and discharge into the Afon Conwy via flapped outfalls in the floodbank. An intensive network of field ditches drain the area.

Abbey View AD and Dolgarrog AD Number 5 are subject to annual weedcutting. In 1997/98 prices, annual maintenance expenditure is estimated to be £763.

4.3.5 Vale of Clwyd

The Afon Clwyd rises in the peaty uplands of the Clocaenog forest to the south west of Ruthin. It flows northwards through the Vale of Clwyd and discharges into Liverpool Bay at Rhyl. The Vale of Clwyd is drained by numerous tributaries of the Afon Clwyd and a comprehensive network of drainage ditches.

The channel of the Afon Clwyd is not subject to regular maintenance. Some tributaries are, however, subject to annual weedcutting.

Ffynnon-y-ddol
The Ffynnon-y-ddol and its tributaries have been selected for study. A map showing the location of the Ffynnon-y-ddol and its tributaries is presented in Appendix VIII. A schematic map is shown in Figure 4.1. The Ffynnon-y-ddol is 5.69 km in length, a tributary of the Afon Clwyd and runs broadly parallel to the coast of North Wales. It discharges into the Afon Clwyd via the Clwyd Pumping Station. The tributaries all discharge under gravity into the Ffynnon-y-ddol with the exception of the Pensarn Drain which is pumped into the Ffynnon-y-ddol via the Belgrano Pumping Station.

The catchment of the Ffynnon-y-ddol is bounded to the east and north by the Afon Clywd and the North Wales coast respectively. The embankment on the left bank of the Afon Gele forms the southern and western boundary to the Ffynnon-y-ddol catchment.

The Ffynnon-y-ddol is culverted through the southern area of Towyn. The main river branches into three: Ffynnon-y-ddol Dyke Farm, Ffynnon-y-ddol Gors Branch and Ffynnon-y-ddol Kinmel Way. These provide alternative routes for the Ffynnon-y-ddol should one culvert become blocked. In an emergency, if levels in the Ffynnon-y-ddol are dangerously high and providing there is sufficient capacity in the Afon Gele, the flap valves may be opened in the bank of the Afon Gele to allow the Gors Branch leg of the Ffynnon-y-ddol to discharge into it.

Three watercourses; Towyn Splashover Drain, Towyn Splashover East and Towyn Splashover West, serve the north of Towyn. Their purpose is to remove surface runoff and to provide a route for sea water should a breach of the sea defences occur.

4.4 Results from the Application of FDMM

4.4.1 Area of benefit and effective reach length

The areas benefiting from maintenance in terms of flood alleviation were derived through discussions with the Environment Agency and IDB/IDDs and field observations. Maps showing the highest known flood event and drainage board boundaries were utilised in this process. In the Welsh region, benefit areas were based on the discrete areas protected by flood banks.

Table 4.1 shows the flood risk areas and associated effective reach length for each case study watercourse. The effective reach length is the length of main river for which a flood risk area is defined. The Ffynnon-y-ddol and its tributaries are not subject to flooding. Channels have been designed to contain flood flows with a return period of over 100 years, hence no flood risk areas are defined. Assessment in thus based purely on drainage benefits.

Table 4.1 Flood risk area and effective reach length by watercourse

	Flood Risk Area (ha)		Effective Reach Length (km)	
Watercourse	Left Bank	Right Bank	Left Bank	Right Bank
Kelwell Stream	72	104	2.7	2.9
Watton Beck	210	250	1.0	1.0
Winestead Drain	460	269	7.3	7.3
Ffos Fawr	38	116	2.1	2.1
Abbey View AD	42	48	1.1	1.1
Ffynnon-y-ddol and tributaries	0	0	0	0

Note: Figures are subject to rounding. Figures are taken from Section 4.3 and the Appendices.

4.4.2 Land use assessment

Flooding and drainage

Land use features of interest within the flood risk area were identified and recorded using the land use assessment sheets contained within FDMM Loose Material A. Table 4.2 shows the total number of HEs affected by flooding and the flood score (HE/effective reach length) for each watercourse.

Table 4.2 House Equivalents affected by flooding and flood score by watercourse

	Total No. HEs affected by Flooding		Flood Score (HE/km) *	
Watercourse	Left Bank	Right Bank	Left Bank	Right Bank
Kelwell Stream	8.25	17.18	3.06	5.92
Watton Beck	110.87	128.85	110.87	128.85
Winestead Drain	190.91	20.64	26.15	2.83
Ffos Fawr	37.78	10.81	18.1	5.17
Abbey View AD	6.79	0.63	6.23	0.58
Ffynnon-y-ddol and tributaries	0.0	0.0	0.0	0.0

Note: Figures are subject to rounding. Figures are taken from the Land Use Assessment Reach Summary Sheets in the Appendices. * HE divided by the effective reach length.

The area within the flood risk area which is subject to inadequate drainage is termed the drainage benefit area. Due to the absence of documentation, the drainage benefit areas were estimated by the Environment Agency, based on knowledge of the drainage network, soil type, land use and site observations.

Under the current maintenance regime, the drainage status of the whole flood risk area for each watercourse, with the exception of the Ffynnon-y-ddol, is classed as good. Approximately 82% of the drainage benefit area of the Ffynnon-y-ddol experiences bad drainage.

According to the procedure defined in FDMM (p3/21), the area of each land use type subject to bad and very bad drainage has been weighted by the appropriate potential waterlogging damage factor (E.g. 1.1 for extensive pasture, FDMM p3/22) to determine the drainage score. This drainage score (HE/km/yr) represents the level of damage caused by waterlogging.

4.4.3 Actual Standard of Service

The flood and drainage scores for each bank have been combined to determine the Standard of Service provided by the current maintenance regime. This is compared with the target score of 0.5-1.0 HE/km/yr. Scores above and below this target indicate that the watercourse is under- or over-serviced respectively (see Table 2.3).

Estimates of the actual SoS provided are, however, sensitive to the effective reach length and the definition of the benefit area. According to FDMM, the effective reach length applies to the main river only and non-main river tributaries are ignored and excluded from analysis. Table 4.3 shows the combined flooding and drainage score for each watercourse, the definition of the effective reach used and the reach status.

Inclusion of IDB watercourses, highland carriers and embanked reaches within the effective reach length has an impact on the reach status (see Table 4.3) as the HEs at risk are apportioned to a longer reach thereby lowering the HE/km/yr score. The flood risk and drainage benefit areas associated with these additional reaches should be identified and the HEs at risk included in the analysis.

For example, the reach status of the Kelwell System changes from one of below target to on target if the IDB tributaries are included in the definition of effective reach length. As described in Section 2.5.4, the lower is the number of HEs/km, the higher is the reach status in terms of Standards of Service. If the embanked reach on Kelwell Stream is included in the analysis of effective reach length, the reach status appears to be above target. This may be misleading, however, as in the analysis presented here, no benefit area associated with this embanked reach has been identified (see Chapter 5 and Appendix I for further details). Similarly, if the highland carrier on Watton Beck is to be included in the calculation of effective reach length, the benefit area associated with it must also be included in the analysis in order to calculate the total HEs affected. Under the present analysis, no benefit area associated with the highland carrier has been identified. Further details on this are presented in Chapter 5 and Appendix IV.

Table 4.3 Sensitivity analysis: effective reach length and actual SoS, by watercourse

Watercourse	Combined Score (HE/km/yr) * (Average of both banks)	Effective Reach	Reach Status
Kelwell System	1.10	Main river only	BTS
	0.79	Main river + IDB tributaries	OTS
	0.49	Main river + IDB tributaries + embanked section	ATS
Watton Beck	22.30	Main river only	BTS
	5.72	Main river + IDB tributaries	BTS
	6.38	Main river + highland carrier	BTS
	2.52	Main river + IDB tributaries + highland carrier	BTS
Winestead Drain	2.80	Main river only	BTS
	1.60	Main river + IDB watercourse	BTS
Ffos Fawr	0.50	Main river only	OTS
	0.22	Main river + IDD tributaries	ATS
Abbey View AD	0.16	Main river only	ATS
Ffynnon-y-ddol and tributaries	0.27	Main river only	ATS

Note: ATS = above target standard, OTS = on target standard, BTS = below target standard.
Figures are subject to rounding. * Figures are derived from AAN_{with} divided by the effective reach length. See Flooding record sheets in Appendices for AAN_{with}.

In comparison, analysis of the Ffos Fawr shows that the reach status is on target. In this case study, the benefit area associated with the IDD tributaries is included within that of the main river. FDMM is thus providing an accurate definition of the benefit area.

As the reach status is used to prioritise maintenance activities, any changes to the maintenance programme on the basis of the reach status alone must be undertaken cautiously, especially as the reach status does not take into account monetary benefits and costs.

4.4.4 Land use band

The flood and drainage scores (HE/km/yr) obtained through analysis of the number of HEs affected per km of main river, are combined to determine the total HE/km for each bank. This combined score is used to classify land use into one of five land use bands (Table 2.2).

Table 4.4 shows that land within the flood risk areas is predominantly classed as band 'C' or 'D'. Land within band 'C' is classed as high grade agricultural land at risk of flooding and impeded drainage with some properties also at risk. Band 'D' denotes mixed agricultural land and isolated farm buildings which are at risk. With the exception of Watton Beck, these classifications are appropriate given the land use observed within the flood risk areas.

Table 4.4 Classification of land use bands, by watercourse

	Land Use Band	
Watercourse	Left Bank	Right Bank
Kelwell Stream	D (D)	C (D)
Watton Beck	A (C)	A (C)
Winestead Drain	B	D
Ffos Fawr	C	C
Abbey View AD	C	E
Ffynnon-y-ddol and tributaries	X - No flood risk area defined	X - No flood risk area defined

Note: Figures are determined from the Land Use Assessment summary sheets in the Appendices and are based on the total HE/km. Land use band in parenthesis includes the embanked reach/highland carrier and IDB tributaries in the analysis of effective reach length.

The flood risk area of Watton Beck is predominantly rural with only a few isolated properties at risk from flooding. A classification of band 'A' which states that large urban areas are at risk of flooding is clearly incorrect. This error has arisen due to the very short effective reach length (1 km) within the flood risk area. An IDB channel upstream of main river and two IDB tributaries all derive benefit from maintenance on the main river and lie wholly within the flood risk area. The highland carrier downstream of the flood risk area provides the conduit for Watton Beck to the outfall into the River Hull. If these tributaries and highland carrier are included in the effective reach length, the land use band would be classed as 'C' for both banks. This latter classification gives a more realistic representation of the type of land use found within the flood risk area.

The land use band classification has also been revised for Kelwell Stream to include the embanked reach in the calculation of effective reach length. In this case, the land use band is classed as 'D' on both banks.

4.4.5 Effect of flooding

The effects of flooding on each site have been based purely on use of the predictive technique as historical records were not available. Using the arithmetic method, an estimated long-term average annual value for HE affected has been derived.

The areas flooded by events of different return periods were identified by the Environment Agency for each bank. These areas are, however, estimated as the actual areas flooded by events of different return periods are not documented. The number of HEs affected was determined on a pro-rata basis by multiplying the total number of HEs which would be inundated by the percentage of the flood risk area flooded. This process was repeated using estimates of the areas flooded without maintenance. Discussions with the IDB/IDDs were used to confirm these estimates.

The total number of agricultural HEs/km affected by flooding without maintenance are multiplied by 1.5 in the case of pasture and 2.2 for arable. These severity weightings are used to adjust the HEs to take account of the impact of timing and duration of flooding on the flood cost.

The annual benefit of maintenance is shown by the benefit to be gained from the avoidance of flooding. This is derived by subtracting the Annual Average Number of HEs affected with maintenance (AAN_{with}) from the Annual Average Number of HEs affected without maintenance ($AAN_{without}$) and multiplying this figure by the value of one HE (£1304 in 1997/98 prices). This procedure is shown by the following equation:

$$(AAN_{without} - AAN_{with}) \times \text{Value of one HE}$$

Table 4.5 uses Watton Beck as an example to illustrate this process. Table 4.6 shows the $AAN_{without}$, AAN_{with} and the annual benefits of flood alleviation for each watercourse. For the purpose of this analysis, the without maintenance scenario represents the base case and is an estimate of the flooding and drainage conditions which are likely to prevail if maintenance were discontinued.

Table 4.5 Average annual number of HEs affected by flooding, Watton Beck

	Left Bank			Right Bank		
	Flood Return Period (yrs)	% Area Flooded	HEs Affected	Flood Return Period (yrs)	% Area Flooded	HEs Affected
With maintenance						
	1	0	0	1	0	0
	20	30	37.94	20	30	44.79
	50	100	126.45	50	100	149.29
Annual average number HEs affected (AAN_{with})			20.48			24.18
Without maintenance						
	1	5	6.32	1	5	7.46
	20	50	63.23	20	50	74.65
	50	100	126.45	50	100	149.29
Annual average number HEs affected ($AAN_{without}$)			35.88			42.36

Annual benefit of flood alleviation
Left bank: (35.88 - 20.48) x 1304 = £20082
Right bank: (42.36 - 24.18) x 1304 = £23706
Total annual benefit of flood alleviation (both banks) £43788

Note: Figures are subject to rounding. Figures are taken from the Flooding record sheets in Appendix IV.

Table 4.6 Annual benefits of flooding, by watercourse: FDMM

Watercourse	HEs Affected by Flooding Without Maintenance ($\text{AAN}_{\text{without}}$) (a)	HEs Affected by Flooding With Maintenance (AAN_{with}) (b)	Total Annual Benefit (£) ((a-b) x 1 HE))
Kelwell Stream			
Left bank	7.22	2.21	6533
Right bank	13.26	4.06	11990
Total			**18523**
Watton Beck			
Left bank	35.88	20.48	20082
Right bank	42.36	24.18	23706
Total			**43788**
Winestead Drain			
Left bank	118.21	34.59	109040
Right bank	21.47	6.28	19808
Total			**128849**
Ffos Fawr			
Left bank	8.30	1.57	8775
Right bank	2.52	0.48	2668
Total			**11443**
Abbey View AD			
Left bank	1.54	0.29	1629
Right bank	0.21	0.04	217
Total			**1846**
Ffynnon-y-ddol	Not subject to flooding		**0**

Note: Figures are subject to rounding. 1997/98 economic prices are used.
1 HE = £1304 (1997/98 prices). Figures are taken from the Flooding record sheets in the Appendices.

In order to derive the agricultural benefits, a second Land Use Assessment reach summary sheet was completed (see the Appendices) for the agricultural areas only, and the benefits of flooding calculated accordingly using the Flooding Record sheets presented in the Appendices.

Table 4.7 uses the Winestead Drain to illustrate this procedure. The difference in benefits of flood alleviation urban/agricultural and agricultural only, provides a measure of the urban benefits. The agricultural only benefits are subtracted from the total agricultural/urban benefits to derive the agricultural only and urban only benefits associated with flood alleviation.

Using the example in Table 4.7, the agricultural benefits of flood alleviation are £48822. The combined agricultural/urban benefits are £128849. The urban benefits are therefore £80026 (£128849 - £48822).

Table 4.7 Calculation of urban benefits, example of Winestead Drain: FDMM

	$\text{AAN}_{\text{without}}$ (HE/km) (Ag. + Urban) (a)	AAN_{with} (HE/km) (Ag. + Urban) (b)	Benefit of Flood Alleviation (£) (Ag. + Urban) (a-b x £1304)=c	$\text{AAN}_{\text{without}}$ (HE/km) (Ag. Only) (d)	AAN_{with} (HE/km) (Ag. Only) (e)	Benefit of Flood Alleviation (£) (Ag. Only) (d-e x £1304)=f	Benefit of Flood Alleviation (£) (Urban Only) (c-f x £1304)
LB	118.21	34.59	109040	33.42	9.78	30827	78213
RB	21.47	6.28	19808	19.51	5.71	17995	1813
Total			128849			48822	80026

Note: Figures are subject to rounding. 1997/98 prices are used. £1304 = value of one HE in 1997/98 prices.

4.4.6 Effect of deterioration in drainage

The predictive technique was used to determine the effect of inadequate drainage on land use in the area at risk. Due to the absence of recorded data and historical records, the historical technique could not be applied.

The drainage status of the drainage benefit area is predicted to deteriorate by one class in the absence of maintenance on Kelwell Stream, Watton Beck and Winestead Drain. This prediction is based on analysis of the watercourse, drainage system and topography.

The predicted deterioration in drainage status for the Ffos Fawr and Abbey View AD sites is from good to very bad. In the case of the Ffynnon-y-ddol and tributaries, the drainage status is predicted to deteriorate from good to bad on intensive pasture and extensive arable land use. Land under extensive pasture is expected to deteriorate from a bad to very bad drainage status in the absence on maintenance.

4.4.7 Drainage benefits

The annual benefit of preventing a deterioration in drainage status is calculated from the area affected (ha) multiplied by the annual benefit (£/ha) to be gained from preventing the deterioration. Table 4.8 shows the total annual drainage benefits for each watercourse.

Table 4.8 Annual benefit of drainage, by watercourse: FDMM

Watercourse	Total Annual Benefit of Maintaining Drainage Status (£)
Kelwell Stream	11440
Watton Beck	29329
Winestead Drain	47213
Ffos Fawr	4620
Abbey View AD	2708
Ffynnon-y-ddol and tributaries	20411

Note: Figures are subject to rounding. 1997/98 economic prices are used.
Figures are taken from the Drainage Benefit record sheets in the Appendices.

This analysis assumes that land use would not change in the absence of maintenance. It is likely, however, that some areas may switch from arable crops to pasture or from intensive to extensive pasture. The drainage benefits associated with maintenance may therefore be under- or over-estimated according to the change in land use that occurs. The users of FDMM and the Guidelines should be aware of this.

As the drainage benefit areas were estimated by the Environment Agency for all the case study watercourses, the areal drainage factors were applied to the flood risk areas to confirm these estimates.

In the case of Kelwell Stream and Watton Beck, due to the soil type and piped drainage, the areal drainage factor is 1 (Table 3.8, FDMM). The drainage benefit area is therefore calculated to be the same as the flood risk area. This is consistent with the assumption made.

If the areal drainage factor is applied to the flood risk area of Winestead Drain, due to the pumped drainage system, the drainage benefit area is assumed to be double that of the flood risk area (areal drainage factor of 2, NRA, 1995). The drainage benefit area would therefore be 1458 ha. Doubling of the flood risk area in this way, represents an attempt to include the drainage benefit area of IDB/IDD watercourses and thus prevent under-estimation of benefits. If the IDB/IDD tributary systems and associated benefit areas were included in the analysis in the first place, however, this areal drainage factor for pumped drainage would not be required. Further details are presented in Chapter 5.

Application of the areal drainage factor to the Ffos Fawr and Abbey View AD results in drainage benefit areas which are 40% of the flood risk area (areal drainage factor of 0.4 (Table 3.8, FDMM)). This, however, has little impact on the benefit cost ratio which still remains favourable. Further details are presented in Appendix VI and VII.

4.4.8 Justification

Justification of the maintenance scheme is undertaken through a comparison of the benefits and costs of maintenance in a simple benefit:cost ratio. Table 4.9 summarises the total annual maintenance expenditure on each main river. The costs of non-annual maintenance such as dredging and tree and bush work have been amortised to derive an equivalent annual cost (see Appendix II). Table 4.9 also shows the combined annual flooding and drainage benefits and the benefit:cost ratio. Table 4.9 contains the benefit:cost ratio for agricultural benefits and shows that for the assumptions made, the current maintenance regimes can be justified.

Table 4.9 Justification of maintenance, by watercourse: FDMM

Watercourse	Annual Maintenance Expenditure (£)	Annual Benefits Lost Without Maintenance (£) (Urban and Agricultural)	Benefit:Cost Ratio (Urban and Agricultural)	Benefit:Cost Ratio (Agricultural Only)
Kelwell Stream	3713	29963	8.07	6.22
including cost for embanked reach	5300	29963	5.65	4.36
Watton Beck	1883	73117	38.83	21.15
including cost for highland carrier	6590	73117	11.10	6.04
Winestead Drain	42939	176062	4.10	2.24
Ffos Fawr	1428	16063	11.24	3.7
Abbey View AD	763	4554	5.96	4.1
Ffynnon-y-ddol and tributaries	9476	20411	2.15	2.2

Note: Figures are subject to rounding. 1997/98 economic prices are used. Maintenance expenditure obtained from the Environment Agency and IDB/IDDs. Figures are taken from the Appendices.

4.4.9 Winestead Drain - without maintenance scenarios

Assessment of the benefits of maintenance on the Winestead Drain is complicated due to the fact that the watercourse is pumped and that an IDB watercourse which lies directly upstream of the main river is served by a pumping station which is sited on the main river.

In the previous analysis, the benefits of maintenance are derived by comparing the total benefits provided by channel maintenance and pumping with the 'do-nothing' option for the main river reach of Winestead Drain only. The IDB watercourse upstream of the main river has been excluded from the analysis. This is in accordance with the procedures set out within FDMM. This IDB watercourse, however, benefits from maintenance and pumping on the main river and in order to determine total benefits and costs, this watercourse and associated benefit area should be included within the analysis. Sensitivity analysis to determine the impact of this has been carried out. Further details of each scenario are provided in the following sections and in Appendix V.

Scenario 1

Scenario 1 compares the total benefits (flooding and drainage) associated with channel maintenance and pumping on the main river and IDB watercourse with the 'do-nothing' option. Table 4.10 summarises total benefits and costs. Under this scenario, drainage water would cease to be evacuated from the floodplain. The capacity of the channel will decrease over time due to a build up of sediment, vegetation and debris in the channel. Channel water levels and hence watertable levels will consequently rise. It is therefore assumed that the drainage status without channel maintenance and pumping will deteriorate over the whole flood risk area. Flooding will also occur more frequently and over a wider area. Further details are presented in Appendix V.

Table 4.10 shows that the current maintenance regime is justified when compared with the 'do-nothing' scenario. In practice, however, under this scenario, there is likely to be a change in land use in part of the benefit area. Some areas of arable land use would revert to pasture which is more tolerant of flooding and inadequate drainage, although productivity may be low. The benefits of maintenance may therefore be over-estimated. No allowance, however, is made for this in the analysis.

Scenario 1A
The Booster Pumping Station at head of main river pumps water from the IDB channel up into the main river which is at a higher level. The 'main' river itself derives no benefit from this pumping station. Table 4.10 compares the benefits associated with channel maintenance and pumping on the main river only and the associated costs, with the 'do-nothing' option. The costs and benefits associated with the Booster Pumping Station at the head of main river on Winestead Drain are therefore omitted from the analysis on the grounds that these relate to areas beyond the study reach. Further details are presented in Appendix V.

Scenario 1B
Table 4.10 compares the benefits associated with channel maintenance and pumping on the IDB watercourse only (Scenario 1B), with the 'do-nothing' option. As the IDB watercourse and associated area benefit from operation of the Booster Pumping Station, the cost associated with this should be attributed to the IDB area. Table 4.10 shows that even if these pumping costs are included in the analysis, maintenance on the IDB watercourse remains justified given the assumptions made.

Table 4.10 Benefit:cost analysis, Winestead Drain: FDMM

Scenario	Total Annual Benefits (£) (Agricultural + Urban)	Annual Maintenance Costs (£)	Benefit:Cost Ratio (Agricultural + Urban)
Scenario 1	248585	46372	5.36
Scenario 1A	176062	26678	6.60
Scenario 1B	72523	19694	3.68

Note: Figures are subject to rounding. 1997/98 prices are used. See Appendix V for further details.

1 Total benefits and costs associated with main river and IDB watercourse.

1A Benefits and costs associated with main river only, excluding costs of Booster Pumping Station.

1B Benefits and costs associated with IDB watercourse only, including costs associated with Booster Pumping Station.

Separate analysis was also undertaken to estimate the impact of (a) pumping only and (b) channel maintenance only, on drainage status and flooding and hence on the benefit:cost ratio. Analysis confirmed that channel maintenance and pumping complement each other. Channel maintenance sustains the operation of the pumping scheme through preventing a build up of vegetation and sediment in the channel and by preventing the blockage of field drainage pipe outfalls. Without channel maintenance, the resultant restrictions in capacity will cause channel water levels and hence field watertable levels to rise. Whilst the pumps may operate more frequently to counteract this, retained water levels are still expected to remain higher than that of a maintained channel. The effectiveness of the pumps will be reduced as they will exert less drawdown than if the channel were kept clear and pumping costs may therefore increase. Without pumping, much of the area would flood and become waterlogged. It is likely that a change in land use will occur and that some arable areas will revert to grassland. Full details on this analysis are presented in Appendix V.

Maintenance expenditure
In accordance with FDMM, maintenance expenditure for each watercourse has been increased by 15% and the benefits reduced by 15% in order to check the sensitivity of assumptions made on the benefit:cost ratio. Due to the relatively high benefit:cost ratios associated with all the case study watercourses, the current maintenance regimes remain justified after these assumptions.

Sensitivity of the benefit:cost ratio to effective reach length
As discussed previously, the effective reach length and benefit areas affect the benefits and costs associated with river maintenance. If IDB/IDD networks, embanked sections and highland carriers are included in the effective reach length, the maintenance costs associated with these channels should be included in the benefit:cost assessment. Full details are presented in the Appendices for each watercourse.

Similarly, if the watercourse discharges into another main river and derives benefit from maintenance on it, a proportion of the maintenance expenditure on this watercourse should ideally be included in the calculation of costs. For example, Kelwell Stream discharges into Foredyke Stream and Holderness Drain, which are both maintained by the Environment Agency. The proportion of maintenance expenditure to be attributed to the Kelwell Stream may be based on the proportion of flow at the outfall of Holderness Drain which is derived from Kelwell Stream and Foredyke Stream. Further details are presented within the Appendices.

Benefits of maintenance
If the maintenance expenditure on the IDB/IDD watercourses, embanked section of main river and highland carriers are taken into account in the benefit:cost assessment, the associated benefits should also be considered.

The embanked section of Kelwell Stream and highland carrier on Watton Beck do not provide a drainage function for the land over which they flow. They do, however, provide the conduit for the watercourse system over the lowland area. Maintenance on this embanked reach and highland carrier therefore provides a benefit for the main river upstream. If maintenance were not carried out, channel capacity would be reduced with a concomitant deterioration in drainage status upstream and increase in flooding.

The benefits provided by the embanked section on Kelwell Stream and the highland carrier on Watton Beck also relate to flood protection. If the embankments were not maintained and were breached, a large part of the lowland drainage area may flood. The exact area affected, however, will depend on many factors such as the location of the breach, time taken to repair it, discharge and topography. Detailed modelling would be required to accurately predict the area affected by a flood event of a particular return period, with a breach at a specific point. Such detailed analysis is not usually possible and an estimate of benefits may need to be made. Similarly, it is likely to be difficult to determine the benefits derived from the proportion of maintenance expenditure on the main rivers into which the case study watercourses discharge.

Estimation of these benefits may, however, introduce error and reduce the accuracy of the benefit:cost analysis. It is recommended that the type of these additional benefits is noted and only if the benefit:cost ratio appears to be marginal, then an estimate of these benefits is made.

The Booster Pumping Station situated at the head of main river on Winestead Drain is used to pump water out of the IDB watercourse into the main river. The Environment Agency is responsible for maintenance and running costs of this pumping station, even though the main river derives no benefit from it. If the costs associated with this pumping station are taken into account, the benefits it provides should also be taken into account in the benefit:cost assessment. Provision for this, however, is not made within FDMM.

4.5 Long Term Deterioration Without Maintenance

At present, on the watercourses studied, maintenance is undertaken annually. The without maintenance situation represents the base case best estimate of the likely conditions which will prevail if maintenance were discontinued. Without maintenance, however, over a period of years the channel capacity is likely to be reduced due to vegetation growth and siltation. Therefore, the impact of the annual flood after 10 years without maintenance, for example, is likely to be greater than its impact after one year without maintenance. The rate and extent of deterioration will depend on the hydraulic and geo-physical features of the watercourse.

If the benefits of maintenance appear to be marginal, sensitivity analysis may be undertaken to estimate the benefits of maintenance, assuming a further deterioration in channel capacity over time due to lack of maintenance. The routines produced by Fisher (1995) through morphological modelling may be used for this purpose. These predict the rate of deterioration in bankfull discharge and freeboard following maintenance (see Appendix III).

To test the sensitivity of FDMM to this, two without maintenance flooding scenarios were used for Kelwell Stream and Watton Beck. Scenario 1, the base case, is a typically representative best estimate and shows the likely number of HEs affected by flooding, and the deterioration in drainage status which may occur, if maintenance were discontinued. Scenario 2 represents the average annual loss of benefit assuming there are incremental losses due to a further deterioration in channel capacity over time due to lack of maintenance and consequently larger areas are flooded and drainage status deteriorates further.

Kelwell Stream is used here as an example to illustrate the methodology. Table 4.11 shows the annual benefit of flood alleviation associated with each scenario.

Table 4.11 Example of calculation of benefits of flood alleviation, using Kelwell Stream

	HEs Affected by Flooding Without Maintenance (AAN $_{without}$) (a)	HEs Affected by Flooding With Maintenance (AAN $_{with}$) (b)	(a) - (b) = (c)	Annual Benefit of Flood Alleviation (£) ((c) x £1304)
Scenario 1, Annual flood occurs in first year of no maintenance				
Left Bank	7.223	2.213	5.010	6533
Right Bank	13.256	4.061	9.194	11990
			Total	18523
Scenario 2, Annual flood occurs in tenth year of no maintenance				
Left Bank	9.494	2.213	7.281	7639 *
Right Bank	17.424	4.061	13.362	14020 *
			Total	21659

Note: 1997/988 prices are used. Figures are subject to rounding.
* Calculation of Scenario 2 benefits is shown in Table 4.12.

Table 4.12 shows the procedure through which the Scenario 2 annual benefits are identified. In this example, the Scenario 2 benefits are an estimate of the losses which may occur if maintenance were discontinued for 10 years. These annual benefits are derived by discounting the average value of incremental losses over the period between Scenario 1 and year 10 to derive the present value of these average incremental losses, and adding this to the loss under Scenario 1. Further details are presented in Appendix I and IV.

Table 4.12 Estimation of losses due to flooding (agricultural + urban), assuming further deterioration without maintenance, Kelwell Stream

		Left Bank	Right Bank
Benefit lost under Scenario 1 (£)	(a)	6533	11990
Benefit lost in year 10 (£)	(b)	9494	17424
Incremental loss over 10 years (£)	(b) - (a) = (c)	2961	5435
Average value of incremental loss (loss in year 5) (£)	(c) / 2 = (d)	1481	2717
Discount factor at 6 % (year 5)	(e) Appendix II	0.747	0.747
Present value of average incremental loss (£)	(d) x (e) = (f)	1106	2031
Average annual loss assuming further deterioration (£)	(f) + (a)	7639	14020
Total of both banks (£)		21659	

Note: Figures are subject to rounding. 1997/98 prices are used.

Drainage benefits are handled in a similar manner to flooding, as shown in Table 4.13. Further details are presented in Appendix I and IV.

Table 4.13 Estimation of losses due to deterioration in drainage status, assuming further deterioration without maintenance, Kelwell Stream

		Left Bank	Right Bank
Benefit lost under Scenario 1 (£) (good to bad drainage)	(a)	4654	6786
Benefit lost in year 10 (£) (good to very bad drainage)	(b)	12029	17539
Incremental loss over 10 years (£)	(b) - (a) = (c)	7375	10753
Average value of incremental loss (loss in year 5) (£)	(c) / 2 = (d)	3687	5377
Discount factor at 6 % (year 5)	(e) Appendix II	0.747	0.747
Present value of average incremental loss (£)	(d) x (e) = (f)	2755	4016
Average annual loss assuming further deterioration (£)	(f) + (a)	7409	10802
Total of both banks (£)			18212

Note: Figures are subject to rounding. 1997/98 prices are used.

Under Scenario 2, total annual benefits of maintenance are therefore £39871 (£21659 + £18212), compared to £29963 for Scenario 1.

4.6 Results from the Application of the Guidelines

The Guidelines have been applied to the same case study watercourses as FDMM, using the same data. The completed record sheets are presented in the Appendices.

The area benefiting from maintenance in terms of its impact on flooding and land drainage is taken to be the same as the flood risk area identified using FDMM. The same flooded areas and return periods were used in the analysis as in FDMM.

Information relating to dominant substrates and channel parameters were estimated during a rapid survey of the channel. Average freeboards under conditions of mean spring flow were estimated by the Environment Agency. This parameter has not been monitored and recorded and so the estimate is based on local knowledge of the watercourse and site observations.

4.6.1 Benefits of maintenance

Table 4.14 shows the benefits of flood alleviation and prevention of a deterioration in drainage status for each watercourse.

As in the case of FDMM, the benefit:cost ratios have been calculated for various maintenance expenditure scenarios which include IDB/IDD watercourses, embanked sections, highland carriers and a proportion of costs associated with the main rivers into which the case study watercourses discharge. Details of this analysis are contained within the Appendices.

Table 4.14 Annual flooding and drainage benefits, by watercourse: Guidelines

Watercourse	Annual Benefits (£) of Flood Alleviation	Annual Benefit of Maintaining Drainage Status(£)	Total Annual Benefits (£)
Kelwell Stream	1329	11616	12945
Watton Beck	322	30360	30682
Winestead Drain	1239	48114	49353
Ffos Fawr	616	3388	4004
Abbey View AD	361	1986	2347
Ffynnon-y-ddol and tributaries	0	22981	22981

Note: Figures are subject to rounding. 1997/98 economic prices are used. Figures taken from the Appendices.

4.6.2 Justification

The total benefits of maintenance are compared with the total cost of maintenance in a simple benefit:cost ratio. A ratio of 1.0 or greater indicates that for the given assumptions, the maintenance regime is justified in purely economic terms.

The Guidelines have been applied to the same without maintenance scenarios as FDMM for all the watercourses. Table 4.15 shows that using the Guidelines, the current maintenance regime is justified on all the case study watercourses. Table 4.16 shows the benefits, costs and benefit:cost ratio associated with each scenario on Winestead Drain.

Table 4.15 Benefit:cost ratio, by watercourse: Guidelines

Watercourse	Annual Benefits (Agricultural Only) (£)	Annual Maintenance Expenditure (£)	Benefit:Cost Ratio (Agricultural Only)
Kelwell Stream	12945	3713	3.49
including cost for embanked reach	12945	5300	2.44
Watton Beck	30682	1883	16.29
including cost for highland carrier	30682	6590	4.66
Winestead Drain	49353	42939	1.15
Ffos Fawr	4004	1428	2.81
Abbey View AD	2347	763	3.08
Ffynnon-y-ddol and tributaries	22981	9476	2.43

Note: Figures are subject to rounding and are taken from the Appendices. 1997/98 economic prices are used.

Table 4.16 Benefit:cost ratio, Winestead Drain, Guidelines

Watercourse	Annual Benefits (Agricultural Only) (£)	Annual Maintenance Expenditure (£)	Benefit:Cost Ratio (Agricultural Only)
Scenario 1	82269	46372	1.77
Scenario 1A	49353	26678	1.85
Scenario 1B	32916	19694	1.67

Note: Figures are subject to rounding and are taken from Appendix V. 1997/98 economic prices are used.

1: Total benefits and costs associated with main river and IDB watercourse.

1A: Benefits and costs associated with main river only, excluding costs of Booster Pumping Station.

1B: Benefits and costs associated with IDB watercourse only, including costs associated with Booster Pumping Station.

As with FDMM, separate analysis was also undertaken to estimate the impact of (a) pumping only and (b) channel maintenance only on drainage status and flooding and hence on the benefit:cost ratio. Analysis confirmed that channel maintenance and pumping complement each other. Full details on this analysis are presented in Appendix V.

4.7 Comparison of Results from FDMM and the Guidelines

The urban benefits identified using FDMM have been added to the benefits obtained using the Guidelines to enable a direct comparison of results. Table 4.17 summarises the benefits and benefit:cost ratios derived from the application of both systems to the same case study watercourses.

Comparison shows that the benefit:cost ratios produced by FDMM are generally higher than those obtained using the Guidelines. For all watercourses, the current maintenance regimes appear justified, using FDMM and the Guidelines, given the assumptions made.

Table 4.17 Benefit:cost ratio, FDMM and Guidelines, by watercourse

Watercourse	FDMM (a) Annual Benefits (Agricultural Only) (£)	GUIDELINES (b) Annual Benefits (Agricultural Only) (£)	Ratio of (a)/(b)	FDMM Benefit:Cost Ratio (Agricultural + Urban)	GUIDELINES Benefit:Cost Ratio (Agricultural + Urban)
Kelwell Stream	23106	12945	1.78	8.1	5.3
Watton Beck	39826	30682	1.30	38.8	34.0
Winestead Drain	96036	49353	1.95	4.1	3.0
Ffos Fawr	5313	4004	1.33	11.2	10.3
Abbey View AD	3114	2347	1.33	6.0	4.9
Ffynnon-y-ddol and tributaries	20411	22981	0.89	2.2	2.4

Note: Figures are subject to rounding. 1997/98 economic prices are used. Figures taken Table 4.8, 4.10 and the Appendices.

The main reasons for the difference in agricultural benefit assessment relate to:

- differences due to use of standardised HE values based on 1991 relative prices which in some cases have changed over time. The HEs for each land use feature were calculated in 1991 relative values inflated to 1997/98 prices. This may not accurately reflect the current situation due to relative price changes in the intervening years, especially with respect to agricultural values which have fallen in real terms;
- differences due to the use of HEs in FDMM to estimate flood costs. Flood costs identified using FDMM are higher than those calculated using the Guidelines. An example of this is

shown below, using comparable land uses, a flood with a return period of 20 years and assuming a large catchment. In this example, there is a difference in flood costs of 33% between those calculated using FDMM and those calculated using the Guidelines. This difference partly reflects the use of HE values based on 1991 relative prices.

FDMM: Flood costs	HE/unit (a)	HE/ha (b)	(b) x £1304 = (c)
Extensive arable	6.3 HE/100 ha	0.063	£82 /ha
(Cereal / oil seed)	Flood return period of 20 years, flood cost is £82/ha/20 = £4 /ha		
GUIDELINES: Flood costs			
Cereal / oil seed	Flood cost for an event with 20 year return period = £3 /ha (assuming large catchment, good drainage)		

- differences in the treatment of flood envelopes, which are assumed overlapping in FDMM and discrete in the Guidelines. Total flood costs calculated in FDMM are based on the sum of the incremental flood costs associated with the areas inundated at different return periods. Within the Guidelines, flood costs associated with each land use and discrete return period events are simply added together. This issue is discussed further in Chapter 6;
- differences in flood costs according to catchment size which are not identified in FDMM but which are identified in the Guidelines. Flood costs for small catchments are higher than those corresponding to the same flooding, land use and drainage scenario in a large catchment. In FDMM, the HEs/unit for agricultural land are based the costs of a typical flood event occurring in a large catchment. If the catchment is classed as small, flood costs may be under-estimated using FDMM;
- differences in the identification of drainage related benefits which are more elaborate in the Guidelines.

4.8 Quality of Results

FDMM and the Guidelines are the products of extensive research and both systems are underpinned by some hydrological and agri-economic modelling.

The accuracy of the results, however, is affected by the assumptions made for the particular circumstances of the watercourse and benefit areas, and the amount of detailed information available. Lack of data available at the present time creates the need to make estimates. As availability of data increases, fewer estimates will be necessary.

Within FDMM, numerous assumptions need to be made due to the absence of data, for example the areas inundated by floods of different return periods and drainage status. Standard data and default values are provided in the Guidelines and to a lesser extent in FDMM, which may be used in the absence of measured data in order to reduce the need for making estimates. This can reduce the possible sources of error which are introduced into the calculation.

4.9 User Confidence

4.9.1 FDMM

At present, there seems to be limited understanding of and linked to this limited confidence in FDMM. Whilst this is mainly because FDMM is a new system and not very familiar to the users, it is also due to its 'black box' image.

Clarification of various elements within FDMM is required and training needed to enable a thorough understanding of the system. In its present format, inconsistencies and anomalies in FDMM are a source of confusion and these need to be addressed. As familiarity with FDMM increases through application to more sites, confidence in it will increase.

4.9.2 Guidelines

The Guidelines are more comprehensive in their treatment of benefits and costs than many other systems and provide a more objective method of assessment. Routines used and data presented in the Guidelines have been derived through site specific hydrological, morphological and agri-economic modelling.

The Guidelines can accommodate more variation in watercourses (for example, highland carriers and IDB/IDD channels) and benefit areas than FDMM and are therefore applicable to a wider variety of circumstances. This, coupled with the fact that the Guidelines are more transparent has lead to confidence being placed in them by users, especially those using RIMS which draws on a similar methodology and approach. In areas where land use is predominantly agricultural, and drainage rather than flood alleviation is the main concern, the Guidelines can help to underpin FDMM and demonstrate that FDMM can be used to accommodate agricultural interests.

4.10 Summary

The characteristics of the case study watercourses have been summarised and a brief description of each site has been given. The methodologies of FDMM and the Guidelines have been compared and the results from the application of FDMM and the Guidelines to the case study watercourses have been summarised. The full results and completed record sheets are contained in separate appendices. Reasons for the difference in the benefit:cost ratio obtained are discussed. The quality of the results and confidence placed in the two systems by their users are summarised.

The following Chapters contain an evaluation of FDMM and the Guidelines. Points of clarification and correction are presented and modifications suggested. Derivation of standard data and adjustment factors are identified.

5. EVALUATION OF FDMM

5.1 Introduction

This Chapter presents a critical review of FDMM with respect to agricultural related assessments. Descriptions of the procedures discussed here and terminology used are presented in Chapter 2. Issues are discussed in order of their appearance in FDMM and not in terms of their significance.

Although FDMM is a comprehensive system for justifying maintenance operations, specific aspects require clarification, elaboration or correction. The derivation of the adjustment factors are summarised and suggested modifications to FDMM are recommended. Recommendations and action points are highlighted in italics.

5.2 Flood Risk Area, Drainage Benefit Area, Effective Reach Definition

The identification of the flood risk area is crucial to the application of FDMM. The benefit:cost analysis is sensitive to the assumptions made, as highlighted by the worked examples shown in previous sections of this report.

In its present form, FDMM requires that the flood risk area relates to that of the main river only. In many cases, Internal Drainage Board (IDB, or Internal Drainage District (IDD)) watercourses extend upstream of the main river limit, as in the case of Winestead Drain. Similarly, IDB watercourses are often tributaries of the main river and lie within the flood risk or drainage benefit areas (as in the case of, for example, Kelwell Stream). If these watercourses derive benefit from maintenance on the main river and are influenced by levels in the main river, their respective benefit areas should ideally be included in the assessment of the flood risk area. If they are excluded, the benefits of maintenance may be underestimated.

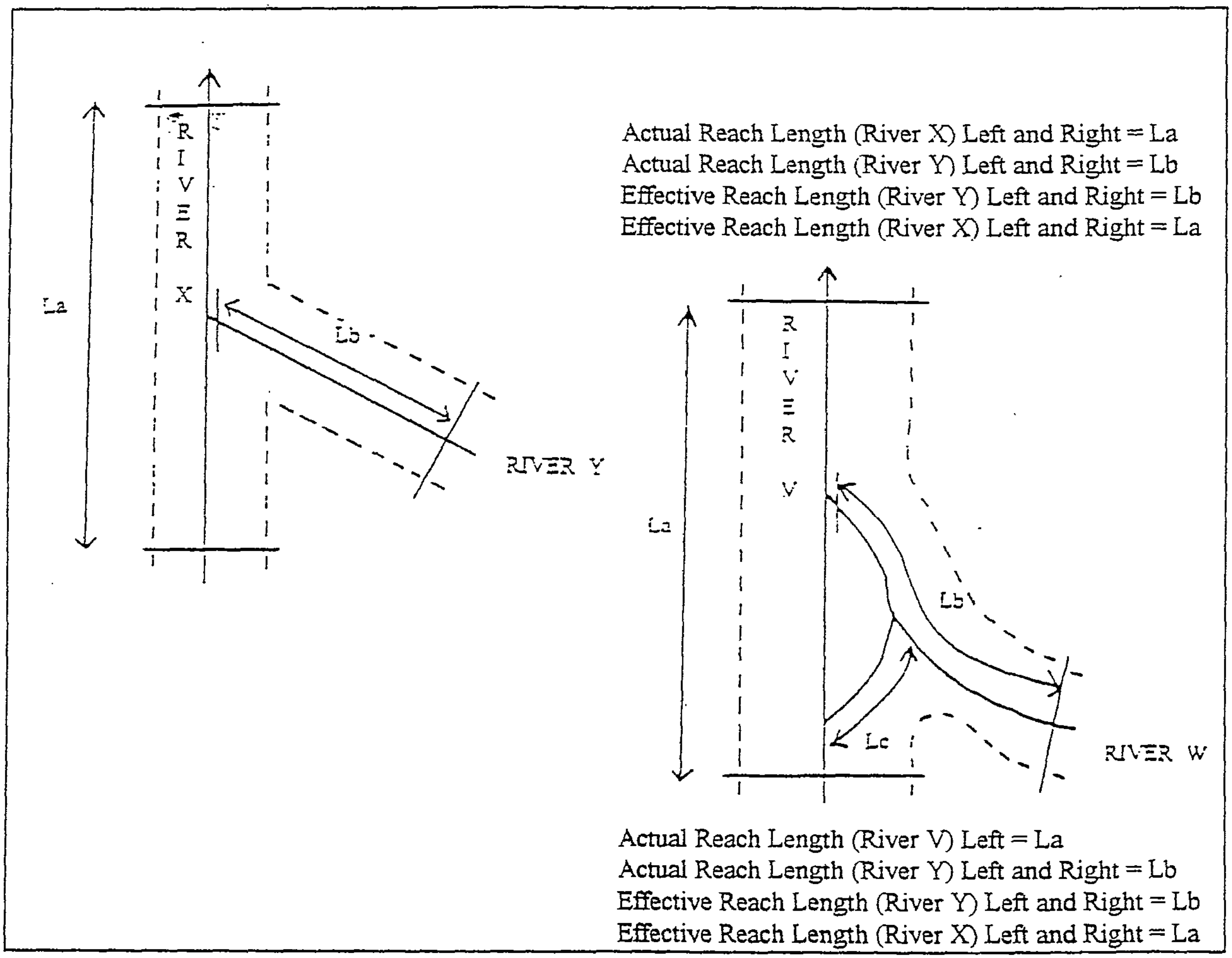
Highland carriers and embanked reaches further complicate the issue. Although they do not provide a service to the land through which they flow, they provide the conduit for the watercourse system upstream. Maintenance on these reaches therefore provides a benefit for the watercourse upstream by providing the outfall. These reaches should therefore be included in the calculation of effective reach length and the associated maintenance expenditure included in total costs.

In addition to this, if their banks failed due to lack of maintenance, large areas may be flooded. Technically, the area which floods should be included in the flood risk area as maintenance of the highland carrier is currently protecting this area. In practice, however, as highlighted in the case of Watton Beck, the potential area which would be inundated by a flood of a given return period is not known. This would vary according to factors such as: the size of the breach; length of time before the breach were repaired; topography; current and previous weather conditions; soil type; vegetation cover; and, nature of the drainage system in the lowland area affected. Because of this, it is *therefore recommended that this potential flood risk area is noted, but not included in the analysis, unless the justification of maintenance appears to be marginal.*

Using existing records and knowledge, those areas within the flood risk area known to be subject to or liable to inadequate drainage are identified (FDMM p3/19 paragraph 63) in order to define the drainage benefit area. This area, however, *may not necessarily lie purely within the flood risk area, especially in low-lying areas with an extensive network of drainage pipes. This point should be made clear in FDMM.*

The effective reach length for flooding is the 'length of main channel for which a flood risk area is defined. This excludes loops and areas for which no flood risk area is defined' (FDMM p2/15 paragraph 64 onwards) and is illustrated by Figure 2.4 in FDMM which is reproduced in Figure 2.2. *If the benefit areas of IDB/IDD watercourses, highland carriers and any other channels are included in the assessment of the flood risk area, they should also be included in the calculation of effective reach length.* This should be made clear within FDMM.

The calculation of reach length and effective reach length where tributaries are present is illustrated in Figure 2.5 of FDMM (p2/16). This figure is reproduced in Figure 5.1. It is assumed that this applies to all tributaries irrespective of whether their outfall into the main channel is flapped. If the outfall is flapped, discharge through the flaps is regulated by flow in the main channel. The question has been raised by the Environment Agency as to whether, in this situation, the tributary should be treated as a completely separate watercourse and FDMM applied accordingly ? *It is recommended that to avoid double counting, the tributary is not treated as a separate watercourse, as drainage status and flooding in the benefit area of the tributary will be influenced to a greater or lesser extent by levels in the main channel, irrespective of whether the outfall into the main channel is flapped. The flood risk area of the tributary may well lie within the flood risk area of the main channel. If this is not the case, then the flood risk area(s) of the tributary must be identified and added to that of the main river.*



Actual Reach Length (River X) Left and Right = La
Actual Reach Length (River Y) Left and Right = Lb
Effective Reach Length (River Y) Left and Right = Lb
Effective Reach Length (River X) Left and Right = La

Actual Reach Length (River V) Left = La
Actual Reach Length (River Y) Left and Right = Lb
Effective Reach Length (River Y) Left and Right = Lb
Effective Reach Length (River X) Left and Right = La

Source: NRA, 1995, Figure 2.5

Figure 5.1 Calculation of reach lengths when tributaries are present

It is also unclear within FDMM whether both banks of the tributary are included in the calculation of effective reach length. For example, if a tributary joins the main channel on the left bank, the effective reach length may comprise the left bank of the main channel plus the length of either one or both banks of the tributary. *It is assumed that both banks of the tributary should be included in the effective reach length. This should be clarified within FDMM* as it has implications for the actual Standard of Service (see Section 5.13).

Within FDMM, various sources of information for the flood risk area are listed. These include, for example, aerial photographs, maps showing the extent of previous floods and hydraulic modelling. The Medway Letter Line may also be used to identify the flood risk area. This line delineates the area which is bounded by a line drawn 2.4 m higher than the known maximum flood extent. The IDB/IDD boundaries are often based on this line.

5.3 House Equivalents

The annual average HE figure should be updated annually by using the appropriate price indices. The value of one HE is calculated to be £1304 in 1997/98 prices (Environment Agency, 1997). HEs do not remain constant through time and should be updated periodically to take account of differential inflation which may distort their values relative to each other. Revision every 4 or 5 years is thought to be sufficient (Howells et al, 1992), or when particular circumstances are thought to arise which may significantly affect the results. *The current HE figures for each land use feature within FDMM are at the 1991 base level. It is therefore recommended that these figures are revised to reflect the situation in 1997/98.*

5.4 Land Use Assessment

5.4.1 Classification

Country parks, garden centres and playgrounds are not included within the land use classification. It is recommended that country parks are included in the formal park classification and that garden centres are added to the non-residential property, retail category. Playgrounds have been classed as playing fields. It is suggested that *if features are encountered within the flood risk area which are not listed in FDMM Appendix 3C, they are allocated to an existing category and the reasons to support this documented.*

5.4.2 Identification of land use

Land use is identified through a visual survey, undertaken at any time of the year except when land is under snow cover. FDMM states that 'evidence can usually be found to identify the cropping system' (FDMM p3/8 paragraph 22), but the key indicators used in identification of the cropping systems are not documented within the manual.

These indicators are likely to be known by many, if not all surveyors, during the later stages of crop growth and during harvest. However, when soils are bare or during the early stages of crop development, determination of land use is more difficult. Reliance on general knowledge of the area may be necessary to determine land use.

It is recommended that key indicators for crop identification are included within FDMM. Additionally, reference may be made to a manual for the identification of agricultural crops through each growth stage. This incorporates time series diagrams, photographs and colour illustrations and was produced for the NRA Severn-Trent Region in 1993, by Silsoe College.

Within FDMM, five land use bands are used, namely: forestry and scrub, extensive pasture, intensive pasture, extensive arable and intensive arable. Guidance is not given within FDMM as to which crops are found in an intensive or extensive arable rotation. *Land under a* *cereal/root crop rotation or horticulture constitutes intensive arable. Grass/arable, all cereal or cereal/oil seed rotations are classified as extensive arable land. It would be beneficial if this were made clear within FDMM.* Table 5.1 may be used for this purpose.

Table 5.1 Land use type: key indicators

Land Use Type	Key Indicators
Forestry and Scrub	Forest, scrub.
Extensive Pasture	Grass, poorly drained, rough grazing for sheep and heavy cattle, presence of nettles, rushes, weeds.
Intensive Pasture	Grass, well drained, even sward which is managed, evidence of reseeding and silage cutting.
Extensive Arable	
Grass / Arable Rotation	Grass, wheat, barley, oats.
Cereal / Oil Seed Rotation	Cereal / oil seeds / legumes (peas, field beans).
Intensive Arable	
Cereal / Root Crop / Vegetables	Wheat, barley, oats, potatoes, sugar beet, turnips, swedes, carrots.
Horticulture	Cabbage, broccoli, leeks, bulb onions, brussel sprouts, cauliflower, salad vegetables, orchard fruit, soft fruit.

Source: Modified from Sutherland et al, 1993b

These five land use types are first referred to in FDMM p3/7, Table 3.2. In Loose Material D, Sheet 3, land use is referred to as types 1 to 5. Whilst it is logical that type 1 refers to forestry and scrub, 2 refers to extensive pasture etc., this link is not made. *For clarity, it is suggested that in FDMM Table 3.2, the five land uses are named and also numbered.*

5.4.3 Land use assessment reach summary sheet

The land use assessment reach summary sheet is first shown in FDMM, p3/10, Table 3.3. The number of HEs or area (m^2 or 100 ha) are multiplied by the HE/unit to derive the total HE for each land use feature.

There is inconsistency in the presentation of the HE/unit for special parks (E.g. a Theme Park). The HE/unit is quoted as being 9.3 (FDMM p3/10 Figure 3.3, p3/7 Table 3.2, p5/15 Table 5.3, p6/21 Table 6.14) and 9.2 (FDMM Loose Material A, p2). Whilst the difference between these two values is small, and is unlikely to significantly alter the total HE or total HE/km; for consistency, a single HE/unit should be used. If different values are presented, confidence in FDMM may be reduced. For the purpose of analysis in this report, the HE/unit for special parks is taken to be 9.3. The value of 9.3 also appears in the CRIMS report (Howells et al, 1992).

The asterisked notes presented under the reach summary sheet (FDMM p3/10 Table 3.3) are not consistent with the information presented in the table itself. *The '***' does not feature in the table at all and should be added.*

In order to improve clarity of presentation and understanding and to address some of the issues discussed in Section 5.4, the land use assessment reach summary sheet has been redesigned. This new sheet is based on that presented in the Summary Guidance Note (FDMM p3/5 Figure 3.1) and is shown in Table 5.2. Additions and alterations to the land use assessment reach summary sheet presented in FDMM are shown in red.

Table 5.2 Revised land use assessment summary sheet

Watercourse	Example	Actual Reach Length (km)	5	
Reach Reference	1234.01.L	Effective Reach Length (km)	4	Flooding
Landranger Map No.	123	Effective Reach Length (km)	2	Drainage
Flood Risk Area Extent Map No.	1	Soil Type	Light	
Agricultural Flood Risk Area (ha)	500	Drainage System	Natural	
		Areal Drainage Factor	1	

Land Use Feature	Unit	Number or Area (a)	House Equivalents HE/unit (b)		Total HE (a) x (b)	
House	Number	*5*	1.00		*5.00*	
Garden / allotments	Number	*5*	0.04		*0.20*	
NRP - Manufacturing	Area (m^2)		0.030			
NRP - Distribution	Area (m^2)		0.054			
NRP - Leisure	Area (m^2)	*100*	0.032		*3.20*	
NRP - Offices	Area (m^2)		0.033			
NRP - Retail	Area (m^2)	*375*	0.035		*13.13*	
NRP - Agricultural	Area (m^2)	*625*	0.010		*6.25*	
C Roads	Number	*2*	2.7		*5.40*	
B Roads	Number		6.3			
A Roads (non trunk)	Number		15.9			
A Roads (trunk)	Number		31.7			
Motorway	Number		63.5			
Railway	Number		63.5			
			Flooding	Drainage	Flooding	Drainage
1. Forestry and scrub	per 100 ha		0.02	0.0		
2. Extensive pasture	per 100 ha	*0.1*	1.3	1.1	*0.13*	*0.11*
3. Intensive pasture	per 100 ha	*0.3*	3	4.5	*0.90*	*1.35*
4. Extensive arable	per 100 ha	*0.6*	6.3	3.6	*3.78*	*2.16*
5. Intensive arable	per 100 ha		44.1	9.7		
Formal parks	Number		0.6			
Golf / race courses	Number		0.7			
Playing field	Number		0.1			
Special parks	Number		9.3			

Total HE (flooding) (c)	37.99 HE
Total HE (drainage) (d)	3.62 HE
Total HEs for reach bank (c + d)	41.61 HE
HE/km flooding ((c)/effective reach length flooding) (e)	9.50 HE/km
HE/km drainage ((d)/effective reach length drainage) (f)	1.81 HE/km
Combined HE/km (e + f)	11.31 HE/km

Note: HE values are at 1991 base

5.5 Determining the Effect of Flooding

The effect of flooding is determined using two complimentary techniques. The historical technique records the events that have occurred over a defined period and the predictive technique assesses the likely incidence of flooding using a probabilistic approach. Ideally, the two techniques are used and the results are compared. If there is a large discrepancy between the results, one of the scores may be rejected or modified on the basis of unreliable data.

In all the examples in this report, analysis of flooding is based purely on use of the predictive technique as no historical records exist. Results cannot therefore be cross-checked against the historical result and therefore, spurious results may not be picked up. However, the predictive score is thought to be the most reliable indicator due to generally poor data sets for historical events in most circumstances.

5.5.1 Historical Technique

The total number of HEs affected by each flood event is adjusted using two factors. Clarification as to the derivation of these two factors was requested by the Environment Agency.

The severity weighting factor is applied to take account of the effect of duration and seasonality of flooding on agricultural losses. The salinity weighting is used to account for the more severe effects of saline flooding compared with freshwater flooding.

Severity weighting

The flood event severity weighting was derived in the CRIMS report (Howells et al, 1992). This factor takes into account seasonality and duration of flooding. It is used to adjust the 'averaged' HE values developed for the land use assessment, so that they can be used for flood scoring of a specific event.

In CRIMS (Howells et al, 1992) calculations were made of the cost of flood damage. These values represented the loss in agricultural net return associated with a typical flood event on a single hectare in a large catchment (>2500 ha). On the basis of gauging station records within the Severn-Trent Region of the NRA, monthly flood probabilities were established in order for the seasonality of flooding to be taken into account. Flood duration was taken to be one week or less. Floods of longer duration would cause greater yield loss but it is seasonality which is the more important factor. Silsoe College (Hess and Morris, 1986) have taken this approach further by calculating monthly flood probabilities for large and small (<2500 ha) catchments.

Salinity weighting

The salinity weighting factors highlight the switch in Standard of Service emphasis from urban flood protection to agricultural protection when the risk is from saline water and not fluvial flooding. The source of the salinity weighting factors is CRIMS (Howells et al, 1992). These factors are based on the losses incurred due to saline flooding such as direct damages and crop losses, the cost of gypsum application and subsequent yield reduction. A range of damage costs for different assumptions were calculated and mean values assumed. Further details are presented in Appendix D of the CRIMS report (Howells et al, 1992).

The HE/unit for saline flooding for houses, gardens and amenity presented in FDMM Table 3.6 (p3/14) are those stated in CRIMS (Howells et al, 1992). *The HE/m^2 for non-residential property are not defined in FDMM Table 3.6 and are said to vary.* These vary according to the size band and nature of the non-residential property (E.g. manufacturing, agricultural, leisure). *The reasons for this variation should be given.* The actual HE/m^2 values for non-residential property are presented in FDMM Table 5.4 p5/17. It is *recommended that Table*

5.4 in FDMM is removed and that the figures are presented in Table 3.6 of FDMM with the other HE/m^2 *values.*

These HE/m^2 factors for non-residential property are repeated in FDMM Table 5.3, although they are presented in a different order. Table 5.3 could be omitted and the user referred back to Table 3.6. Similarly, the salinity weighting factors are repeated in Table 5.9, although they are renamed as saline multipliers. To avoid confusion, if tables are to be repeated, the same titles and layout should be used.

It would be beneficial to *include an example of saline flooding* within FDMM in order to demonstrate the application of the salinity weighting factors. Also, it is suggested that whenever referring to the value of HEs affected/km per year, *the units HE/km/yr are used.* This is a more concise unit and is therefore easier to identify within the text.

5.5.2 Predictive Technique

The predictive technique takes account of the 'likely incidence of flooding in any year and identifies an anticipated long-term average annual value for HE affected'. A severity weighting factor (FDMM p3/17) is applied to the agricultural HE to take account of the timing and duration of flooding. This serves to increase the total HE affected without maintenance, which increases the benefits of flood alleviation. The severity weighting is, however, not applied to the agricultural HE affected by flooding in the 'with maintenance' situation. There is therefore inconsistency in its application. *It is recommended that the origin of these severity weighting factors is identified.*

Using the predictive technique, the average number of HE/km/yr affected by flooding may be derived by plotting a graph of HE affected by a particular event, against the return period of the event, or through an arithmetic process. In the text of FDMM, only the graphical method is discussed although worksheets for both methods are contained within Loose Material G. *The arithmetic method should be mentioned in the text of FDMM* in order for the user to make a decision as to which procedure to follow.

Similarly, in the flood damage assessment-approach 2 (FDMM p5/14 step 3), the annual average number of HEs affected without project (AAN_{without}) may be calculated using the arithmetic or graphical method. Again, *these two options should be stated in FDMM.*

5.6 Drainage Status

Throughout earlier flood defence studies, the terms 'good', 'bad' and 'very bad' are used consistently to describe drainage status (Hess et al, 1989, Howells et al, 1993, Dunderdale and Morris, 1996, 1996a, 1996b). These studies, amongst others, form the background to FDMM. *It is recommended that the terminology remains consistent* and that 'Good', 'Bad' and 'Very Bad' are used to reflect drainage status. The watertable depths by which these are classified are well documented in earlier literature and reports to the previous Water Authorities and the NRA.

Currently, within FDMM, drainage status is described in various ways as shown in Table 5.3. The term 'average' drainage status is misleading. For example, the average drainage status could be interpreted as the average drainage status which occurs across the floodplain or benefit area. Good drainage may occur most often and is dominant, therefore the 'average' drainage status is good. For this reason it recommended that the term 'average' is not used to describe the drainage status.

Table 5.3 Drainage status terminology

Drainage Status Terminology			FDMM Reference
Good	Bad	Very Bad	Chapter 5 p 5/23 paragraph 66 and Table 5.12
Good	Indeterminate	Poor	Chapter 3 p 3/22 paragraph 75
Good	Borderline	Poor	Chapter 3, p 3D/5
-	Average	Poor	Summary Guidance Notes p 3/12

Source: NRA, (1995) and Summary Guidance Notes (undated)

The terms indeterminate and borderline are both used to describe the same drainage status. Borderline drainage status implies that the watertable depth is such that it is difficult to determine whether the drainage is classified as good or very bad. In fact, this middle class of drainage status (bad) is a class in its own right. However, in practice the boundaries between good, bad and very bad drainage status are not well defined and may be difficult to determine.

5.7 Land Use Assessment - Drainage

5.7.1 Drainage benefit area

The drainage benefit area is defined as the area(s) within the flood risk area known to be subject to or liable to drainage problems (FDMM p3/19 paragraph 63). This allows the HE affected by inadequate drainage to be identified, which contributes to the combined flood and drainage score used in determining the actual Standard of Service provided.

If the current drainage status is good, then no drainage benefit area is identified and the drainage score is zero. Good drainage, however, is likely to prevail because of the existing maintenance programme. If maintenance were discontinued, drainage conditions may deteriorate. Therefore, there is a *question as to whether this area under good drainage should be included in the drainage benefit area and identified on the land use assessment summary sheet (FDMM Loose Material A) as this area is deriving benefit from maintenance and is influenced by water levels in the channel. The definition of the drainage benefit area could be redefined to reflect the area at risk.* If this were the case, the combined flood and drainage score may be higher, with consequent impacts on the actual Standards of Service and reach status. *Guidance on this is needed within FDMM.*

5.7.2 Areal drainage factor

In order to assess the HE affected by inadequate drainage, the agricultural HE score for the reach is adjusted. Two adjustment factors are used in FDMM: the areal drainage factor (FDMM Table 3.8 p3/21) and the potential waterlogging damage factor (FDMM Table 3.9 p3/22).

The areal drainage factor 'reflects the fact that the area affected by inadequate drainage will vary depending on soil type and the type of drainage system' (FDMM p3/21 paragraph 69). This areal drainage factor has its origins in CRIMS (Howells et al, 1992).

CRIMS reported that the influence of river water levels on drainage status depends on drainage intensity; whether attributable to natural or artificial drainage. Wetness conditions on heavy, undrained soils are predominantly influenced by weather conditions. In comparison, the wetness condition of light soils, or those which are artificially drained, is significantly influenced by river and ditch levels. Soil type and drainage system can therefore be used to determine the likely areal influence of the river over the floodplain. In practice, this influence is partly reflected in land use. Light, well drained soils are favoured by arable crops and intensive pasture. Estimates of areal influence were derived, and are shown in Table 5.4.

Table 5.4 Areal influence of river levels on floodplain wetness

Land Use	Soil Type	Drainage System	Area of Influence
Arable and intensive pasture	Any	Natural or piped	100 %
Extensive pasture	Clays	Natural, limited ditch system	20 %
Extensive pasture	Clays	Natural, developed ditch system	40 %

Source: Howells et al, 1992

Within FDMM, these areas of influence have been translated into the areal drainage factors which are shown in Table 5.5.

Table 5.5 Areal drainage factors

Soil Type	Drainage System In Flood Risk Area	Areal Drainage Factor
Heavy	Natural or limited ditch system	0.2
Heavy	Developed ditch system	0.4
Light	Natural or ditch system	1.0
Any	Piped system	1.0
Any	Pumped drainage	2.0

Source: NRA, (1995) Table 3.8, p3/21

Within FDMM, use of the areal drainage factor, however, appears open to interpretation. It is not clear as to whether the areal drainage factor is used:

- to amend the total HE score to take account of the impact of soil type and drainage system on land drainage; or,
- to assign a proportion of the flood risk area to a drainage benefit area, if the drainage benefit area is not known.

The information presented here on the derivation of the areal drainage factor shows that this factor should only be applied if the drainage benefit area is not known. This factor is therefore used to assign a proportion of the flood risk area to a drainage benefit area, taking into account soil type and drainage system. *Clarification on the use of the areal drainage factor is required within FDMM. Worked examples may be beneficial in demonstrating the purpose and application of this factor.*

In FDMM, Table 3.8, an areal drainage factor of 2.0 is listed for pumped drainage systems. This factor is not derived from CRIMS and its origin is unclear. In a pumped drainage situation, if this factor is applied, the drainage benefit area is taken to be twice that of the flood risk area. Pumped drainage systems are usually connected to IDB/IDD watercourses. Doubling of the flood risk area in this way, may be an attempt to include the drainage benefit area of IDB/IDD watercourses and thus to prevent under-estimation of benefits. If the IDB/IDD tributary systems and associated benefit areas were included in the analysis, this areal drainage factor for pumped drainage would not be required. This issue is highlighted by the Winestead Drain case study which is presented in Appendix V.

The areal drainage factors are shown in two separate tables in FDMM. It is suggested that Table 5.13 in FDMM (p5/25) is removed as it is a partial repeat of Table 3.8 p3/21. The user may be referred back to Table 3.8. It is not advisable that the same information is presented in different ways in FDMM as confusion may arise. Inconsistency in the table content may also reduce the confidence placed by the user in FDMM.

5.7.3 Soil type

Light and heavy soils are referred to in FDMM (E.g. Table 3.8 p3/21). Whilst sand and clay are categorised as light and heavy soils respectively, soils such as silty loams may be more difficult for the user of FDMM to classify without the use of secondary sources such as maps produced by the Soil Survey and Land Research Centre (SSLRC, formerly Soil Survey of England and Wales (SSEW)). It is suggested therefore, that guidance is given within FDMM as to which soils may be classed as light or heavy. The following table may be used for this purpose.

Table 5.6 Classification of soil type

Category	Soil Type
Light	Predominantly sands, loams and sandy loams
Heavy	Predominantly clays and silts

5.7.4 Potential waterlogging damage factor

The potential waterlogging damage factor (FDMM Table 3.9 p3/22) is used in addition to the areal drainage factor, described in Section 5.8.2, to adjust the agricultural HE score to take account of inadequate drainage. These factors, which were originally listed within CRIMS (Howells et al, 1992) are shown in Table 5.7.

Table 5.7 Potential waterlogging damage factors

Land Use	Potential Waterlogging Damage Factor (HE/100 ha)
Forestry and scrub	0.0
Extensive pasture	4.2
Intensive pasture	17.9
Extensive arable	14.5
Intensive arable	39.0

Source: Howells et al, 1992

The potential waterlogging damage factor is used to reflect the monetary loss (£/ha) associated with a deterioration in drainage status from good to very bad, irrespective of whether the drainage system is piped or naturally draining.

Intensive pasture is used as an example in Table 5.8, to illustrate the derivation of this potential waterlogging damage factor. The price based used in this example is that for 1991/92, as it is this on which the potential waterlogging damage factors listed in FDMM Table 3.9 are based.

The monetary loss associated with a deterioration in drainage status from good to very bad, for intensive pasture is £204/ha (1991/92 economic prices). This loss is converted into a loss per 100 ha and divided by the value of one HE, in order to express this loss in terms of HEs. This results in 17.9 HE/100 ha, which is the potential waterlogging damage factor for intensive pasture, listed in Table 5.9.

Table 5.8 Derivation of the potential waterlogging damage factor using intensive pasture as an example

Economic net return according to drainage status (£/ha) (1991/92 prices)			
Good	328		
Bad	155		
Very bad	124		
Economic loss associated with deterioration in drainage status (£/ha)			
Good to bad	73		
Bad to very bad	131		
Good to very bad	204		
Derivation of potential waterlogging damage factor			
	Associated loss (£/ha)	Associated loss (£/100 ha)	Expressed in HE *
Good to very bad	204	20400	**17.9**

Note: * Associated loss (£/100 ha) divided by value of one HE which was £1134.64 in 1991/92 prices
Source of the value of one HE is Howells et al, 1992

Within FDMM, three different sets of potential waterlogging damage factors are given. The drainage status assessment sheet (Loose Material Sheet D) contains the potential waterlogging damage factors which were listed in CRIMS. It is this sheet which is used to calculate the predictive and historical drainage scores. Table 3.9 of FDMM (p3/22), however, lists a different set of figures; the source of which is not disclosed. It appears that the original figures have been reduced by a factor of four to derive the other lower figures; the reason for this is not documented. The Summary Guidance Notes for FDMM, Supplement to the Summary Guidance Notes and FDMS also contain different figures. Table 5.9 lists the various potential waterlogging damage factors and the locations in which they are found.

Despite discussions with the FDMM Board, members of the FDMM Drainage Group and other Environment Agency personnel, it has not been possible within the confines of this report to identify the sources of these different potential waterlogging damage factors or to ascertain the rationale which supports their variation.

Table 5.9 Potential waterlogging damage factors

Land Use	Potential Waterlogging Damage (HE/100 ha)				
	(a)	(b)	(c)	(d)	(e)
Forestry and scrub	0.0	0.0	0.0	0.0	0.0
Extensive pasture	4.2	1.1	4.8	4.1	1.8
Intensive pasture	17.9	4.5	15.2	13.2	4.1
Extensive arable	14.5	3.6	16.4	14.3	6.1
Intensive arable	39.0	9.7	70.1	61.0	31.4

Location in which these factors are found:
(a) Howells et al, 1992, FDMM Loose Material D (NRA, 1995).
(b) FDMM p3/10 Table 3.9, Loose Material A, Managing Flood Defence Summary Guidance (undated) p3/5 Figure 3.1, p3\12 Figure 3.4, Managing Flood Defence Summary Guidance 1997 Ed. p3/12 Figure 3.4 (NRA, 1995).
(c) Managing Flood Defence Summary Guidance 1997 Ed. p3/5 Figure 3.1, Managing Flood Defence Supplement to FDMM Summary Guidance 1997 Ed. p2/4, p2/5, p6/3.
(d) FDMS Interim System ('poor' drainage).
(e) FDMS Interim System ('average' drainage).

It is recommended that the potential waterlogging damage factors are revised according to the methodology presented in Table 5.8 and using the net returns (1997/98 economic prices) presented in Table 5.14. It is important that there is consistency in the derivation of these factors and that the same factors are presented in all documents relating to FDMM and FDMS.

The units of potential waterlogging damage presented in FDMM are inconsistent. FDMM Table 3.9 (p3/22) shows the units as HE/100 ha. The drainage status assessment sheet (Loose Material D), and Summary Guidance Notes give units of HE/100 ha/yr. *It is recommended that the same units are used for the drainage score and flooding score.* It is assumed that the units should be HE/100 ha/yr.

5.8 Effect of Inadequate Drainage

Two methods may be used to determine the effects of inadequate drainage in the area at risk and to derive the drainage score; namely, the historical and predictive technique.

5.8.1 Historical technique

The historical technique involves the identification of areas subject to inadequate drainage through local knowledge and use of visual indicators. *Sheet 5 of the Loose Material D, is used to do this. This should be made clear in FDMM p3/22 paragraph 72.*

The user is required to identify whether the drainage is good or bad, using historical information and knowledge. *For consistency, it is recommended that the three drainage classes: good, bad and very bad are used and that the length of effective reach drainage affected by these three drainage classes be identified.* This will aid the process of assigning agricultural drainage benefits, when the three drainage classes are used.

5.8.2 Predictive technique

Calculation sheets within Loose Material D enable the effect of inadequate drainage to be assessed using the predictive technique. This technique is based on a comparison of the freeboard requirements with the dominant water level in the reach (FDMM p3D/4). The dominant water level is described as that which is exceeded for 20% of the time during the period March-April over the previous five years. In FDMM p3/22 paragraph 73, however, the technique is said to be based on a 'comparison of the theoretical freeboard with the actual freeboard at times of dominant discharge'. This use of different terminology may be misleading. *It is recommended that the term 'freeboard' is used and that all terms are defined in the glossary which appears at the front of FDMM, beginning on page (xi).*

In FDMM (p3/22 paragraph 75) the reach length within the drainage benefit area with indeterminate (bad) drainage, is reclassified and assigned to the good or poor (very bad) categories. This reclassification is an over-simplification and will alter the drainage score. *It is recommended that the proportion of the reach under bad or very bad drainage is identified. The reach length referred to is the reach length within the drainage benefit area and should therefore be referred to as the effective reach length drainage.*

5.9 Drainage Status Assessment

Guidance on the assessment of drainage status based on freeboard indicators measured at critical times of the year, is provided in FDMM Table 5.11 (p5/24). The origin of these data is CRIMS (Howells et al, 1992).

Originally, the annual benefit derived from achieving a satisfactory drainage condition was based on the benefit area and the marginal return, which was adjusted according to various factors, as shown in the following equation.

Annual benefit = D x W x F1 x F2 x F3 x F4 x marginal return
Where: D = decrease in freeboard if maintenance is not carried out.
W = benefit width, defined for the base case for a unit change in freeboard.
F1 F2 F3 F4 = multiplication factors for depth to impermeable layer, soil permeability, rainfall and floodplain slope, used to assess the impact of parameter values being other than those assumed for the base case.
Marginal return = the difference between gross margin and semi-fixed costs.

The Steering Group for the CRIMS study (C Candish, J Fitzsimons, D Major) thought this was over-complicated and a simpler approach was derived. The number of variables were reduced to soil type (light or heavy), floodplain slope and freeboard and figures were drawn up to provide guidance on whether drainage was likely to be good or bad. These figures are those presented in FDMM Table 5.11 p5/24 (Drainage status assessment).

Originally, the clearance to pipe outfalls for drainage to be classed as good was set at 0.2 m by MAFF. In FDMM Table 5.11 (p5/24), this has been reduced to 0.1 m. Technically, providing there is some freeboard (for example, even only 0.01 m), the drainage pipes will serve their purpose. The use of a clearance to pipe outfall of 0.1 is therefore acceptable. However, the smaller the freeboard, the lower the storage capacity in the watercourse and the greater the frequency with which the pipe outfalls will be submerged.

This reduction of the freeboard requirement from 0.2 m to 0.1 m may serve a variety of purposes. Depending on the time of year, the resulting increased water level in the channel may increase the opportunity for sub-irrigation, which may in turn, aid crop and grass development. The higher water levels may also enable irrigation to continue when previously, due to lower water levels, restrictions may have been imposed. Also, higher water levels may be of benefit to the wildlife and ecology of the watercourse and a less intense maintenance regime may possibly be adopted.

5.9.1 Drainage assessment calculation sheet

The drainage assessment calculation sheets are presented in FDMM as Loose Material D. Sheet 3 enables the drainage score (HE/km/yr) to be derived. The Managing Flood Defences Summary Guidance Notes (undated), however, contain a different record sheet.

There are various inconsistencies on these sheets, as previously mentioned: namely, reference to indeterminate, average and poor drainage and the different potential waterlogging damage factors. In order *to address some of these inconsistencies and to improve clarity, Sheet 3 in Loose Material D has been redesigned*, as shown in Table 5.10. This revised version contains elements from both sheets. Changes are highlighted in red.

Table 5.10 Revised drainage status assessment calculation sheet (sheet 3 of 5 in FDMM)

To replace Sheet 3 of 5 in FDMM
Loose Material D

Data to be collected in the field

Assessor's name			Date	
Weather (wet or dry)				
Watercourse				
Bank				
Effective reach length drainage in flat floodplain (< 0.5 %)		km	Drainage system	
Effective reach length drainage in rising floodplain (> 0.5 %)		km	Drainage system	
Effective reach length drainage with underdrainage (km)		km		
Drainage status - Predictive	Good	km	Dominant soil type	
	Bad	km	Light	
	Very bad	km	Heavy	
Drainage status - Historical	Good	km	Flood risk area (ha) *	
	Bad	km	Areal drainage factor *	
	Very bad	km	Drainage benefit area (ha) **	

* Only required if drainage benefit area is not known

** If not known, multiply flood risk area by areal drainage factor

Analysis

		1	2	3	4	5
a	Land use type	Forestry scrub	Extensive pasture	Intensive pasture	Extensive arable	Intensive arable
b	Proportion of drainage benefit area (100 ha) under each land use					
c	Area subject to deterioration in drainage status, without maintenance (100 ha)					
d	Losses due to deterioration in drainage status (HE/100 ha/yr)	0	1.1	4.5	3.6	9.7
e	Losses per land use type (c * d)					
f	Total losses for reach (HE/yr) (sum of line e)					
g	Net loss (HE/yr)	Predictive			Historical	
h	Drainage score (HE/km/yr) (g / effective reach length)					

Note: In line (d), the potential waterlogging damage factors listed in FDMM Table 3.9 are used.

5.10 Agricultural Drainage Benefits

The net returns contained within FDMM, which were produced by Silsoe College, are based on 1993 economic prices. They are a measure of the change in farm income and expenditure expressed in terms of gross margin (value of output less direct variable costs) and semi-fixed costs, as for example, when an area of land changes from arable to grazing due to inadequate drainage, without affecting the major cost structure of the farm. If, however, land use switched from arable to pasture over the whole farm, the cost structure of the farm would change. Fixed costs may be reduced and semi-fixed costs may rise. This may lead to an over-estimation of the losses associated with a deterioration in drainage status in the absence of maintenance. Throughout the whole analysis in FDMM it is assumed that the cost structure of the farm does not change. The user must be aware of this.

Economic prices show the value of benefits and costs to the nation after removing Government taxes and subsidies and other distortions to market prices.

The net returns presented in FDMM (Table 5.12) need to be updated in order to reflect the changes in market and agricultural policy which have occurred since 1993. The revised figures, in 1997/98 prices are shown in Table 5.11. Some of the input prices were updated using relevant price indices and the remainder, using agri-economic databases and routines. In order to avoid the need to update these figures annually, medium term price inflation indices may be used to reflect predicted input/output values over, for example, a five year period.

Table 5.11 Losses due to deterioration in drainage status (£/ha) by land use

Existing Land Use	Extensive Pasture	Intensive Pasture	Arable
Deterioration in drainage status not leading to land use change			
Good to Bad	8	75	65
Bad to Very Bad	22	114	104
Good to Very Bad	30	189	169
Serious deterioration in drainage status leading to land use change			
Intensive Pasture to Extensive Pasture *		401	
Extensive Arable to Extensive Pasture **			378

Note: * based on intensive pasture good drainage switching to extensive pasture bad drainage
** based on extensive arable good drainage switching to extensive pasture bad drainage
1997/98 economic prices

In the calculation of the change in net return due to drainage deterioration, within FDMM, intensive and extensive arable land have been reclassified as arable. As shown in Table 5.12, the impact of this reduced detail on the losses associated with drainage status deterioration, however, is minimal. This is because the use of economic prices requires that the gross output of cereals, oil seeds and grain legumes such as peas and beans are reduced by 10% to derive economic values. Enterprises subject to quota such as milk, potatoes and sugar beet are treated as wheat on the grounds that output losses in one area would be made up by increased production elsewhere, displacing wheat in the process. The current set-aside area is also treated as wheat because the set-aside scheme is seen as a transitional programme with land returning to productive use at some future time.

Table 5.12 Losses due to deterioration in drainage status: extensive and intensive arable (£/ha)

Change in Drainage Status	Extensive Arable (£/ha)	Intensive Arable (£/ha)	Arable (£/ha)
Good to bad	66	63	65
Bad to very bad	102	108	104
Good to very bad	168	171	169

1997/98 economic prices

The view has been expressed by personnel within the Environment Agency that Table 5.12 in FDMM (p5/25), reproduced here in Table 5.13, is not easily interpreted. It shows the changes in net return which would result for a given land use if a deterioration in drainage status were to occur. Negative values indicate a loss in net return and positive values indicate a saving. These figures have been derived from the net returns (£/ha, 1993 economic prices) produced by Silsoe College for each land use according to drainage status.

Table 5.13 Deterioration in maintenance standards, change in economic net margins (£ per ha)*

Existing Land Use	Extensive Pasture	Intensive Pasture	Arable
Deterioration not leading to land use change			
Good to Bad	-2	+14	-98
Bad to Very Bad	-9	+1	-148
Good to Very Bad	-11	+15	-246
Serious deterioration leading to land use change			
Intensive Pasture to Extensive Pasture		+106	
Extensive Arable to Extensive Pasture			-228

Note: * Net margins per hectare taken as gross margins less semi-fixed costs, at 1993 economic prices
Source: NRA, 1995, Table 5.12

It has been *suggested that this table is replaced with that shown in Table 5.14, in order for the net returns for each land use under each drainage condition to be easily identified.*

It is considered that this revised table would aid understanding of the economic impact of drainage status deterioration and would serve as a useful tool when explaining maintenance decisions to the Public, especially farmers.

Table 5.14 Economic net return according to land use and drainage status

	Existing Land Use		
Drainage Status	Extensive Pasture	Intensive Pasture	Arable
Economic Net Return (£/ha)			
Good	-73	320	293
Bad	-81	245	228
Very Bad	-103	131	124
Marginal Economic Losses Associated with Drainage Status Deterioration (£/ha)			
Good to Bad	8	75 *	65
Bad to Very Bad	22	114	104
Good to Very Bad	30	189	169
Deterioration Leading to Land Use Change			
Intensive Pasture to Extensive Pasture			423 **
Arable to Extensive Pasture			374 ***

Note: 1997/98 economic prices are used. Figures are subject to rounding.
* Deterioration in drainage status from Good to Bad on Intensive Pasture results in a loss of £75/ha.
** Deterioration from Good drainage on Intensive Pasture to Very Bad drainage and change in land use to Extensive Pasture results in a loss of £423/ha. (Net return of £320/ha is replaced by one of £-103/ha).
*** Deterioration from Good drainage on Arable land to Bad drainage leading to a change in land use to Extensive Pasture results in a loss of £374/ha. (Net return of £293/ha is replaced by one of £-81/ha).

5.11 Maintenance Expenditure, Maintenance Benefits and Justification

FDMM requires that expenditure on maintenance and capital projects for the reach in question is identified. This expenditure relates to that on the main river only. *If, however, IDB/IDD watercourses, highland carriers and other channels are included in the calculation of flood risk area and effective reach length, the associated maintenance expenditure should also be included in the benefit:cost analysis.* This should be made clear in FDMM.

If the main river under consideration discharges into another main river and derives benefit from maintenance on the latter, for example, as in the case of Watton Beck discharging into the River Hull, a proportion of the maintenance expenditure associated with this latter main river should be attributed to that for the river under study. This associated cost may be apportioned on the basis of percentage of flow derived from each watercourse at the point of confluence.

If IDB/IDD and other watercourses are included in the analysis of flood risk area and effective reach length, their associated benefits must also be included. If these benefit areas lie within that for the main river, they are automatically included in the analysis. If this is not the case, the benefit areas must be identified and FDMM applied in the normal way in order to identify associated benefits. If the benefits are not known, as in the case of highland carriers, it is recommended that these benefits are not estimated as this would reduce the accuracy of the FDMM justification process. Instead, *it is suggested that the type of these additional benefits is noted and only if the maintenance scheme appears to be marginal, should some measure of these additional benefits be made in order to assess the justification for the scheme.*

Similarly the *benefits of tree and bush maintenance* are difficult to quantify, especially without detailed hydrological modelling of the catchment and flow regime. The benefits of such work may include, for example, the prevention of structural damage to bridges, through the undermining of their foundations due to localised erosion caused by debris dam forming against bridge supports. This type of benefit *should be noted.*

Within FDMM, it must be made clear that local circumstances and peculiarities should be taken into account when calculating maintenance benefits and expenditure. For example, in the case of Winestead Drain, a pumping station situated at the head of 'main river' is used to pump water from the IDB watercourse which lies upstream, into Winestead Drain. The adjacent floodplain of the main river which lies downstream of the pumping station derives no benefit from this pumping station and yet its maintenance expenditure and running costs are taken into account when justifying maintenance. *In order to balance the assessment, the benefits afforded by the pumping station should be added to the benefits of maintenance on Winestead Drain and taken into account in the benefit:cost analysis.* This would mean the inclusion of the IDB watercourse and any associated costs, in the analysis. This has been addressed in Chapter 4.

The variations described here will have an impact on the results from the benefit:cost analysis for each of the case study watercourses. To avoid under-estimation of maintenance expenditure, it is *suggested that a systems, approach is adopted, whereby the total costs of maintenance works within the system (asset management such as maintenance of pumping stations, floodbanks and weirs, routine maintenance and reactive maintenance such as removal of debris which accumulates against bridge supports) are compared to total benefits.*

It is *recommended that before using FDMM, a simplified catchment map is drawn* which identifies all watercourses within it. This would enable a catchment approach to be adopted rather than focusing on specific reaches.

5.11.1 Annual maintenance

The benefits of flood alleviation are determined by subtracting the average annual number of HEs affected with maintenance (AAN_{with}) from the average annual number of HEs affected without maintenance ($\text{AAN}_{\text{without}}$) and multiplying this figure by the value of one HE. Table 5.15 uses Kelwell Stream as an example to illustrate this process.

Table 5.15 Example of calculation of benefits of flood alleviation, using Kelwell Stream

	HEs Affected by Flooding Without Maintenance ($\text{AAN}_{\text{without}}$) (a)	HEs Affected by Flooding With Maintenance (AAN_{with}) (b)	(a) - (b) = (c)	Annual Benefit of Flood Alleviation (£) *
Scenario 1, Annual flood occurs in first year of no maintenance				
Left Bank	7.223	2.213	5.010	6533
Right Bank	13.256	4.061	9.194	11990
			Total	18523
Scenario 2, Annual flood occurs in tenth year of no maintenance				
Left Bank	9.494	2.213	7.281	9494
Right Bank	17.424	4.061	13.362	17424
			Total	26918

Note: * Annual benefit of flood alleviation = (c) x value of one HE (£1304)
1997/98 prices are used. Figures are subject to rounding.

Without maintenance, over a number of years, channel capacity is expected to be reduced due to vegetation growth, siltation and accumulation of debris. Consequently, the impact of the annual flood occurring after, for example, 10 years without maintenance, is liable to be greater than if the annual flood occurred after one year without maintenance.

This point should be noted in FDMM with a recommendation that *sensitivity analysis be carried out to determine the impact on the* $\text{AAN}_{\text{without}}$ *of the annual flood occurring at different times following the cessation of maintenance. If the benefits of maintenance appear* *to be marginal, a representative annual benefit may be derived by discounting the average value of incremental losses over the period from Scenario 1 - year 10, for example, to derive the present value of these average incremental losses, and adding this to the losses under Scenario 1.* Table 5.16 shows a worked example of this. Further details are presented in Chapter 4 and in Appendix I and IV.

Table 5.16 Estimation of losses due to flooding, assuming deterioration in channel capacity without maintenance, Kelwell Stream

		Left Bank	Right Bank
Benefit lost under Scenario 1 (£)	(a)	6533	11990
Benefit lost in year 10 (£)	(b)	9494	17424
Incremental loss over 10 years (£)	(b) - (a) = (c)	2961	5435
Average value of incremental loss (loss in year 5) (£)	(c) / 2 = (d)	1481	2717
Discount factor at 6 % (year 5)	(e) see Appendix II	0.747	0.747
Present value of average incremental loss (£)	(d) x (e) = (f)	1106	2031
Average annual loss assuming further deterioration (£)	(f) + (a)	7639	14020
Total of both banks (£)		21659	

Note: Figures are subject to rounding. 1997/98 prices are used.

5.12 Actual Standard of Service

Attention is drawn to the target Standard of Service identified in FDMM. The key issue is whether the existing maintenance regime is providing a service appropriate to the associated land use, and if not, how it should be adjusted to do so. Maintenance activities are prioritised on the basis of the degree to which the reach is over- or under-serviced.

Based on an analysis of existing Standards of Service in 489 examples from the Wessex region of the previous NRA, a target Standard of Service of 0.5-1.0 HE/km/yr has been set by the Environment Agency. This serves as an initial recommendation (Howells et al, 1992). These trials using Standard of Service data from the Wessex region showed the method to be a high level, simple method for prioritisation. However, the majority of reaches were assigned a low priority even though they received most of the maintenance expenditure. This was attributed to the fact that the Standard of Service score only accounted for flooding. Maintenance carried out for land drainage benefits was not considered. CRIMS recommended that the drainage element should be included in the Standard of Service score. This recommendation has been carried out within FDMM.

Following the application of FDMM to a significant proportion of watercourses in a region, it is suggested that the target Standard of Service of 0.5-1.0 HE/km/yr is reviewed. This target should reflect policy, criteria, public perception and available resources at a given point in time. If the target range is altered, the rationale for doing so should be documented for future reference. The basis for determining the target Standard of Service should be transparent. The links between the Standard of Service provided and the associated benefit:cost ratio should be understood.

5.13 Worked Example

Throughout FDMM various examples are used to illustrate particular procedures. *It is recommended that the same example watercourse be used throughout FDMM to demonstrate its application.* Winestead Drain or Watton Beck could be used as the example. The benefit of using either of these watercourses is that some of the points raised in the preceding sections are highlighted by these sites.

5.14 References and Data Sources

It is *suggested* that in addition to including references in the text throughout FDMM, a *comprehensive list of references cited and supporting documentation is presented at the end of the manual.*

Users of FDMM may also find it beneficial if the *source of data presented in tables were cited underneath the table.* This would increase the transparency of FDMM and help to remove some of the mystery surrounding derivation of data. Sources of the data are quoted throughout this report and summarised here in Table 5.15.

5.15 Glossary

It is recommended that the glossary presented at the front of FDMM (Page xi-) is expanded to include the following technical terms which are used in FDMM:

- Amortisation
- Bankfull discharge
- Discounting
- Dominant discharge
- Dominant water level
- Effective benefit width
- Flat/rising floodplain
- Justification
- Net return
- Theoretical freeboard

Table 5.17 Sources of data contained within FDMM (Volume 029 Version 1, 1995)

Table	Page	Title	Source
3.1	3/4	Standards of Service land use bands and targets	Economic Appraisal of Non-Grant Aided Work. Howells et al. (1993) R&D Note 187.
3.2	3/7	Features of interest - flood risk area	Source unknown.
3.4	3/12	Land use bands, HEs/km and typical description	Flood Defence Levels of Service. Stage 2. Robertson Gould Consultants, (1990).
3.5	3/14	Flood event severity weighting factors - historical method	Based on Hess and Morris (1986). Technical papers.
3.6	3/14	Salinity weighting factor	Economic Appraisal of Non-Grant Aided Work. Howells et al. (1993) Project Record.
3.8	3/21	Areal drainage factor	CRIMS Project Record. Howells et al. (1992).
3.9	3/22	Potential waterlogging damage	Derived from CRIMS Project Record. Howells et al. (1992).
3.10	3/24	Actual Standard of Service	CRIMS Project Record (Howells et al. (1992).
5.1	5/5	Appropriate levels for appraisal input	Economic Appraisal of Non-Grant Aided Work. Howells et al. (1993) R&D Note 187.
5.2	5/14	Approach 1 -normalised damage value and annual benefits	Economic Appraisal of Non-Grant Aided Work. Howells et al. (1993) R&D Note 187.

5.3	5/15	House equivalents for fluvial and saline flooding	Economic Appraisal of Non-Grant Aided Work. Howells et al. (1993) Project Record.
5.4	5/17	Non-residential property size bands and values	CRIMS Project Record. Howells, et al. (1992).
5.5	5/17	Non-residential property size guide	CRIMS Project Record. Howells, et al. (1992).
5.6	5/19	HE depth damage data	Economic Appraisal of Non-Grant Aided Work. Howells et al. (1993) R&D Note 187.
5.7	5/19	Reduction in damages owing to flood warning	Economic Appraisal of Non-Grant Aided Work. Howells et al. (1993) R&D Note 187.
5.8	5/20	Average annual costs (£/ha) for a single flood occurring in a year	Economic Appraisal of Non-Grant Aided Work. Howells et al. (1993) R&D Note 187. Calculations in Appendix A by Silsoe College.
5.9	5/20	Saline multipliers	Economic Appraisal of Non-Grant Aided Work. Howells et al. (1993) Project Record.
5.10	5/21	Traffic disruption costs	Economic Appraisal of Non-Grant Aided Work. Howells et al. (1993) R&D Note 187. Modified "Red Manual" method.
5.11	5/24	Drainage status assessment	CRIMS Project Record. Howells, et al. (1992).
5.12	5/25	Deterioration in maintenance standards, change in economic net margins (£/ha)	Economic Appraisal of Non-Grant Aided Work. Howells et al. (1993) Project Record.
5.13	5/25	Areal drainage factors	CRIMS Project Record. Howells, et al. (1992).
	5/26	Emergency relief	Urban Flood Protection benefit: A Project Appraisal Guide. Parker et al. (1987). ("Red Manual").
5.3	5/13	Normalised damage frequency curve	Economic Appraisal of Non-Grant Aided Work. Howells et al. (1993) R&D Note 187.
5.4	5/16	Annual average number HEs affected	Economic Appraisal of Non-Grant Aided Work. Howells et al. (1993) R&D Note 187.
5.5	5/22	Annual average damages	Economic Appraisal of Non-Grant Aided Work. Howells et al. (1993) R&D Note 187.

5.16 Additional Points

To aid interpretation of FDMM it is recommended that the following changes and corrections are made:

- *Reference to the National Rivers Authority (NRA) is replaced by the Environment Agency*, unless it is the NRA that is being quoted specifically.
- *One consistent definition of a flood defence system should be used:* In the glossary and on p2/3 paragraph 5, two different definitions are given.
- It would be beneficial if a *definition of the effective benefit width* (FDMM p3/23 paragraph 77) were included in the glossary. This is defined as the average floodplain width multiplied by the areal drainage factor in the Loose Material D, Sheet 3.
- There is *inconsistency in terminology* between the land use assessment reach summary sheet presented in FDMM p3/10, Table 3.3 and in Loose Material A, p2. It is assumed that reach length (FDMM Table 3.3) should read effective reach length (flooding) as it is the effective reach length that is referred to in the text (FDMM p3/11 paragraph 28).

- In FDMM Table 3.3 p3/10, the *land use area shown within the reach summary totals 300 ha, which is different to the floodplain area shown at the top of the table (250 ha). These total areas should be the same.*
- *The agricultural drainage assessment is described in FDMM paragraphs 60-70, and not in paragraph 62, as stated in FDMM (p3/11 paragraph 29).*
- *For consistency, number may be referred to as either 'Nr'. or 'Number'* throughout FDMM. Currently, both are used although 'Number' is used most frequently.
- *Throughout FDMM when the flood and drainage score are discussed, it is recommended that the identifiers 'flood' or 'drainage' are used.* The term 'score' when used on its own may be misleading.
- *All prices within FDMM should be updated to 1997/98 values.* The location of tables containing price data are shown in Table 5.16.

Table 5.18 Location of price data within FDMM which needs updating to 1997/98 values

FDMM Reference	Location	Title	Price base used in FDMM
Table 5.7	Page 5/19	HE Depth damage data	1993
Table 5.8	Page 5/20	Average annual cost (£/ha) for a single flood occurring in a year	1993
Table 5.10	Page 5/21	Traffic disruption costs	1993
Table 5.12	Page 5/25	Deterioration in maintenance standards, change in economic net margins (£/ha)	1993
	Page 5/26	Emergency relief	1985

- Financial and economic prices are both used in FDMM. The distinction between these two sets of prices should be made clear. Financial prices show the prices paid and received by private individuals such as farmers. Economic prices show the value of benefits and costs to the nation after removing Government taxes and subsidies and other distortions to market prices.
- The general appearance of FDMM could be improved if there was consistency in layout and presentation. For example, making sure that a space is left before and after each table and that table headings line up with the text.
- For simplicity, it is suggested that the loose material and record sheets within FDMM are renamed as Form 1,2,3 etc. rather than for example, 'Loose Material D Sheet 1/5'.
- It is recommended that FDMM is revised to take account of the modifications and points suggested in this Chapter and that the respective record sheets are re-designed accordingly.

5.17 Summary

This Chapter has presented the findings from an evaluation of FDMM. Modifications to FDMM have been suggested. These relate in particular to the reflection of site specific circumstances. Clarification of elements within FDMM including the derivation of the various adjustment factors has been provided. In addition, general points relating to layout, corrections and terminology have been made.

The following Chapter contains a critical evaluation of the Guidelines for the Justification of River Maintenance.

6. EVALUATION OF THE GUIDELINES

6.1 Introduction

This Chapter presents a critical review of the Guidelines for the Justification of River Maintenance. Descriptions of the procedures discussed here and terminology used are presented in Chapter 2. Issues are discussed in order of their appearance in the Guidelines and not in terms of their significance.

Although the Guidelines are a comprehensive system for justifying maintenance operations, specific aspects require clarification and elaboration. These, in addition to modifications and recommendations to the Guidelines are discussed in this Chapter.

The Guidelines adopt a system approach, whereby the total benefit of maintenance are compared with the total costs of maintenance works within the system. Tributaries and IDB/IDD watercourses are included in the analysis.

6.2 Benefit Area

The identification of the benefit area is crucial to the application of the Guidelines and the benefit:cost analysis is sensitive to the assumptions made.

The benefit area relates to the total agricultural area of the floodplain which benefits from maintenance in terms of flood alleviation and improved standards of drainage service. This includes the area served by tributaries and IDB/IDD watercourses. Urban areas are excluded from the analysis as these receive different standards of flood protection.

For simplicity, no distinction is made between the area served on the left or right bank. It is suggested that if analysis of each bank is to be undertaken separately, two sets of record sheets are completed; one set for the left bank, and one for the right bank. It is not recommended that the current record sheets are revised in order that the benefit area may split into that lying on the left and right bank of the watercourse as this would increase the complexity and reduce the clarity of the record sheets.

6.3 Reach Length

The reach length represents the length of watercourse which lies within the area benefiting from maintenance activities. This should be made clear within the Guidelines. It is therefore recommended that the benefit area is identified prior to calculation of the reach length. The 'General Information' record sheet has been redesigned to reflect this as shown in Appendix X.

6.4 Catchment Size

Catchment size influences the seasonal distribution of flooding. Large catchments experience predominantly winter flooding whilst small catchments contain a relatively higher incidence of summer flooding. Currently within the Guidelines, the unit of sq. km is used to define catchment size. It is recommended that this unit is replaced with hectares (1 km^2 = 100 ha) in order for consistency to be maintained throughout the Guidelines (hectares are used as a measurement of benefit area and flooded area). Hectares are also generally more widely used by the farming community than sq. km as a unit of area. A large catchment would therefore have an area greater than 2500 ha and a small catchment less than 2500 ha respectively.

6.5 Land Use

Within the Guidelines, seven land use types are identified; namely, extensive grass, intensive grass, grass/arable rotation, all cereals, cereal/oilseed rotation, cereal/rootcrop rotation and horticulture. For consistency within FDMM, it is recommended that the term grass is replaced with pasture.

Land use which is not classified as one of these seven types is classed as 'other'. It is recommended that this eighth category of land use is removed from the Guidelines as this 'other' land use does not feature in the analysis and benefits and costs are not assigned to it.

6.6 Soil Type

For simplicity, the Guidelines identify four soil types; namely: sand, silt, loam and clay. If for example, the actual soil type in the benefit area is clay loam, the soil type is taken to be clay as clay is listed first and therefore is assumed to be the major soil particle component. This point should be made clear in the Guidelines.

It is not recommended that the number of soil types identified within the Guidelines is increased as this would greatly increase the complexity of the system. For example, if the second major soil component were included, for example as in, sandy silt, sandy clay and sandy loam, the number of soil types represented in the Guidelines immediately increases from four to 16. Emphasis is placed on the major soil component as it is this which has the most influence on determining soil type and hence the response to river maintenance.

6.7 Channel Parameters

The Guidelines are reliant on data relating to channel parameters and are sensitive to assumptions made. The average bed width, average channel depth and bankfull discharge under the current situation are used to determine the impact of maintenance on freeboard and bankfull discharge. At the present time these parameters are often estimated by the Environment Agency, due to a lack of measured data. Whilst these estimates are based on experience and knowledge of the specific watercourse, estimates introduce an element of error into the analysis.

A rapid and possibly more accurate method of determining bankfull discharge is to combine information on channel roughness and dimensions using the Manning's equation (Richards, 1985). The components of this equation may be obtained from cross-sectional surveys or through rapid visual assessment of the channel. Further information on this is presented in Dunderdale and Morris, 1996a, River Maintenance Evaluation.

$$Q = \frac{AR^{2/3}S^{1/2}}{n}$$

where: Q = Discharge, m^3/s
A = Cross-sectional area, m^3
R = Hydraulic radius, m (cross-sectional area divided by perimeter)
S = Slope
n = Manning's 'n' coefficient

The bankfull discharge is used to calculate flood return periods. If these are known, then it is not necessary to calculate the bankfull discharge. This should be made clear in the Guidelines.

6.8 Drainage and Flooding Benefit Areas

The area benefiting from improvement in the standard of drainage service provided may not be the same area as that benefiting from flood alleviation, as currently assumed within the Guidelines.

6.8.1 Drainage benefit area

If undertaking a simple or rapid assessment of maintenance benefits, whereby the dominant land use is used, drainage benefit areas may be identified for each bank, in order to increase the accuracy of analysis. This modification may be easily incorporated into the Design Standard record sheet without increasing complexity, as shown in Appendix X.

If a detailed assessment is required, the drainage benefit area of each land may be identified. As shown in Appendix X. Identification of these various drainage benefit areas will not increase the complexity of the Guidelines.

6.8.2 Flooding benefit area

If a simple or rapid assessment is being undertaken using the dominant land use, the area benefiting from flood alleviation due to maintenance is identified. This may, or may not be the same as the drainage benefit area.

If a detailed assessment is undertaken, the area under each land use which benefits from flood alleviation is identified.

The Design standard record sheet has been redesigned to accommodate these modifications and is shown in Appendix X.

6.9 Drainage Status

If the drainage status 'with' and 'without' maintenance is known, this can be entered directly into the record sheets, avoiding the need to calculate the freeboard and associated watertable depth. This point must be made clear in the Guidelines.

6.10 Freeboard : Watertable Relationship

Through use of the Guidelines, it has become clear that further explanation as to the interpretation of the freeboard:watertable relationship graphs is required. It is recommended that several examples are used to illustrate their use and to provide clarification.

For example, in a rising floodplain, with a clay loam soil and freeboard of 1 m, the depth to watertable is taken to be 0.5 m, if the user reads off the graph along the clay/loam line. If, however, the soil components indicate a higher proportion of clay than loam, the user may wish to take this into account by selecting a point below the clay/loam line, nearer towards the clay line. If the mid-point between the clay/loam and clay line were used, the depth to watertable would be 0.3 m. This clearly has implications for the classification of drainage status and Standard of Service provided. The triangular diagram for determination of soil texture based on the proportional content of sand, silt and clay may be used to assist the user in selecting the appropriate point on the freeboard:watertable graph (E.g. Landon, 1991, Appendix IX).

6.11 Economic Net Return

Economic prices show the value of benefits and costs to the nation after removing Government taxes and subsidies and other distortions to market prices.

The net returns are a measure of the change in farm income and expenditure expressed in terms of gross margin (value of output less direct variable costs) and semi-fixed costs, as for example, when an area of land changes from arable to grazing due to inadequate drainage, without affecting the major cost structure of the farm. If, however, land use switched from arable to pasture over the whole farm, the cost structure of the farm would change. Fixed costs may be reduced and semi-fixed costs may rise. This may lead to an over-estimation of the losses associated with a deterioration in drainage status in the absence of maintenance. Throughout the whole analysis in the Guidelines it is assumed that the cost structure of the farm does not change. The user must be aware of this.

At present, the economic net return is calculated in £/ha using the record sheets presented in the Guidelines. In order to provide a measure of total benefits and to enable a direct comparison with FDMM, it is recommended that the record sheets are modified to calculate net returns in £/ha and in total (£) across the whole drainage benefit area.

6.12 Flood Return Periods and Costs

The flood return period is selected from 1-2 years, 3-5, 6-10 and >10 years. If flooding occurs at a frequency of less than every 10 years, the associated costs and impact on productivity are minimal, hence return periods of greater than 10 years are not identified. This should be made clear in the Guidelines.

If a detailed analysis is undertaken, the area of each land use flooded is calculated as in Section 10.7.2 and the associated flood return period identified from the range provided (1-2, 3-5, 6-10, >10 years). This procedure is contained within the original Guidelines whereby flooding envelopes are identified.

As the Guidelines stand at present, flood costs are assumed to be additive. For example, if 10 ha of intensive pasture floods with a return period of 3-5 years (bad drainage, large catchment) the flood cost is £4/ha or £40 (1997/98 prices). If a further 20 ha of land under a cereal/oilseed rotation within the same catchment floods with a return period of 6-10 years at a cost of £6/ha (good drainage), total flood costs for this land use are £120 (1997/98 prices). Within the Guidelines, these flood costs are added to derive a total annual flood cost of £160 (1997/98 prices) (£40 + £120).

This methodology was adopted in the Guidelines for the purpose of simplification and to keep the data requirements to a minimum. Within earlier documentation which was the precursor to the Guidelines, flooding envelopes were identified and incremental costs were calculated. This is the approach currently adopted in FDMM (Approach 2, p5/14).

Using this approach, an estimate of average annual flood damage costs for the entire benefit area can be obtained by combining data on flood return period and area flooded with the annual costs per flood of a given frequency. For example, areas flooded at different return periods are shown in Table 6.1. The corresponding flood costs are shown in Table 6.2.

A graph is drawn to show the relationship between area flooded and flood costs (Figure 6.1). The area under the curve represents the total average annual flood damage costs at a given level of flood risk. The incremental flood costs are calculated from Figure 6.1 and shown in Table 6.3.

Table 6.1 Flood return period, flows and area flooded

Return Period (years)	Tp *	Flow (cumecs)	Flooded Area (ha)	Percentage
2	1.4	40	550	19.6
5	4.5	61	1130	40.4
10	9.5	75	1530	54.6
etc.	etc.	etc.	etc.	etc.

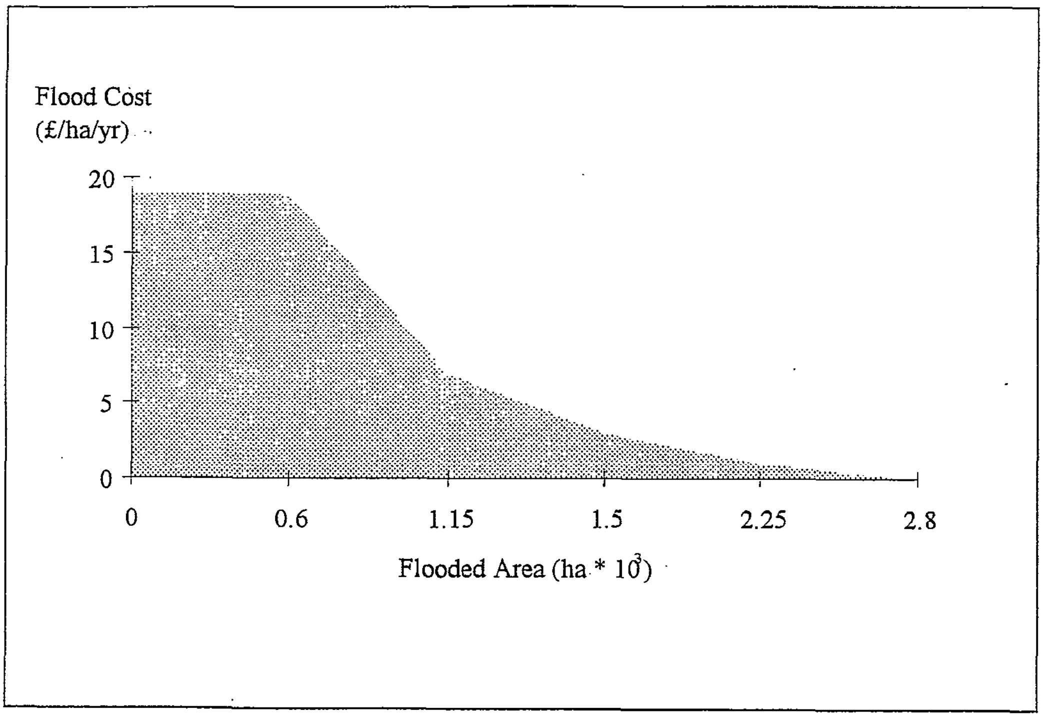
* Peaks over threshold: average interval (years) between flows of a given magnitude
Source: Morris and Hess, 1988

Table 6.2 Summer flood damage

Return Period (years)	Tp *	Flow (cumecs)	Flooded Area (ha)	Probability of 1 Flood	Probability of 2 Floods	Flood Cost (£/ha/yr)
2	1.4	40	550	35 %	12 %	19.54
5	4.5	61	1130	18 %	2 %	7.27
10	9.5	75	1530	9 %	0 %	3.49
etc.	etc.	etc.	etc.			

Source: Morris and Hess, 1988

This approach prevents the double counting of flood costs and therefore over-estimation of the benefits of flood alleviation. It is suggested that this procedure is reintroduced into the Guidelines to provide an alternative approach to the calculation of flood costs. The level of data available and the level of detail at which the analysis is to be undertaken will determine which methodology is used.



The area under the curve represents the total average annual flood costs at given level of flood risk
Source: Morris and Hess, 1988

Figure 6.1 Flood costs: 'area under the curve' methodology

Table 6.3 Summary of flood events, area and costs

Return Period (years)	Flow (cumecs)	Flooded Area (ha)	Annual Loss (£/ha/yr) *	Total Incremental Costs (£/yr)	Cumulative Average Annual Cost (£/yr)
2	40	550	19.54	10747	10747
5	61	1130	7.27	7775	18522
10	75	1530	3.49	2153 **	20675
etc.	etc.	etc.			

* Estimated by interpolation along the curve in Figure 6.1

** E.g. ((7.27 + 3.49)/2) x (1530 - 1130) = £2153/yr. Figures are subject to rounding.

Source: Morris and Hess, 1988

6.13 Maintenance Benefits

To avoid under-estimation of maintenance expenditure, a system, approach is adopted in the Guidelines, whereby the total costs of maintenance works within the system (asset management such as maintenance of pumping stations, floodbanks and weirs, routine maintenance and reactive maintenance such as removal of debris which accumulates against bridge supports) are compared with total benefits. The benefits associated with IDB/IDD watercourses and highland carriers are therefore taken into account.

This approach may be highlighted through use of Winestead Drain as an example. A pumping station is situated at the head of 'main river' and is used to pump water from the IDB reach of Winestead Drain into the main river. The maintenance expenditure associated with this pumping station and the IDB reach and the benefits of it, are included in that of main river. A true picture of costs and benefit is thus obtained, unlike within the FDMM whereby the costs of this pumping station are included in the analysis but the benefits are excluded.

The benefits of flood protection provided by highland carriers are also calculated in the Guidelines. The benefits of tree and bush maintenance however, are difficult to quantify, especially without detailed hydrological modelling of the flow regime and topography. This type of benefit should be noted and only estimated if the benefits of maintenance appear to be marginal.

6.14 Maintenance Expenditure

The Guidelines require that the total annual maintenance expenditure is identified for the reach under consideration. If tributaries of the main river and IDB/IDD watercourses are included in the analysis of the reach length and their associated benefit areas are included in the assessment, the maintenance expenditure on these watercourses is automatically included in the analysis. This point should be emphasised within the Guidelines. Expenditure on highland carriers and embanked reaches is included within the calculation of maintenance costs, as this expenditure enables delivery of the benefits associated with maintenance upstream. The Guidelines may also be used to justify the flood protection they provide.

In addition to expenditure on regular channel maintenance, the annual cost of maintenance on structures such as weed screens and outfall flaps should also be included in the analysis. In the current version of the Guidelines this is not clear.

6.15 Worked Example

A worked example is used in the Guidelines to demonstrate their use. It is recommended that several different examples are used to highlight usage of the simple and detailed approaches which may be adopted.

6.16 References and Data Sources

It is suggested that in addition to including references in the text throughout the Guidelines, a comprehensive list of references cited and supporting documentation is presented at the end of the document.

Sources of the data used within the Guidelines are quoted throughout this report and summarised here in Table 6.4.

Table 6.4 Sources of data contained within the Guidelines

Reference	Page	Title	Source
Table 1	16	Land use type	Sutherland and Morris (1993)
Table 2	17	River freeboard requirements	Morris, 1990, Hess et al, 1989
Table 3	17	Hydraulic conductivity	Various literature
Figure 1	18	Freeboard : watertable relationship, rising floodplain	Youngs et al, 1989
Figure 2	18	Freeboard : watertable relationship, flat floodplain	Youngs et al, 1989
Table 4	19	Drainage status and productivity	Sutherland and Morris (1993)
Table 5	20	Net returns	Dunderdale and Morris, 1996a
Figure 3	22	Regional growth curve area	NERC, 1975
Figure 4	23	Regional growth curves	NERC, 1975
Table 6	24	Flood costs for large catchment	Dunderdale, 1997, using SCADE
Table 7	24	Flood costs for small catchment	Dunderdale, 1997, using SCADE
Table 8-15	25-27	Impact of deepening, widening and vegetation cutting on freeboard and bankfull discharge	after Fisher, 1995
Table 16-17	27-28	Change in bankfull discharge and freeboard	after Fisher, 1995
Table 19	31	Discount, annuity and amortisation factors	Dunderdale and Morris, 1996a

6.17 Glossary

It is recommended that the glossary presented in the Guidelines (Page xi) is expanded to include the following technical terms:

- Amortisation
- Drainage benefit area
- Economic prices
- Financial prices
- Flooding benefit area
- Flooding envelopes

- Highland carrier
- Justification
- Net return - a clearer definition is required
- Waterlogging

6.18 Additional Points

To aid interpretation of the Guidelines it is recommended that the following changes and corrections are made:

- All prices within the Guidelines should be updated to 1997/98 values. The location of tables containing price data are shown in Table 6.5.

Table 6.5 Location of price data within the Guidelines which needs updating to 1997/98 values

Guideline Reference	Location	Title	Price base used in Guidelines
Table 5	Page 20	Net returns	1995/96
Table 6	Page 24	Flood costs for large catchment	1995/96
Table 7	Page 24	Flood costs for small catchment	1995/96

- The price base which is used in the analysis (E.g. 1997/98) should be clearly stated on the record sheets.
- Financial and economic prices are both used in the Guidelines. The distinction between these two sets of prices should be emphasised. Financial prices show the prices paid and received by private individuals such as farmers. Economic prices show the value of benefits and costs to the nation after removing Government taxes and subsidies and other distortions to market prices.
- All economic net returns, flood costs and maintenance expenditure is expressed as an annual figure. This should be made clear in the Guidelines and on the record sheets.
- The current version of the Guidelines calculates costs and benefits of maintenance in terms of £/ha. For ease of analysis and comparison with FDMM, it is suggested that the total benefits and costs are shown for the benefit area as a whole (£).
- It is recommended that the flow charts presented at the beginning of the Guidelines are removed. Their purpose was to guide the user through each step in the justification process. The record sheets, however, serve the same purpose and are clearer to interpret and use.
- It is recommended that the Guidelines are revised to take account of the modifications and points suggested in this Chapter and that the record sheets are re-designed accordingly. The revised record sheets are presented in Appendix IX.

6.19 Summary

This Chapter has presented the findings from an evaluation of the Guidelines. Modifications to the Guidelines have been suggested. These relate in particular the derivation of watertable depth and hence drainage status and the calculation of flood costs. Clarification of elements within the Guidelines has been provided. In addition, general points relating to terminology and layout have been made.

7. CONCLUSIONS AND RECOMMENDATIONS

7.1 Introduction

This Chapter summarises the aims and results of the Study and draws a number of conclusions. Recommendations arising from the Study are made. The ways in which the Guidelines may be used to support the agricultural component of FDMM are identified.

7.2 Summary

The aim of this Study was to evaluate the performance of FDMM through application to case study watercourses in predominantly rural areas, with reference to agricultural benefit assessment. For this purpose, six watercourses were selected for study within the North East and Welsh regions of the Environment Agency. These watercourses reflected a range of circumstances, flooding and drainage scenarios, land uses and maintenance activities.

Through application of FDMM and the Guidelines to these watercourses, the performance of the two systems has been evaluated.

The current maintenance regimes on all the case study watercourses appear to be justified using FDMM. The benefit:cost ratio obtained using FDMM is generally higher than that derived using the Guidelines. The methodological frameworks of each system have been compared and reasons for these differences in result explained.

Modifications to both systems have been suggested. These relate in particular to the reflection of site specific circumstances and peculiarities within FDMM and guidance in use of the adjustment factors. With respect to the Guidelines, modifications relate in particular to the way in which drainage status and flood costs are calculated. In areas where land use is predominantly agricultural, and drainage rather than flood alleviation is the main concern, the Guidelines can help to underpin FDMM and demonstrate that FDMM can be used to accommodate moderate agricultural interests.

7.3 Conclusions

The general conclusion of the study is that in the main, FDMM serves the purposes intended. It does provide an objective basis for deciding Standard of Service and assessing benefit:cost performance of river maintenance works.

Problems lie in the use and interpretation of underlying data, assumptions and procedures. These can be addressed to improve its ease and accuracy of use.

7.3.1 Application of FDMM and the Guidelines

A number of conclusions can be drawn regarding application of FDMM and the Guidelines:

- careful consideration must be given to drawing up a list of data requirements prior to undertaking data collection to ensure that FDMM is used to its full potential;
- correct identification of the benefit area is crucial;
- there is a general lack of data relating to flood return periods and areas inundated;
- estimation of data may reduce the accuracy of the analysis. However, estimates of the drainage benefit area were confirmed by use of the areal drainage factor;

- estimates of the actual Standard of Service provided are sensitive to the definition of effective reach length flooding and benefit area. Any changes to the prioritisation of maintenance activities based purely on the reach status must be undertaken cautiously;
- the benefit:cost ratio is sensitive to the assumptions made regarding expenditure associated with the operation and maintenance of pumping stations. Due to the great variability in these costs, this expenditure may be excluded from the analysis in order to determine if the current maintenance regime is justified;
- a catchment scale of analysis should be adopted whereby total benefits and costs attributed to the whole watercourse system, including areas served by IDB/IDD networks, embanked reaches and highland carriers, are included; and,
- a systems approach is adopted whereby the costs associated with asset management are included in the identification of total costs.

7.3.2 Comparison of results from FDMM and the Guidelines

Comparison of the benefit:cost ratios produced through application of FDMM and the Guidelines shows that the results are broadly similar. The ratios produced by FDMM are generally higher than those produced through the Guidelines. This is due to a combination of the following factors:

- in the absence of documented historical records, drainage status is estimated in FDMM whereas the Guidelines draw on standard data which are based on the results of extensive research and watertable modelling;
- within FDMM flood costs are calculated on the basis of the number of HEs affected. These HEs were calculated in 1991 and hence may not accurately reflect the current situation due to inflation and market factors which have changed in the intervening years;
- differences in the treatment of flood envelopes, which are assumed overlapping in FDMM and discrete in the Guidelines. Total flood costs calculated in FDMM are based on the sum of the incremental flood costs associated with the areas inundated at different return periods. Within the Guidelines, flood costs associated with each land use and return period are simply added together. This issue is discussed further in Chapter 6; and,
- differences in flood costs according to catchment size which is not identified in FDMM but which is identified in the Guidelines. Flood costs for small catchments are higher than those corresponding to the same flooding, land use and drainage scenario in a large catchment. In FDMM, the HEs/unit for agricultural land are based on the costs of a typical flood event occurring in a large catchment. If the catchment is classed as small, flood costs may be under-estimated using FDMM.

7.3.3 Quality of Results and User Confidence

FDMM and the Guidelines are the products of extensive research and both systems are underpinned by some hydrological and agri-economic modelling. Accuracy of the results obtained through their application is affected by the assumptions made and availability of detailed data.

Confidence in FDMM will increase as the approach and methods become more familiar to the user through more widespread adoption.

The Guidelines accommodate more variation in watercourses (for example, highland carriers and IDB/IDD channels) and benefit areas than FDMM and are therefore applicable to a wider variety of circumstances. This, coupled with the fact that the Guidelines offer a more transparent assessment has lead to confidence being placed in them by users for the purpose of agricultural benefit assessment.

7.4 Recommendations Regarding FDMM

The recommendation arising from the study which relate to FDMM are that:

- the modifications to FDMM which are discussed in Chapter 5 are implemented and the record sheets re-designed accordingly;
- attention is given to the definition of data requirements to enable FDMM to be used to its full potential;
- a catchment scale of analysis is adopted whereby benefits and costs of the whole watercourse system are studied, including IDB/IDD drainage networks, embanked reaches and highland carriers and costs associated with asset management;
- the derivation and application of the potential waterlogging damage factor is reviewed;
- default values are generated for use in cases where data are absent or limited;
- case studies are developed to show the application of FDMM. These would provide examples of their application to a range of circumstances;
- a case study is developed to demonstrate the integration of urban, semi-urban, rural and semi-rural benefit assessment;
- a training programme is devised and implemented throughout the Environment Agency. This would address needs which were specific to each user group, and would include training in the use of FDMM, including the background to its development and the derivation of the adjustment factors;
- a summary version of FDMM is produced for use on site; and,
- a review of FDMS is undertaken through application to the same case study watercourses used in this study to enable a comparison with FDMM. Currently, the results produced by these two methods are inconsistent.

7.5 Use of the Guidelines to Support FDMM

The agricultural component of FDMM may be supported by the Guidelines. The Guidelines may be used to:

- justify maintenance on IDB/IDD drainage networks which are tributaries of the main river. This would be particularly useful in areas of Wales such as in the Conwy Valley and in Lincolnshire where IDD/IDB watercourses are abundant;
- justify the flood protection provided by highland carriers. At present, flood risk areas associated with highland carriers are not defined using FDMM. The area at risk if a breach occurred should be included in the analysis. The Guidelines adopt a systems approach and therefore include the benefits and costs associated with maintenance on highland carriers;

- justify to a third party, such as a farmer, the rationale behind a decision to change the Standard of Service provided. The concept of HEs is rather abstract and complicated and more difficult to explain than that of monetary values. Detailed explanation will be required to help third parties understand the principle of HEs. The use of £/ha by the Guidelines directly relates changes in drainage status and flooding to the level of maintenance and Standard of Service provided. This concept will be more familiar and meaningful to the third party and sets the discussion at a level which will be understood more readily and easily; and,
- determine the current drainage status and that which is likely to prevail in the absence of maintenance if measured data are not available. These drainage conditions may then be used in FDMM. This will reduce the number of estimations which are made and hence the potential sources of error.

7.6 Recommendations Regarding the Guidelines

The recommendation arising from the study which relate to the Guidelines are that:

- the modifications to the Guidelines which are discussed in Chapter 6 are implemented and the assessment sheets re-designed accordingly;
- case studies are developed to show the application of the Guidelines in support of FDMM to accommodate peculiar circumstances and different levels of detail;
- the training programme recommended in support of FDMM and implemented throughout the Environment Agency includes training in the use of the Guidelines in support of FDMM; and,
- a spreadsheet version of the Guidelines is developed for use by the Environment Agency.

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Note: References in bold are major sources of data and methods on which FDMM draws.

APPENDICES

APPENDIX I

1. KELWELL STREAM

1.1 Introduction

This Appendix presents the results of the application of FDMM and the Guidelines to Kelwell Stream, North Kelwell and South Kelwell, in the North East of England.

1.2 Study Area

1.2.1 Channel characteristics and drainage network

Kelwell Stream and its feeder streams North Kelwell and South Kelwell rise near Old Ellerby approximately 4 km north east of Kingston upon Hull. The study reach extends from the upstream limit of main river on North Kelwell (GR. TA 51543 43729) and South Kelwell (GR. TA 51560 43680) to the confluence of Kelwell Stream with Foredyke Stream (GR. TA 51145 43730) (Figure 1).

The catchment area of Kelwell Stream, North Kelwell and South Kelwell, is estimated to be 16.7 km^2 (1670 ha). It is intensively drained both through field drains and the natural ditch system. The Environment Agency 'main' river total reach length is 5.2 km. The Beverly and Holderness Internal Drainage Board (IDB) also maintain two watercourses within the catchment, with a total reach length of 1.1 km. These discharge into Kelwell Stream.

Kelwell Stream, North Kelwell and South Kelwell (Kelwell System) discharge under gravity into Foredyke Stream and then into the Holderness Drain and finally into the River Humber through two pointed doors. Holderness Drain is tide-locked twice every day during periods of high tide.

The Kelwell System is embanked for much of its length. Downstream from Great Stanks (GR. TA 51372 43712) to the confluence with Foredyke Stream, the channel is wholly embanked for approximately 2.4 km. This section of Kelwell Stream does not provide a drainage function for the land through which it flows. This area is served by a network of IDB watercourses which flow underneath Kelwell Stream through culverts and discharge into Foredyke Stream just upstream of its confluence with Holderness Drain.

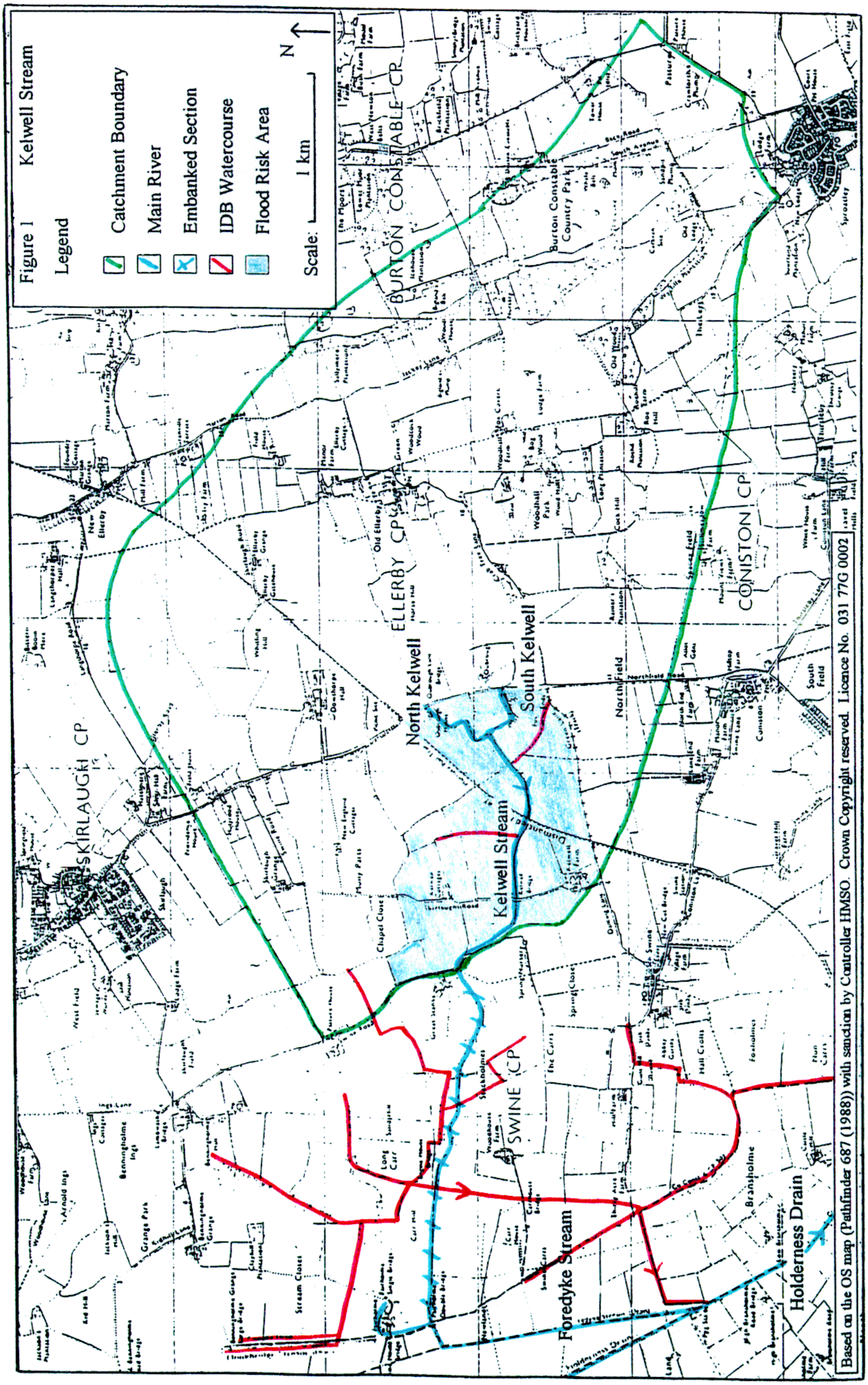
The channel of the Kelwell System is typically 4 m deep and 1.5 m wide at bed level, with a clay substrate. Freeboard under conditions of mean spring flow is estimated to be 1 m. The outfall of the field drains into the Kelwell System are typically at a depth of 1.5 to 2.5 m. Such a depth is needed to provide a sufficient gradient for the pipes to discharge into the river because the floodplain commonly falls away from the channel.

1.2.2 Catchment characteristics

This lowland catchment is predominantly rural in character. The area is well suited to the growing of cereal crops; in particular winter wheat and barley, with oilseed rape used as a break crop (Jarvis et al, 1984). From a visual survey of the catchment, details on land use were obtained. Land use is dominated by cereal and oilseed crops (98%), with small areas under potatoes (1%) and extensive pasture (0.5%). Small areas of woodland and scrub are also found within the catchment.

The solid geology of the area is characterised by chalk which is overlain by chalky till and alluvium. The Holderness Soil Association is characteristic of the area (Jarvis et al, 1984). It is a slowly permeable fine loamy soil with deposits of glaciofluvial drift. The most extensive soils are the Holderness series, which are fine, loamy stagnogley soils (Jarvis et al, 1984). (Stagnogley soils are gleyed soils in which a slowly permeable subsoil impedes surface water drainage). Soils of the Wallasea I Association may be found to follow the line of drainage ditches on land below the high tide level. The dominant soil type is clay loam.

Figure 1 Kelwell Stream



Based on the OS map (Pathfinder 687 (1988)) with sanction by Controller HMSO. Crown Copyright reserved. Licence No. 031 77G 0002

1.2.3 River Maintenance

Kelwell Stream, North Kelwell and South Kelwell are subject to annual weedcutting using an hydraulic excavator during the period September to November. All the aquatic vegetation in channel is removed. Prior to maintenance, the channel is usually completely choked with emergent vegetation with *Glyceria* (Reed Sweet Grass) and *Iris* (Yellow Iris) being the dominant types. The embankments of Kelwell Stream are flail mown and the numbers of vermin (rats/moles) are controlled.

The channel is subject to dredging approximately every 10 years. Between 0.1 and 0.2 m of silt is removed to reach hard bed level. Aquatic plant root systems are also removed with the silt which helps to reduce weed growth in the first few years following dredging.

Total annual maintenance costs for Kelwell Stream, including the embanked section, North Kelwell and South Kelwell are estimated to be £5300 (1997/98 prices).

The IDB channels are also subject to annual weedcutting using an hydraulic excavator during the same period (September to November). All the aquatic vegetation is removed. Tree and bush maintenance is carried out as required. Dredging of the channel takes place on average every 10 years. Approximately 0.2 m of silt is removed to reach the solid bed level. Total maintenance cost for 1997/98 are estimated to be £550. This includes a charge for desilting and tree and bush work, the costs of which have been amortised to derive an equivalent annual cost. (Amortisation is used to spread a single cost out as a series of annual payments). Further details on maintenance expenditure are presented in Appendix II.

1.3 Application of FDMM

1.3.1 Area of benefit

The area benefiting from maintenance in terms of flood alleviation is estimated to be 176 ha. This is termed the flood risk area and is shown in Figure 1. This area was derived from discussions with Environment Agency and IDB personnel. It follows the limit of the highest known flood event.

1.3.2 Land use assessment

Flooding

Land use and features of interest within the flood risk area are shown in the land use assessment reach summary sheet for the left and right bank which are presented at the end of this Appendix.

The area affected by fluvial flooding on the left and right bank is estimated to be 71.6 ha and 104.4 ha respectively. The area is not affected by saline flooding. The effective reach (the length of the main river for which a flood risk area is defined) is estimated to be 2.7 km for the left bank and 2.9 km for the right bank.

The flood score is derived by dividing the total HEs/km affected by flooding by the effective reach length.

Drainage

The area of each land use type subject to bad or very bad drainage conditions is determined and weighted by the appropriate factor (e.g. 3.6 HE/100 ha/yr for extensive arable). This drainage score represents the level of damage caused by waterlogging.

Under the current maintenance regime, the drainage status for the whole catchment is described as good, therefore the drainage score is zero.

1.3.3 Land use band

The flood and drainage HE/km scores are combined to determine the total HE/km for each bank (Table 1). The HE/km falls within the land use band 'D' range for the left bank (1.25-4.99 HE/km, see Table 2.2). Mixed agricultural land and isolated properties are at risk of flooding and waterlogging. The right bank is classed as band 'C'. High grade agricultural land is at risk of flooding and impeded drainage, with some properties also at risk of flooding.

Table 1 Land use band, Kelwell System

	Flood Score (HE/km)	Drainage Score (HE/km)	Total Score (HE/km)	Land Use band
Left Bank	3.06	0.0 *	3.06	D
Right Bank	5.92	0.0 *	5.92	C

Note: * the drainage status is described as good under the current maintenance situation
Figures are subject to rounding.

If the IDB tributaries were included in the effective reach length; as these derive benefit from maintenance on the main river and the embanked reach were included on the basis that it provides the outfall for the watercourse system, the land use band would be classed as 'D' on both banks. This is a realistic classification given land use observed in the floodplain.

1.3.4 Determining the effect of flooding

No historical records exist for Kelwell Stream, North Kelwell and South Kelwell as flooding is a rare occurrence due to frequent maintenance and large channel capacity. The effect of flooding is, therefore, based purely on use of the predictive technique.

The arithmetic method has been used. The predictive technique takes account of the flood return period at which different areas are inundated and an estimated long-term average annual value for HE affected is derived. The completed record sheets are presented at the end of this Appendix.

The area flooded by events with a return period of 1, 20 and 50 years were identified by the Environment Agency for the left and right bank under the current maintained situation. It must be noted that these areas are estimated as the actual areas flooded by the infrequent events are not documented. It is estimated that with a flood return period of 1 year, no flooding would occur. Under events with a return period of 20 and 50 years, it is estimated that 30% and 100% of the flood risk area would be inundated respectively.

A severity weighting of 2.2 has been applied to the total HEs/km affected by flooding to take account of the impact of timing and duration of flooding on arable crops. The number of HEs affected by flooding was derived on a pro-rata basis by multiplying the total number of HEs affected by 30% and 100%.

The process was repeated using estimates of flooded areas under the same return periods for the without maintenance situation.

At present, maintenance is undertaken annually. Without maintenance, over a period of years the channel capacity is expected to be reduced due to vegetation growth and siltation. Consequently, the impact of the annual flood after 10 years without maintenance, for example, is likely to be greater than its impact after one year without maintenance. To test the sensitivity of FDMM to this, the impact of two without maintenance scenarios (Table 2) has been assessed.

Table 2 Flooding scenarios, Kelwell System

	Annual Flood	Area Flooded (%)
Scenario 1	Impact of annual flood after one year without maintenance	5
Scenario 2	Impact of annual flood after 10 years without maintenance (Year 10)	40

The annual benefit of maintenance is shown by the benefit to be gained from the avoidance of flooding. This is derived by subtracting the Annual Average Number HEs affected with maintenance (AAN $_{\text{with}}$) from the Annual Average Number of HEs affected without maintenance (AAN $_{\text{without}}$) and multiplying this figure by the value of one HE (£1304 in 1997/98 prices).

The benefits (£) associated with each flooding scenario for both banks are shown in Table 3. The benefits associated with Scenario 1 are straight forward and represent the best estimate of benefits (associated with flood alleviation) which would be lost if maintenance were discontinued. Scenario 2 represents the average annual loss of benefit assuming there is a further deterioration in channel capacity over time due to lack of maintenance and consequently larger areas are flooded. These Scenario 2 benefits have been derived by discounting the average value of incremental losses over the period year between Scenario 1 and year 10 to derive the present value of these average incremental losses, and adding this to the loss under Scenario 1. Further details are presented at the end of this Appendix.

Table 3 Annual benefit associated with flood alleviation, Kelwell System

	AAN without (HE/km) (a)	AAN with (HE/km) (b)	(a) - (b)	Annual Benefit (£)
Left Bank				
Scenario 1	7.223	2.213	5.010	6533
Scenario 2	9.494	2.213	7.281	7639
Right Bank				
Scenario 1	13.256	4.061	9.194	11990 *
Scenario 2	17.424	4.061	13.362	14020 *

Note: 1997/98 prices are used. Figures are subject to rounding.
* Average annual loss of benefit assuming further deterioration.
Further details are presented at the end of the Appendix.

1.3.5 Determining the effect of deterioration in drainage

To determine the effect of inadequate drainage on land use in the area at risk, the predictive technique was used. No historical records exist and so the historical technique could not be applied. Under Scenario 1, the base case, in the absence of maintenance the drainage status of the whole flood risk area is expected to deteriorate from a good to a bad drainage condition. Under Scenario 2, due to further deterioration in channel capacity without maintenance, the drainage status is expected to deteriorate from good to very bad.

The annual benefits of preventing a deterioration in drainage status are calculated from the area affected (ha) multiplied by the annual benefit (£/ha) to be gained from preventing the deterioration. The annual benefit of maintaining good drainage is £65/ha or £4654 for the left bank and £6786 on the right bank (1997/98 economic prices) under Scenario 1. Under Scenario 2, annual drainage benefits are £7409 for the left bank and £10802 on the right bank (1997/98 economic prices). As with flooding, these Scenario 2 benefits have been derived by discounting the average value of incremental losses over the period from Scenario 1 to year 10 to derive the present value of these average incremental losses, and adding this to the loss under Scenario 1. Under Scenario 2, it is assumed that the drainage status deteriorates from good to very bad without maintenance. Further details are presented at the end of this Appendix.

1.3.6 Actual SoS

The combined flood score and drainage score (HE/km/yr) for the current, with maintenance situation provides an indication of the adequacy of the existing maintenance regime with respect to set Standards of Service (SoS). This score for the Kelwell System for the left and right bank is shown in Table 4. Scores are derived by dividing the HE/km by the effective reach length.

Comparison of the total score with a target score of 0.5-1.0 HE/km/yr enables the current level of service provided to be determined (see Table 2.5 in main text). This on target standard (OTS, 0.5-1.0 HE/km/yr) was derived by the Environment Agency, based on analysis of existing SoS (see Section 5.13 in main text). The reach status of the left bank is on target and the right bank below target standard. If the average of the score for the left and right bank is taken, the standard of service provided is approximately on target.

Table 4 Actual standard of service provided under the current maintenance regime, Kelwell System

	Flooding (AAN $_{with}$) (HE/km) (a)	Effective Reach Length (km) (b)	Flood Score (HE/km/yr) (a/b) = (c)	Drainage Score (HE/km/yr) (d)	Total (c)+(d)
Left Bank	2.21	2.7	0.8	0.0 *	0.8
Right Bank	4.06	2.9	1.4	0.0 *	1.4
Both Banks				Average Score	1.1

Note: * the drainage status is described as good under the current maintenance situation, therefore the drainage score is zero. Figures are subject to rounding.

1.3.7 Justification

Justification of the maintenance scheme is undertaken using a comparison of the benefits and costs of maintenance in a simple benefit:cost ratio.

The total annual maintenance expenditure of the Environment Agency on the Kelwell System, excluding the embanked section (1997/98 prices) is estimated to be £3713. The total benefits of maintenance, taking into account flooding and drainage benefits on both banks are presented in Table 5. The benefit:cost ratios are presented in Table 6.

Table 5 Total benefits of maintenance, Kelwell System

		Annual Benefit of Flood Alleviation (£)	Annual Benefit of Maintaining Drainage Status (£)	Total Annual Benefit (£)
Scenario 1	Left bank	6533	4654	
	Right bank	11990	6786	
	Total	18523	11440	29963
Scenario 2	Left bank	7639	7409	
	Right bank	14020	10802	
	Total	21659	18212	39871

Note: 1997/98 prices are used. Figures are subject to rounding.

Table 6 Benefit:cost ratio, Kelwell System

	Total Annual Benefit (£)	Total Annual Maintenance Cost (£)	Benefit:Cost Ratio
Scenario 1	29963	3713	8.07
Scenario 2	39871	3713	10.74

Note: Maintenance costs for main river within flood risk area only, including North and South Kelwell. 1997/98 prices are used. Figures are subject to rounding.

Under both scenarios, the benefit:cost ratio is greater than one, thus the current maintenance regime appears justified, for the assumptions made.

1.4 Sensitivity Analysis

1.4.1 Flooding

As previously discussed (Section 1.3.4), the benefits of flooding vary according to the area inundated. Some sensitivity analysis has been undertaken to determine the impact of different areas flooded by the annual event one and 10 years after maintenance ceases.

1.4.2 Drainage

As the drainage benefit area is estimated to be the same as the flood risk area, but not supported by historical evidence, the benefit:cost analysis was repeated assuming that only 50% of this flood risk area would be subject to bad drainage in the absence of maintenance. Table 7 shows the corresponding benefit:cost ratio for Scenario 1. The drainage benefits are shown in Appendix II. The maintenance scheme is still justified as the benefit:cost ratio is greater than 1.0.

The drainage benefit area can be estimated by applying the areal drainage factor to the flood risk area. However, in this case, as the soil type is classed as heavy and there is piped drainage, the areal drainage factor is 1 (Table 3.8, FDMM). The drainage benefit area is therefore calculated to be the same as the flood risk area. This is consistent with the assumption made in Section 1.3.5.

It is predicted by the Environment Agency that in the absence of maintenance, due to the intensive nature of the drainage network and low relief, the drainage status of the whole catchment would deteriorate to a bad condition. The drainage benefits would consequently be high. However, FDMM was not applied to this scenario as the maintenance scheme was found to be justified using the same flood risk and drainage benefit area and therefore this additional analysis was not deemed necessary.

Table 7 **Benefit:cost ratio, 50% of flood risk area affected by bad drainage, Kelwell System**

	Total Annual Benefit (£)	Total Annual Maintenance Cost (£)	Benefit:Cost Ratio
Scenario 1	24243	3713	6.53

Note: Maintenance costs for main river within flood risk area only, including North and South Kelwell. 1997/98 prices are used. Figures are subject to rounding.

1.4.3 Actual SoS

Estimates of the actual standard of service provided are sensitive to the effective reach length used as shown in Table 8. This parameter is determined by the user of FDMM and is open to interpretation and subjectivity.

Two IDB watercourses discharge into the Kelwell Stream. As these watercourses lie wholly within the flood risk area, and derive benefit from maintenance on the main river, they should be included in the calculation of the effective reach length and treated as tributaries. Currently within FDMM non-main river tributaries are ignored and excluded from analysis.

Table 8 **Sensitivity analysis: effective reach length and reach status, Kelwell System**

Bank	Flooding (HE/km) (a)	Effective Reach Length (km) (b)	Flood Score (HE/km/yr) (a/b) = (c)	Drainage Score (HE/km/yr) (d)	Total (c)+(d)	Reach Status
Effective reach comprises: main river in flood risk area only						
LB	2.21	2.7	0.8	0.0 *	0.8	OTS
RB	4.06	2.9	1.4	0.0 *	1.4	BTS
				Average	1.1	c. OTS
Effective reach comprises: main river in flood risk area and IDB tributaries						
LB	2.21	3.7	0.59	0.0 *	0.59	OTS
RB	4.06	4.1	0.99	0.0 *	0.99	OTS
				Average	0.79	OTS
Effective reach comprises: main river in flood risk area, IDB tributaries and embanked section						
LB	2.21	6.1	0.36	0.0 *	0.36	ATS
RB	4.06	6.5	0.62	0.0 *	0.62	OTS
				Average	0.49	ATS

Note: * the drainage status is described as good under the current maintenance situation, therefore the drainage score is zero. Figures are subject to rounding.

The embanked section of Kelwell Stream does not provide a drainage function for the land through which it flows although it is not described as a highland carrier. It does, however, provide the outfall of Kelwell Stream into Foredyke Stream. If this section were included in the definition of effective reach length, the standard of service currently provided would be described as being above target. However, no benefit area associated with the embanked section has been identified therefore the associated HEs are not included in the calculation of total HEs at risk. If the embanked reach is included in calculation of effective reach length, these associated HEs must also be included.

1.4.4 Maintenance costs

In accordance with FDMM, maintenance expenditure has been increased by 15% and the benefits reduced by 15% in order to check the sensitivity of assumptions made on the benefit:cost ratio. The results of this are shown in Table 9 using the average benefits of Scenario 1, 2 and 3. Due to the high benefits and low maintenance costs, the maintenance regime would be justified even if costs increased and benefits reduced by 15%.

The embanked reach provides the conduit for Kelwell Stream over a lowland area to Foredyke Stream into which it discharges. Maintenance on this embanked reach therefore provides a benefit for the main river upstream. If maintenance were not carried out on the embanked reach, channel capacity may be reduced with a concomitant deterioration in drainage status upstream and increase in flooding.

Table 9 Sensitivity analysis: benefit:cost ratio, Kelwell System

Total Annual Benefit (£)	Total Annual Maintenance Cost (£)	Benefit:Cost Ratio
Maintenance costs increased by 15%		
29963	4270	7.02
Benefits reduced by 15%		
25469	3713	6.86
Maintenance costs increased by 15% and benefits reduced by 15%		
25469	4270	5.96

Note: Maintenance costs for main river within flood risk area only, including North and South Kelwell. 1997/98 prices used. Figures are subject to rounding.

The maintenance costs on the embanked reach should therefore be included in the benefit:cost analysis. Provision for this, however, is not made within FDMM. Sensitivity of the benefit:cost ratio to this is shown in Table 10. The results show that the benefit:cost ratio is sensitive to assumptions made regarding maintenance costs, although in this case study, the benefit:cost ratios remain favourable.

Table 10 Sensitivity of benefit:cost ratio to maintenance costs, Kelwell System

Total Annual Benefit (£)	Total Annual Maintenance Cost (£)	Benefit:Cost Ratio
Maintenance costs for Kelwell System, main river in flood risk area only		
29963	3713	8.07
Maintenance costs for Kelwell System, main river in flood risk area only and IDB watercourses		
29963	4263	7.03
Maintenance costs for whole of the Kelwell System, including the embanked section		
29963	5300	5.65
Maintenance costs for whole of Kelwell System, including the embanked section and IDB watercourses		
29963	5850	5.12
Maintenance costs for whole of Kelwell System, including the embanked section and IDB watercourses and proportion of costs on Foredyke Stream and Holderness Drain		
29963	9050	3.31

Note: 1997/98 prices used. Figures are subject to rounding.

As the Kelwell System discharges into Foredyke Stream and Holderness Drain, and derives benefit from maintenance on these main rivers, a proportion of the maintenance expenditure on Foredyke Stream and Holderness Drain should ideally be included in the costs for the Kelwell System. This proportion of maintenance expenditure is estimated by the Environment Agency to be £3750 (1997/98 prices) and is based on the proportion of flow derived from each watercourse. If a proportion of maintenance expenditure on these other main rivers is taken into account, the maintenance scheme on the Kelwell System is still justified.

1.4.5 Benefits

If the maintenance expenditure on the IDB watercourses and the embanked section of main river are taken into account in the benefit:cost equation, the associated benefits should also be considered.

The benefits provided by the embanked section relate to flood protection of the lowland area and provision of an outfall for the main river upstream. If the embankments were not maintained and were breached, a large part of the lowland drainage area may flood. The exact area affected, however, will depend on many factors such as the location of the breach, time taken to repair it, discharge and topography. Detailed modelling would be required to accurately predict the area affected by a flood event of a particular return period, with a breach at a specific point. Such detailed analysis is not usually possible and an estimate of benefits may need to be made. Similarly, it is likely to be difficult to determine the benefits derived from the proportion of maintenance expenditure on Foredyke Stream and Holderness Drain associated with the Kelwell System.

Estimation of these benefits will, however, reduce the accuracy of the benefit:cost analysis. It is recommended that the type of these additional benefits is noted and only if the benefits of maintenance appear to be marginal, then an estimate of these benefits is made.

1.5 Application of the Guidelines to the Kelwell System

1.5.1 Introduction

The following sections present the results of the application of the Guidelines to the Kelwell System. The same data are used as in the application of FDMM in order that results from the two methods may be compared. The completed record sheets and tables/figures required in the use of the Guidelines are presented at the end of this Appendix.

1.5.2 General information

Dominant substrate

Following rapid survey of the watercourse and discussions with the Environment Agency, the dominant substrate is classed as clay.

Floodplain topography

The floodplain is classed as rising as it has a slope of > 1%.

Catchment size

As the catchment is less that 2500 ha, it is described as small.

Benefit area

The area benefiting from maintenance in terms of its impact on flooding and land drainage is taken to be the same as the flood risk area identified using FDMM. This area is 176 ha in total. The left and right banks are not treated separately in the Guidelines.

Land use type

Following site survey, the dominant land use type is classed as a cereal/oilseed rotation (LUT 5). The rotation is dominated by winter wheat, winter barley and oilseed rape and equates to the extensive arable land use of FDMM.

Dominant soil type

From a rapid assessment of the benefit area and using secondary sources (SSEW 1983), the dominant soil type is identified as clay loam. As the Guidelines only identify the major soil particle component, the soil type is taken to be clay as clay is listed first and therefore assumed to be dominant.

1.5.3 Design standard (maintained condition)

Average bed width and average channel depth

The average bed width and channel depth are 1.5 m and 4 m respectively. These parameters were estimated by the Environment Agency, during a rapid survey of the channel.

Freeboard

The average freeboard under conditions of mean spring flow is estimated by the Environment Agency to be 1 m. This parameter has not been monitored and recorded and so the estimate is based on local knowledge and judgement. This corresponds to the default freeboard requirement for clay soils with piped drainage in a rising floodplain, which is identified in the Guidelines for use when actual data are limited.

Watertable depth and drainage status

The watertable depth associated with the rising floodplain, clay soil and freeboard of 1 m is estimated from Figure 2.6 in the main text, to be 0.5 m. The drainage status is therefore classed as good.

Economic net return

Using the dominant land use type of a cereal/oilseed rotation and good drainage status, the economic net return is calculated to be £329 /ha (1997/98 economic prices). The total economic net return for the benefit area is therefore £57904 (1997/98 prices).

Bankfull discharge

As the flood return periods are known for the 'with' and 'without' maintenance situation, the bankfull discharge does not need to be calculated.

Flood costs

Annual flood costs were identified using the Guidelines for the cereal/oilseed rotation under good drainage, for events with a return period of 1, 20 and 50 years. The same flooded areas and return periods were used as in FDMM.

The flood costs corresponding with these return periods are shown in Table 11. It is assumed that these costs are additive. Total flood costs for the 'with' maintenance situation are £1830 (1997/98 prices).

Table 11 Flood costs under the current maintained situation, Kelwell System

Flood Return Period (yr)	Area Flooded (%)	Area Flooded (ha)	Annual Flood Cost (£/ha)	Annual Flood Cost (£)
1	0	0	0	0
20	30	52.8	8	422
50	100	176.0	8	1408
			Total	1830

Note: 1997/98 prices used. Figures are subject to rounding.

Design standard benefit area value

The value of the benefit area under the current maintenance regime is calculated by subtracting the flood costs from the net return, as shown in Table 12.

Table 12 Design standard, value of benefit area, Kelwell System

Total Net Return (£) (a)	Total Flood Cost (£) (b)	Benefit Area Value (£) (a-b)
57904	1830	56074

Note: 1997/98 prices used. Figures are subject to rounding.

1.5.4 Maintenance regime

It is assumed that maintenance increases the channel width by 50% through removal of emergent vegetation. Due to lack of data this parameter has been estimated. Through desilting, during which 0.2 m of sediment is removed, channel depth is increased by approximately 5%.

The impacts of widening and deepening the channel on freeboard were calculated using Table 2.8 in the main text. Assuming an increase in width of 50% and depth of 5%, the corresponding increase in freeboard is 11.5% (9% + 2.5%). This equates to an increase in freeboard of 0.12 m.

1.5.5 Do-nothing (without maintenance)

Drainage status

The change in freeboard as a consequence of maintenance is used to determine the watertable depth and the corresponding drainage status which would prevail in the absence of maintenance. Assuming a freeboard of 0.8 m without maintenance (1 m - 0.12 m), using Figure 2.6 in the main text, the without maintenance drainage status is assessed as bad. Under Scenario 2, the drainage status is expected to deteriorate from good to very bad.

Economic net return

Using the dominant land use type of a cereal/oilseed rotation and bad drainage, the economic net return is calculated to be £263 /ha (1997/98 economic prices) (Scenario 1). The total economic net return for the whole benefit area is therefore £46288 (1997/98 prices).

Under Scenario 2, the loss associated with the extra deterioration to very bad drainage is £18060. If this is subtracted from the net return with maintenance, the net return without maintenance under Scenario 2 is £39844 (1997/98 prices). These Scenario 2 figures have been derived following the same approach as for flooding. Further details are presented at the end of this Appendix.

Flood costs

Annual flood costs were identified using the Guidelines for the cereal/oilseed rotation under bad drainage, for events with the same return periods as under the 'with' maintenance situation. The same flooded areas and return periods were used as in FDMM. The flood costs corresponding to the return periods are shown in the record sheets at the end of this Appendix. Flood costs under Scenario 1 are £3159. Under Scenario 2, flood costs are £4977.

Without maintenance benefit area value

The value of the benefit area under the 'without' maintenance situation of bad drainage is calculated by subtracting the flood costs from the net return, as shown in Table 13.

Table 13 Without maintenance benefit area value, Kelwell system

	Total Net Return (£) (a)	Total Flood Cost (£) (b)	Benefit Area Value (£) (a-b)
Scenario 1	46288	3159	43129
Scenario 2	39844	4977	34867

Note: 1997/98 prises are used. Figures are subject to rounding.

1.5.6 Maintenance costs

The total annual maintenance expenditure on the Kelwell System main river, excluding the embanked section, is £3713 (1997/98 prices).

1.5.7 Benefit of maintenance

The difference in value of the benefit area 'with' and 'without' maintenance is used to determine the benefit of maintenance. From the figures presented in Tables 12 and 13, the benefit of maintenance is calculated to be £12945 under Scenario 1 and £21207 under Scenario 2.

1.5.8 Justification

The net benefit of maintenance is greater than the annual maintenance expenditure, therefore the maintenance regime is justified. The benefit:cost ratio is 3.49 under Scenario 1 and 5.71 under Scenario 2.

1.6 Sensitivity Analysis

1.6.1 Flooding

As previously discussed (Section 1.3.4), the benefits of flooding vary according areas inundated. Some sensitivity analysis has been undertaken to determine the impact of different areas flooded by the annual flood occurring after one and 10 years without maintenance.

1.6.2 Maintenance costs

The benefits of maintenance are sensitive to assumptions made regarding maintenance expenditure. In the preceding analysis, maintenance expenditure for main river only, excluding the embanked section has been taken into account. As with FDMM, benefit:cost ratios have been calculated for various maintenance expenditure scenarios. The results of this analysis are shown in Table 14.

Table 14 Sensitivity of benefit:cost ratio to maintenance costs, Kelwell System

Total Annual Benefit (£)	Total Annual Maintenance Cost (£)	Benefit:Cost Ratio
Maintenance costs for Kelwell System, main river in flood risk area only		
12945	3713	3.48
Maintenance costs for Kelwell System, main river in flood risk area only and IDB watercourses		
12945	4263	3.04
Maintenance costs for whole of the Kelwell System, including the embanked section		
12945	5300	2.44
Maintenance costs for Kelwell System, including the embanked section and IDB watercourses		
12945	5850	2.21
Maintenance costs for whole of Kelwell System, including the embanked section and IDB watercourses and proportion of costs on Foredyke Stream and Holderness Drain		
12945	9600	1.35

Note: 1997/98 prices are used. Figures are subject to rounding.

KELWELL STREAM

Order of record sheets presented in the following pages:

FDMM

Annual maintenance costs

Land use assessment: reach summary

Flooding

Drainage benefits

Agricultural benefits only: Land use assessment - reach summary

Agricultural benefits only: Flooding

GUIDELINES

General information

Design standard

Maintenance regime

'Do-nothing' - Without maintenance

Maintenance expenditure and benefits of maintenance

ANNUAL MAINTENANCE COSTS

Kelwell Stream, North Kelwell, South Kelwell
1997/98 prices

Element	Annual Maintenance Cost (£)
Kelwell Stream within flood risk area only	913
Kelwell Stream, embanked section	1587
Total costs on main river	2500
North Kelwell	1400
South Kelwell	1400
Proportion of associated costs on Holderness Drain	3750
Internal Drainage Board watercourses	550

Source: Environment Agency (North East Region) and Beverly & Holderness IDB

Note: All maintenance costs relate to annual costs, expressed in 1997/98 prices.
The proportion of maintenance costs on Foredyke Stream and Holderness Drain which may be associated with the Kelwell System is based on flow with costs apportioned as follows:

Total maintenance cost on Holderness Drain is £30 000.
50 % of flow in Holderness Drain is from Foredyke Stream, therefore £15 000 is apportioned Foredyke Stream and £15 000 apportioned to Holderness Drain.
50% of flow in Foredyke stream is from Monk Dyke, therefore £7500 remaining.
25% of remaining is apportioned each to Lambwath Stream and Kelwell Stream, therefore £3750 apportioned to each.
No costs are apportioned from Foredyke Stream itself as this is a highland carrier only.

LAND USE ASSESSMENT : REACH SUMMARY

Watercourse	**Kelwell Stream, South Kelwell**
Bank	**Left Bank**
OS Map	Pathfinder 687
Flood risk area (ha)	71.6
Effective reach length (km)	2.7 (1.9 km Kelwell Stream + (0.4 * 2 both banks) South Kelwel

Land Use Factor	Unit	Number or area (a)	House Equivalents HE/unit (b)		Total HE (a) x (b)	
House	Number	*1*	1.00		*1*	
Garden / allotments	Number	*1*	0.04		*0.04*	
NRP - Manufacturing	Area (m^2)		0.030		*0*	
NRP - Distribution	Area (m^2)		0.054		*0*	
NRP - Leisure	Area (m^2)		0.032		*0*	
N R P - Offices	Area (m^2)		0.033		*0*	
N R P - Retail	Area (m^2)		0.035		*0*	
N R P - Agricultural	Area (m^2)		0.010		*0*	
C Roads	Number	*1*	2.7		*2.7*	
B Roads	Number		6.3		*0*	
A Roads (non trunk)	Number		15.9		*0*	
A Roads (trunk)	Number		31.7		*0*	
Motorway	Number		63.5		*0*	
Railway	Number		63.5		*0*	
			Flooding	Drainage	Flooding	Drainage **
Forestry and scrub *	per 100 ha	*0.716*	0.02	0.0	*4.51*	*0*
Extensive pasture *	per 100 ha		1.3	1.1		
Intensive pasture *	per 100 ha		3	4.5		
Extensive arable *	per 100 ha		6.3	3.6		
Intensive arable *	per 100 ha		44.1	9.7		
Formal parks	Number		0.6		*0*	
Golf / race courses	Number		0.7		*0*	
Playing field	Number		0.1		*0*	
Special parks	Number		9.3		*0*	
				Total HE (c) *	*8.25*	
				HE/km ((c) / effective reach length)	*3.06*	

Note

* Flooding / drainage scores to be summed

** Apply areal drainage factor if required

HE values are at 1991 base

LAND USE ASSESSMENT : REACH SUMMARY

Watercourse	**Kelwell Stream, North Kelwell**	
Bank	**Right Bank**	
OS Map	Pathfinder 687	
Flood risk area (ha)	104.4	
Effective reach length (km)	2.9	(1.9 km Kelwell Stream + (0.5 km x 2 both banks) North Kelwell)

Land Use Factor	Unit	Number or area (a)	House Equivalents HE/unit (b)		Total HE (a) x (b)	
House	Number	*5*	1.00		*5*	
Garden / allotments	Number	*5*	0.04		*0.2*	
NRP - Manufacturing	Area (m^2)		0.030		*0*	
NRP - Distribution	Area (m^2)		0.054		*0*	
NRP - Leisure	Area (m^2)		0.032		*0*	
N R P - Offices	Area (m^2)		0.033		*0*	
N R P - Retail	Area (m^2)		0.035		*0*	
N R P - Agricultural	Area (m^2)		0.010		*0*	
C Roads	Number	*2*	2.7		*5.4*	
B Roads	Number		6.3		*0*	
A Roads (non trunk)	Number		15.9		*0*	
A Roads (trunk)	Number		31.7		*0*	
Motorway	Number		63.5		*0*	
Railway	Number		63.5		*0*	
			Flooding	Drainage	Flooding	Drainage **
Forestry and scrub *	per 100 ha		0.02	0.0		
Extensive pasture *	per 100 ha		1.3	1.1		
Intensive pasture *	per 100 ha		3	4.5		
Extensive arable *	per 100 ha	*1.044*	6.3	3.6	*6.5772*	*0*
Intensive arable *	per 100 ha		44.1	9.7		
Formal parks	Number		0.6		*0*	
Golf / race courses	Number		0.7		*0*	
Playing field	Number		0.1		*0*	
Special parks	Number		9.3		*0*	
				Total HE (c) *	*17.18*	
				HE/km ((c) / effective reach length)	*5.92*	

Note

* Flooding / drainage scores to be summed

** Apply areal drainage factor if required

HE values are at 1991 base.

FLOODING

Watercourse	**Kelwell Stream, South Kelwell**
Bank	**Left Bank**
Flood risk area (ha)	71.6
Effective reach length (km)	2.7

With maintenance - current situation

Flood Return Period (years)	Probability	Nr. HEs Affected	Probability Interval (a)	Average Nr. HEs Affected (b)	(a) x (b)
1	1	0.00			
no flooding			0.95	2.05	1.95
20	0.05	4.10			
30 % flooded			0.03	8.88	0.27
50	0.02	13.66			
100 % flooded					
				Annual Average Number HEs affected with maintenance (AAN_{with})	2.21

Scenario 1 - without maintenance

Impact of annual flood after 1 year without maintenance

Flood Return Period (years)	Probability	Nr. HEs Affected	Probability Interval (a)	Average Nr. HEs Affected (b)	(a) x (b)
1	1	0.68			
5 % flooded			0.95	7.17	6.81
20	0.05	13.66			
100 % flooded			0.03	13.66	0.41
50	0.02	13.66			
100 % flooded					
				Annual Average Number HEs affected without maintenance ($\text{AAN}_{\text{without}}$)	7.22

Scenario 2 - without maintenance

Impact of annual flood after 10 years without maintenance

Flood Return Period (years)	Probability	Nr. HEs Affected	Probability Interval (a)	Average Nr. HEs Affected (b)	(a) x (b)
1	1	5.46			
40 % flooded			0.95	9.56	9.08
20	0.05	13.66			
100 % flooded			0.03	13.66	0.41
50	0.02	13.66			
100 % flooded					
				Annual Average Number HEs affected without maintenance ($\text{AAN}_{\text{without}}$)	9.49

Summary: flooding **Left Bank**	$\text{AAN}_{\text{without}}$ (a)	AAN_{with} (b)	(a) - (b) = c	Benefit (£) c * value one HE
Scenario 1, year 0	7.223	2.213	5.010	6533
Scenario 2, year 10	9.494	2.213	7.281	9494
Value of one HE (£) *	1304			

* 1997/98 price

Note: Severity weightings have been applied to HEs affected by flooding	arable	2.2
	pasture	1.5

FLOODING

Watercourse	**Kelwell Stream, North Kelwell**
Bank	**Right Bank**
Flood risk area (ha)	104.4
Effective reach length (km)	2.9

With maintenance - current situation

Flood Return Period (years)	Probability	Nr. HEs Affected	Probability Interval (a)	Average Nr. HEs Affected (b)	(a) x (b)
1	1	0.00			
no flooding			0.95	3.76	3.57
20	0.05	7.52			
30 % flooded			0.03	16.30	0.49
50	0.02	25.07			
100 % flooded					
Annual Average Number HEs affected with maintenance (AAN_{with})					4.06

Scenario 1 - without maintenance

Impact of annual flood after 1 year without maintenance

Flood Return Period (years)	Probability	Nr. HEs Affected	Probability Interval (a)	Average Nr. HEs Affected (b)	(a) x (b)
1	1	1.25			
5 % flooded			0.95	13.16	12.50
20	0.05	25.07			
100 % flooded			0.03	25.07	0.75
50	0.02	25.07			
100 % flooded					
Annual Average Number HEs affected without maintenance ($AAN_{without}$)					13.26

Scenario 2 - without maintenance

Impact of annual flood after 10 years without maintenance

Flood Return Period (years)	Probability	Nr. HEs Affected	Probability Interval (a)	Average Nr. HEs Affected (b)	(a) x (b)
1	1	10.03			
40 % flooded			0.95	17.55	16.67
20	0.05	25.07			
100 % flooded			0.03	25.07	0.75
50	0.02	25.07			
100 % flooded					
Annual Average Number HEs affected without maintenance ($AAN_{without}$)					17.42

Summary: flooding **Right Bank**	$AAN_{without}$ (a)	AAN_{with} (b)	(a) - (b) = c	Benefit (£) c * value one HE
Scenario 1, year 0	13.256	4.061	9.194	11990
Scenario 2, year 10	17.424	4.061	13.362	17424
Value of one HE (£) *	1304			

* 1997/98 price

Note: Severity weightings have been applied to HEs affected by flooding

arable	2.2
pasture	1.5

FDMM

Kelwell Stream

Estimation of benefits of flood alleviation assuming further deterioration in subsequent years

		Left Bank £	Right Bank £
Benefit lost in year 0	(a)	6533	11990
Benefit lost in year 10	(b)	9494	17424
Incremental loss over 10 years	(b)-(a) = (c)	2961	5435
Average value of incremental loss (loss in year 5)	(c)/2 = (d)	1481	2717
Discount factor at 6% (year 5)	(e)	0.747	0.747
Present value of average incremental loss	(d) x (e) = (f)	1106	2031
Average annual loss assuming further deterioration	(f) + (a)	7639	14020
Total for both banks			21659

1997/98 prices are used. Figures are subject to rounding.

FDMM

Kelwell Stream

Estimation of Benefits from Flooding assuming further deterioration in subsequent years

		Left Bank	Right Bank
		£	£
Benefit lost in year 0	a	4746	6920
Benefit lost in year 10	b	6897	10057
Incremental loss over 10 years	(b-a) = c	2151	3137
Average value of incremental loss (loss in year 5)	(c/2) = d	1076	1568
Discount factor at 6% (year 5)	e	0.747	0.747
Present value of average incremental loss	(d x e) = f	804	1172
Average annual loss assuming further deterioratio	f+a	5550	8092
Total for both banks			13642

1997/98 prices are used. Figures are subject to rounding.

AGRICULTURAL BENEFITS ONLY

FLOODING

Watercourse	**Kelwell Stream, North Kelwell**
Bank	**Right Bank**
Flood risk area (ha)	104.4
Effective reach length (km)	2.9

With maintenance - current situation

Flood Return Period (years)	Probability	Nr. HEs Affected	Probability Interval (a)	Average Nr. HEs Affected (b)	(a) x (b)
1	1	0.00			
no flooding			0.95	2.17	2.06
20	0.05	4.34			
30 % flooded			0.03	9.41	0.28
50	0.02	14.47			
100 % flooded					
Annual Average Number HEs affected with maintenance (AAN_{with})					2.34

Scenario 1 - without maintenance

Impact of annual flood after 1 year without maintenance

Flood Return Period (years)	Probability	Nr. HEs Affected	Probability Interval (a)	Average Nr. HEs Affected (b)	(a) x (b)
1	1	0.72			
5 % flooded			0.95	7.60	7.22
20	0.05	14.47			
100 % flooded			0.03	14.47	0.43
50	0.02	14.47			
100 % flooded					
Annual Average Number HEs affected without maintenance ($AAN_{without}$)					7.65

Scenario 2 - without maintenance

Impact of annual flood after 10 years without maintenance

Flood Return Period (years)	Probability	Nr. HEs Affected	Probability Interval (a)	Average Nr. HEs Affected (b)	(a) x (b)
1	1	5.79			
40 % flooded			0.95	10.13	9.62
20	0.05	14.47			
100 % flooded			0.03	14.47	0.43
50	0.02	14.47			
100 % flooded					
Annual Average Number HEs affected without maintenance ($AAN_{without}$)					10.06

Summary: Flooding **Right Bank**	$AAN_{without}$ (a)	AAN_{with} (b)	(a) - (b) = c	Benefit (£) c x value one HE
Scenario 1, year 0	7.651	2.344	5.307	6920
Scenario 2, year 10	10.057	2.344	7.712	10057
Value of one HE (£) *	1304			

* 1997/98 price

Note: Severity weightings have been applied to HEs affected by flooding

arable	2.2
pasture	1.5

AGRICULTURAL BENEFITS ONLY

FLOODING

Watercourse	**Kelwell Stream, South Kelwell**
Bank	**Left Bank**
Flood risk area (ha)	71.6
Effective reach length (km)	2.7

With maintenance - current situation

Flood Return Period (years)	Probability	Nr. HEs Affected	Probability Interval (a)	Average Nr. HEs Affected (b)	(a) x (b)
1	1	0.00			
no flooding			0.95	1.49	1.41
20	0.05	2.98			
30 % flooded			0.03	6.45	0.19
50	0.02	9.92			
100 % flooded					
	Annual Average Number HEs affected with maintenance (AAN $_{with}$)				1.61

Scenario 1 - without maintenance

Impact of annual flood after 1 year without maintenance

Flood Return Period (years)	Probability	Nr. HEs Affected	Probability Interval (a)	Average Nr. HEs Affected (b)	(a) x (b)
1	1	0.50			
5 % flooded			0.95	5.21	4.95
20	0.05	9.92			
100 % flooded			0.03	9.92	0.30
50	0.02	9.92			
100 % flooded					
	Annual Average Number HEs affected without maintenance (AAN $_{without}$)				5.25

Scenario 2 - without maintenance

Impact of annual flood after 10 years without maintenance

Flood Return Period (years)	Probability	Nr. HEs Affected	Probability Interval (a)	Average Nr. HEs Affected (b)	(a) x (b)
1	1	3.97			
40 % flooded			0.95	6.95	6.60
20	0.05	9.92			
100 % flooded			0.03	9.92	0.30
50	0.02	9.92			
100 % flooded					
	Annual Average Number HEs affected without maintenance (AAN $_{without}$)				6.90

Summary: Flooding **Left Bank**	AAN $_{without}$ (a)	AAN $_{with}$ (b)	(a) - (b) = c	Benefit (£) c x value one HE
Scenario 1, year 0	5.247	1.608	3.640	4746
Scenario 2, year 10	6.897	1.608	5.289	6897
Value of one HE (£) *	1304			

* 1997/98 price

Note: Severity weightings have been applied to HEs affected by flooding

arable	2.2
pasture	1.5

AGRICULTURAL BENEFITS ONLY

LAND USE ASSESSMENT : REACH SUMMARY

Watercourse	**Kelwell Stream, North Kelwell**
Bank	**Right Bank**
OS Map	Pathfinder 687
Flood risk area (ha)	104.4
Effective reach length (km)	2.9

Land Use Factor	Unit	Number or area (a)	House Equivalents HE/unit (b)		Total HE (a) x (b)	
House	Number		1.00		*0*	
Garden / allotments	Number		0.04		*0*	
NRP - Manufacturing	Area (m^2)		0.030		*0*	
NRP - Distribution	Area (m^2)		0.054		*0*	
NRP - Leisure	Area (m^2)		0.032		*0*	
N R P - Offices	Area (m^2)		0.033		*0*	
N R P - Retail	Area (m^2)		0.035		*0*	
N R P - Agricultural	Area (m^2)		0.010		*0*	
C Roads	Number		2.7		*0*	
B Roads	Number		6.3		*0*	
A Roads (non trunk)	Number		15.9		*0*	
A Roads (trunk)	Number		31.7		*0*	
Motorway	Number		63.5		*0*	
Railway	Number		63.5		*0*	
			Flooding	Drainage	Flooding	Drainage **
Forestry and scrub *	per 100 ha		0.02	0.0		
Extensive pasture *	per 100 ha		1.3	1.1		
Intensive pasture *	per 100 ha		3	4.5		
Extensive arable *	per 100 ha	*1.044*	6.3	3.6	*6.5772*	*0*
Intensive arable *	per 100 ha		44.1	9.7		
Formal parks	Number		0.6		*0*	
Golf / race courses	Number		0.7		*0*	
Playing field	Number		0.1		*0*	
Special parks	Number		9.3		*0*	
Total HE (c) *					*6.58*	
HE/km ((c) / effective reach length)					*2.27*	

Note

* Flooding / drainage scores to be summed ** Apply areal drainage factor if required

HE values are at 1991 base

AGRICULTURAL BENEFITS ONLY

LAND USE ASSESSMENT : REACH SUMMARY

Watercourse	**Kelwell Stream, South Kelwell**
Bank	**Left Bank**
OS Map	Pathfinder 687
Flood risk area (ha)	71.6
Effective reach length (km)	2.7

Land Use Factor	Unit	Number or area (a)	House Equivalents HE/unit (b)		Total HE (a) x (b)	
House	Number		1.00		0	
Garden / allotments	Number		0.04		0	
NRP - Manufacturing	Area (m^2)		0.030		0	
NRP - Distribution	Area (m^2)		0.054		0	
NRP - Leisure	Area (m^2)		0.032		0	
N R P - Offices	Area (m^2)		0.033		0	
N R P - Retail	Area (m^2)		0.035		0	
N R P - Agricultural	Area (m^2)		0.010		0	
C Roads	Number		2.7		0	
B Roads	Number		6.3		0	
A Roads (non trunk)	Number		15.9		0	
A Roads (trunk)	Number		31.7		0	
Motorway	Number		63.5		0	
Railway	Number		63.5		0	
			Flooding	Drainage	Flooding	Drainage **
Forestry and scrub *	per 100 ha	*0.716*	0.02	0.0	*4.51*	0
Extensive pasture *	per 100 ha		1.3	1.1		
Intensive pasture *	per 100 ha		3	4.5		
Extensive arable *	per 100 ha		6.3	3.6		
Intensive arable *	per 100 ha		44.1	9.7		
Formal parks	Number		0.6		0	
Golf / race courses	Number		0.7		0	
Playing field	Number		0.1		0	
Special parks	Number		9.3		0	
Total HE (c) *					*4.51*	
HE/km ((c) / effective reach length)					*1.67*	

Note
* Flooding / drainage scores to be summed
** Apply areal drainage factor if required.
HE values are at 1991 base

FDMM
Kelwell Stream
Estimation of Drainage Benefits assuming further deterioration in subsequent years

		Left Bank £	Right Bank £
Benefit lost in year 0 (Good to bad drainage)	(a)	4654	6786
Benefit lost in year 10 (Good to very bad drainage)	(b)	12029	17539
Incremental loss over 10 years	(b)-(a) = (c)	7375	10753
Average value of incremental loss (loss in year 5)	(c)/2 = (d)	3687	5377
Discount factor at 6% (year 5)	(e)	0.747	0.747
Present value of average incremental loss	(d) x (e) = (f)	2755	4016
Average annual loss assuming further deterioration	(f) + (a)	7409	10802
Total for both banks			18212

1997/98 prices are used. Figures are subject to rounding.

Sensitivity analysis
Assuming 50% flood risk area on each bank subject to inadequate drainage

DRAINAGE BENEFITS

Watercourse	**Kelwell Stream South Kelwell**	**Kelwell Stream North Kelwell**
Bank	**Left Bank**	**Right Bank**
Drainage benefit area (ha)	35.8	52.2
Effective reach length (km)	2.8	3
Floodplain topography	Rising	Rising
Predominant soil type	Heavy	Heavy
Drainage system	Piped	Piped
With maintenance, drainage status	Good	Good
Without maintenance, drainage status	Bad	Bad
Annual benefit (£/ha) *	65	65
Total benefit (£) *	2327	3393

* 1997/98 economic prices. Figures are subject to rounding.

DRAINAGE BENEFITS

Scenario 1, Year 0

Watercourse	Kelwell Stream South Kelwell	Kelwell Stream North Kelwell
Bank	**Left Bank**	**Right Bank**
Drainage benefit area (ha)	71.6	104.4
Effective reach length (km)	2.7	2.9
Floodplain topography	Rising	Rising
Predominant soil type	Heavy	Heavy
Drainage system	Piped	Piped
With maintenance, drainage status	Good	Good
Without maintenance, drainage status	Bad	Bad
Annual benefit (£/ha) *	65	65
Total benefit (£) *	4654	6786

* 1997/98 economic prices. Figures are subject to rounding.

Note

If the drainage benefit area is not known, multiply the flood risk area by the appropriate areal drainage factor, according to soil type and drainage system.

Scenario 2, Year 10

Watercourse	Kelwell Stream South Kelwell	Kelwell Stream North Kelwell
Bank	**Left Bank**	**Right Bank**
Drainage benefit area (ha)	71.6	104.4
Effective reach length (km)	2.8	3
Floodplain topography	Rising	Rising
Predominant soil type	Heavy	Heavy
Drainage system	Piped	Piped
With maintenance, drainage status	Good	Good
Without maintenance, drainage status	Very bad	Very bad
Annual benefit (£/ha) *	168	168
Total benefit (£) *	12029	17539

* 1997/98 economic prices. Figures are subject to rounding.

GENERAL INFORMATION

River — 1a **KELWELL**

Reach Code — 1b **01**

Reach Length (km) — 2 **2.8**

Dominant Substrate Type:-
Gravel, Sand or Silt
(Treat clay as silt) — 3 **CLAY**

Floodplain -
Rising (>1 %) or Flat (< 1 %) — 4 **RISING**

Catchment Size
Large (> 25 sq. km)
Small (< 25 sq. km) — 5 **SMALL**

Benefit Area (ha)
(Area deriving benefit from maintenance) — 6 **176**

Dominant Land Use Type (LUT)
(Table 1) — 7 **CEREAL/OILS (5)**

Dominant Soil Type — 9 **CLAY LOAM**

Varied Land Use Types (LUT)
(Table 1)

LUT	7 % Benefit Area as decimal	8a Does the LUT flood ?	8b If yes, % that floods (as decimal)
1 Ext grass			
2 Int grass			
3 Grass/arable			
4 All cereals			
5 Cereal/oil seed			
6 Cereal/root			
7 Horticulture			
8 Other			

Note: All table numbers and references relate to R&D Note 511, Guidelines for the Justification of River Maintenance

DESIGN STANDARD

Average Bed Width (m)	10	1.5
Average Channel Depth (m)	11	4
% Weed Cover (In channel, submerged & floating weed)	12	0 (Emergent vegetation only)
Freeboard (m)	13	1
Watertable Depth (m) *(Box 4, 9, 13 & Figure 1 or 2)*	14	0.5
Drainage Status *(Box 14 & Table 4)*	15	GOOD

Economic Net Return
(Table 5, using Box 7 & Box 15)

			16
For either :-	Dominant land use	(£/ha)	329
		(£)	57904
or :-	Varied land use	(£/ha)	
		(£)	

LUT	16a Net Return (£/ha)	16b Weighted Net Return
1		
2		
3		
4		
5		
6		
7		

Bankfull Discharge (Qbf) (cumecs)	17	
* Regional Growth Curve Area *(Figure 3)*	18	
* Mean Annual Flood (Q bar) (cumecs)	19	
* Qbf/Q bar (cumecs) *(Box 17 / Box 19)*	20	

* Flooding Envelopes
* % BA with different flood return periods (years)
(Table 6 or 7, boxes 5, 7, 15)

FRP (yr)	21 % area of each LUT that floods	21a Flooded Area (ha)	22 Flood Cost (£/ha)	22a Total Flood Cost (£) *(Box 21a * box 22)*
0	0	0	0	0
1 - 2				
3 - 5				
6 - 10				
> 10 (20 yr)	30	52.8	8	422
(50 yr)	100	176	8	1408
			Total	1830

* *Not necessary unless detailed information and assessment is required*

Flood Return Period (years)		23	AS ABOVE
Total Flood Cost	(£)	24	1830
Design Net Return Less Flood Cost *(Box 16 - box 24)*	(£)	24a	56074

Note: All table numbers and references relate to R&D Note 511, Guidelines for the Justification of River Maintenance

MAINTENANCE REGIME

	25a (m)	25b (%)
Widening, change in width, expressed in metres and as a %, (including cutting of banks and emergent vegetation)	0.75	50
	26a (m)	26b (%)
Deepening, change in depth, expressed in metres and as a %	0.2	5
		27
Weed cutting, % cover removed (Submerged & floating weed)		
	28a (m)	28b (%)
Change in freeboard, expressed in metres and as a % (Table 8 - 15, & boxes 25, 26, 27)	0.12	11.5
	29a (m)	29b (%)
Change in Qbf, expressed in metres and as a % (Table 8 - 15, & boxes 25, 26, 27)		

Note: All table numbers and references relate to R&D Note 511, Guidelines for the Justification of River Maintenance

"DO NOTHING" (WITHOUT MAINTENANCE)

30
W/o Maintenance Width (m) **0.75**
(Box 10 - box 25a)

31
W/o Maintenance Depth (m) **3.8**
(Box 11 - box 26a)

32
W/o Maintenance Freeboard (m) **0.8**
(Box 13 - box 28a)

33
W/o Maintenance Watertable Depth (m) **0.4**
(Box 4, 9, 32, Table 3, Figure 1 or 2)

34
W/o Maintenance Drainage Status Scenario 1 **BAD**
(Table 4, box 33) Scenario 2 **VERY BAD**

Economic Net Return (W/o maintenance)
(Table 5, box 8, 34)

		35	
For either :-		Scenario 1	Scenario 2
Dominant land use	(£/ha)	**263**	**165**
	£	**46288**	**29040**
or :-			
Varied land use	(£/ha)		
	£		

	35b	35a	
LUT		Net Return (£/ha)	Weighted Net Return
1			
2			
3			
4			
5			
6			
7			

36
W/o Maintenance Bankfull Discharge (Qbf) (cumecs)
(Box 17 - box 29)

37
* W/o Maintenance Qbf/Q bar (cumecs)
(Box 36 / box 19)

SCENARIO 1 (Year 0)

* Flooding Envelopes
* % BA with different flood return periods (years)
(Table 6 or 7, boxes 5, 7, 34)

	38	38a	39	39a
FRP (yr.)	% area of each LUT that floods	Flooded Area (ha)	Flood Cost (£/ha)	Total Flood Cost (£) *(Box 38a * box 39)*
0				
<1				
1 - 2	**5**	**8.8**	**79**	**695**
3 - 5				
6 - 10				
> 10 (20 yr)	**100**	**176**	**7**	**1232**
> 10 (50 yr)	**100**	**176**	**7**	**1232**
			Total	**3159**

SCENARIO 2 (Year 10)

FRP (yr.)				
0				
<1				
1 - 2	**40**	**70.4**	**79**	**5562**
3 - 5				
6 - 10				
> 10 (20 yr)	**100**	**176**	**7**	**1232**
> 10 (50 yr)	**100**	**176**	**7**	**1232**
			Total	**8026**

Estimation of loss assuming further deterioration in subsequent years

		Drainage	**Flooding**
Loss without maintenance in year 0 (£)	a	11616	3159
Loss without maintenance in year 10 (£)	b	28864	8026
Incremental loss over 10 years (£)	(b-a) = c	17248	4866
Average value of incremental loss (loss in year 5) (£)	(c/2) = d	8624	2433
Discount factor at 6% (year 5) (£)	e	0.747	0.747
Present value of average incremental loss (£)	(d x e) = f	6444	1818
Average annual loss assuming further deterioration (£)	f + a	18060	4977

40
W/o Maintenance FRP (years) **AS ABOVE**

41
Total Average Flood Cost (£) **3159** Scenario 1 **4977** Scenario 2

41a
Do-nothing
Net Return Less Flood Cost (£) **43129** Scenario 1 **34867** Scenario 2
(Box 35 - box 41)

Note: All table numbers and references relate to R&D Note 511, Guidelines for the Justification of River Maintenance

MAINTENANCE EXPENDITURE

	42	43	44	45	46	47
Maintenance Activity	Unit Cost (£)	No. of Units (specify)	Cost/Reach/ Activity (£)	Interval Between Maintenance Activities (years)	Amortisation Value at 6 % Discount Rate *(Box 45, Table 18)*	Annual Cost (£) *(Box 44 * box 46)*
Weedcutting and desilting						**3713**

Total annual cost/reach (£)	*(Sum box 47)*	48	**3713**
Benefit Area (ha)	*(Box 6)*	49	**176**
Total annual maintenance cost/ha	*(Box 48 / box 49)*	50	**21**

BENEFITS OF MAINTENANCE

Design Standard (With maintenance)	Net return less flood costs	*(Box 24a)*	(£)	51	**56074**			
Do Nothing (Without maintenance)	Net return less flood costs	*(Box 41a)*	(£)	52	**43129**	Scenario 1	**34867**	Scenario 2
Change in Net Benefit Due to Maintenance		*(Box 51 - box 52)*	(£)	53	**12945**	Scenario 1	**21207**	Scenario 2
Net Benefit of Maintenance	Change in net benefit-total annual maintenance costs	*(Box 53 - box 49 or 50)*	(£)	54	**9232**	Scenario 1	**17494**	Scenario 2
	Benefit : cost ratio	*(Box 53/box 48)*			**3.49**	Scenario 1	**5.71**	Scenario 2

Note: All table numbers and references relate to R&D Note 511, Guidelines for the Justification of River Maintenance

APPENDIX II AMORTISATION FACTORS

This Appendix presents amortisation factors which are used to spread a single benefit out as a series of annual payments.

Discount, annuity and amortisation factors

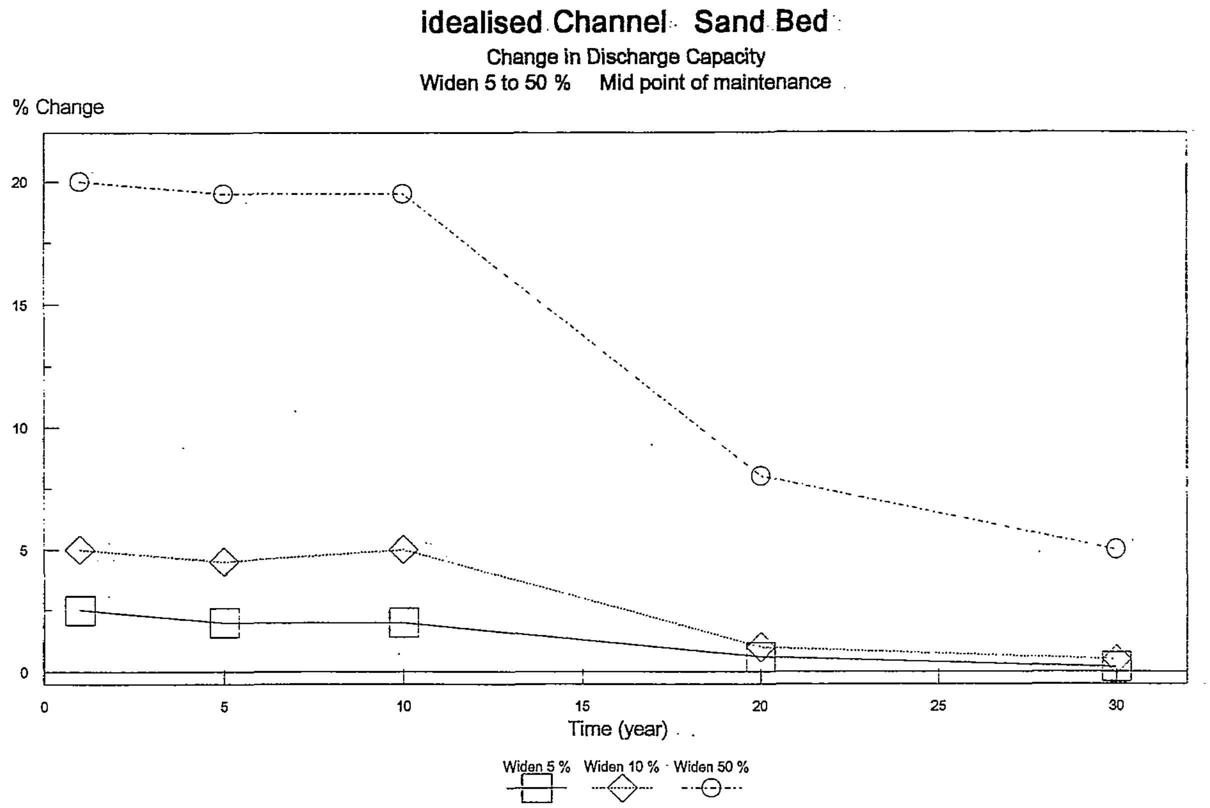
Year	Discount Factor	Annuity Factor (Cumulative sum)	Amortisation Factors
		6 % Discount Rate	
1	0.943	0.943	1.00
2	0.890	1.833	0.55
3	0.840	2.673	0.37
4	0.792	3.465	0.29
5	0.747	4.212	0.24
6	0.705	4.917	0.20
7	0.665	5.582	0.18
8	0.627	6.209	0.16
9	0.592	6.801	0.15
10	0.558	7.359	0.14
11	0.527	7.886	0.13
12	0.497	8.383	0.12
13	0.469	8.852	0.11
14	0.442	9.294	0.11
15	0.417	9.711	0.10
20	0.312	10.023	0.10
25	0.233	10.256	0.10
30	0.174	10.430	0.10
		10 % Discount Rate	
1	0.909	0.909	1.00
2	0.826	1.735	0.58
3	0.751	2.486	0.40
4	0.683	3.169	0.32
5	0.621	3.790	0.26
6	0.564	4.354	0.23
7	0.513	4.867	0.21
8	0.467	5.334	0.19
9	0.424	5.758	0.17
10	0.386	6.144	0.16
11	0.350	6.494	0.15
12	0.319	6.813	0.15
13	0.290	7.103	0.14
14	0.263	7.366	0.14
15	0.239	7.605	0.13
20	0.149	7.754	0.13
25	0.092	7.846	0.13
30	0.057	7.903	0.13

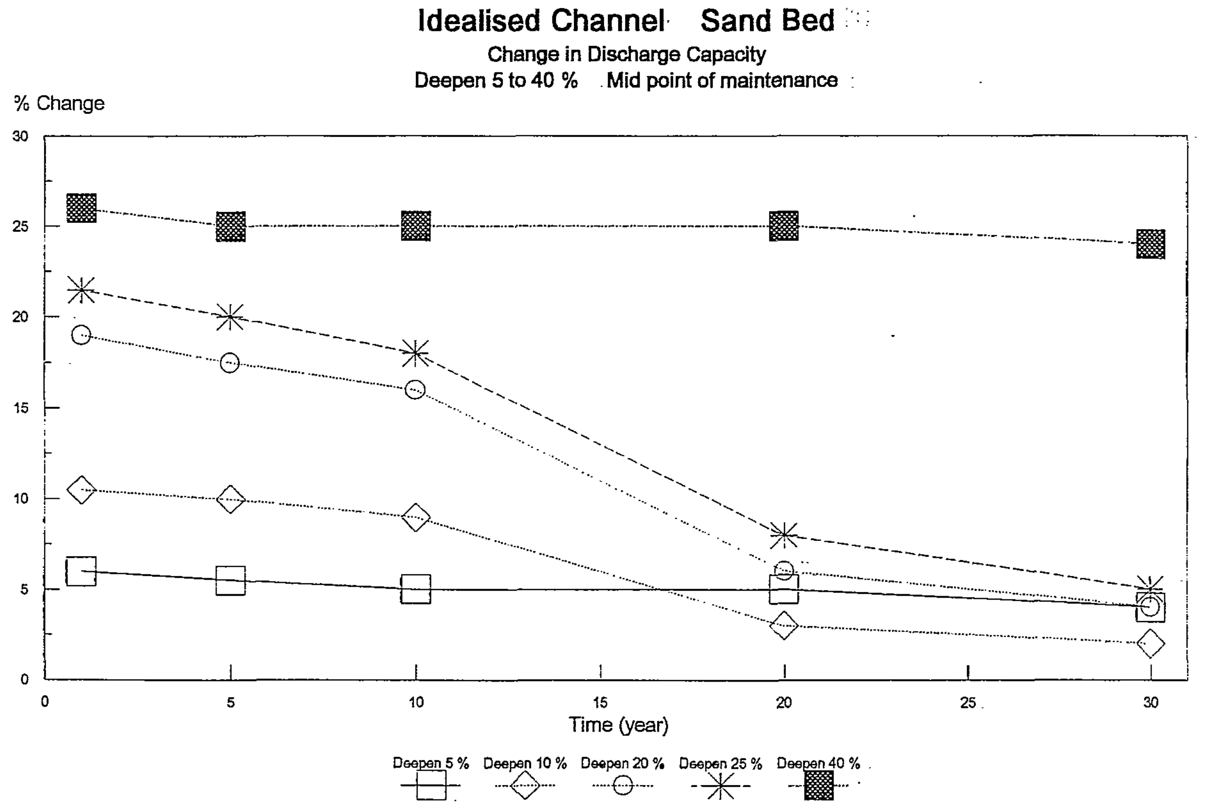
E.g. The benefits of a maintenance scheme performed every 5 years are £13542. To derive the annual benefit, multiply the total benefit by the amortisation factor of 0.24, using the current discount rate of 6 %.
£13542 x 0.24 = benefit of £3250 / year.

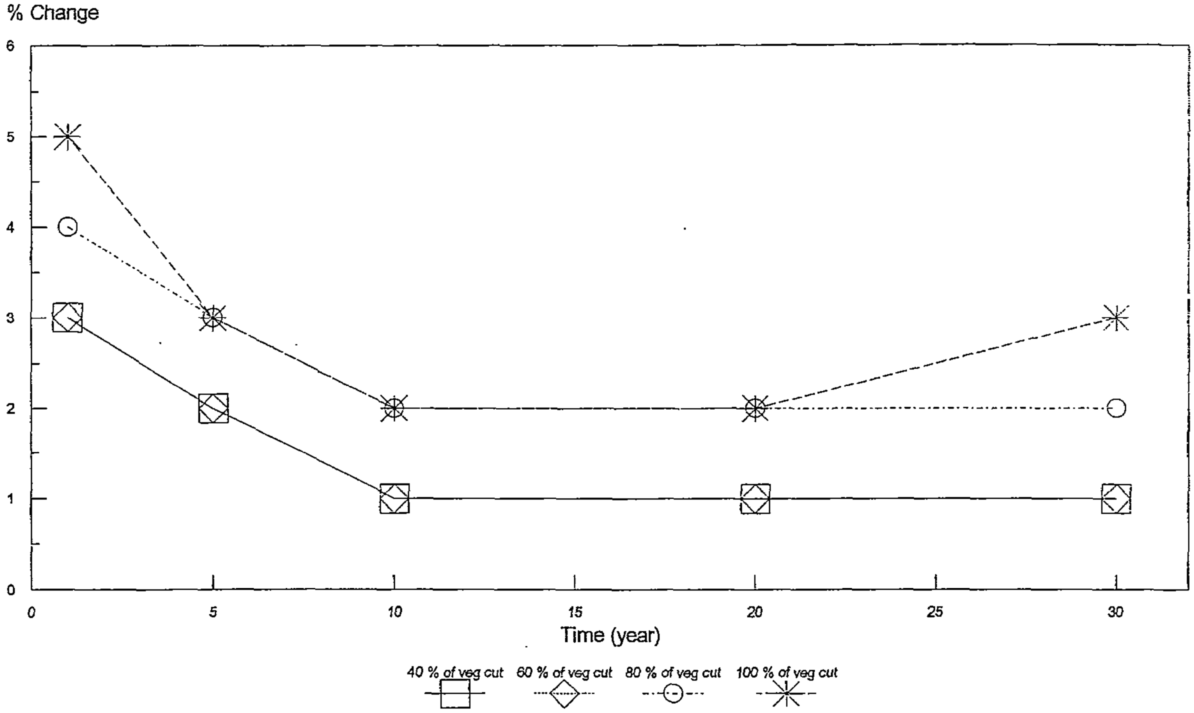
APPENDIX III LONGEVITY OF MAINTENANCE

This Appendix contains graphs which show the longevity of maintenance impacts over a 30 year period in sand and silt bed channels. The impacts of widening, deepening and vegetation removal are shown.

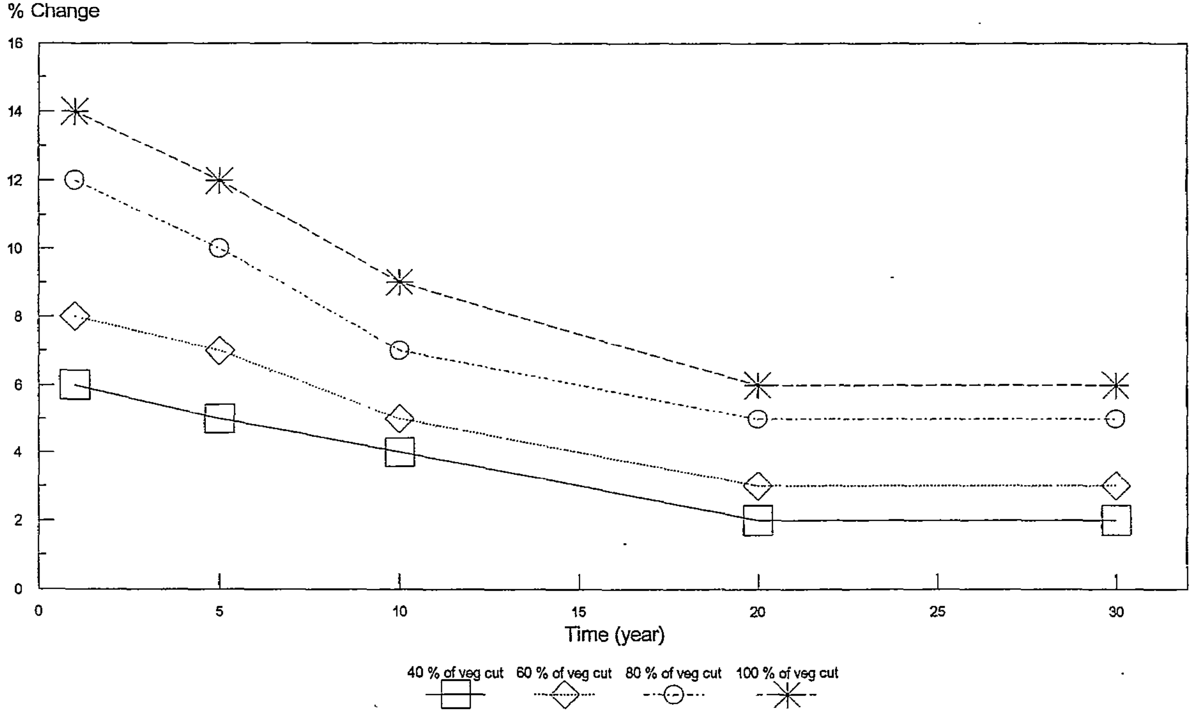
Source: modified from Fisher, 1995.


idealised Channel Sand Bed
Change in Discharge Capacity
Widen 5 to 50 % Mid point of maintenance
% Change
20
15
10
5
0
0
5
10
15
20
25
30
Time (year)
Widen 5 %
Widen 10 %
Widen 50 %

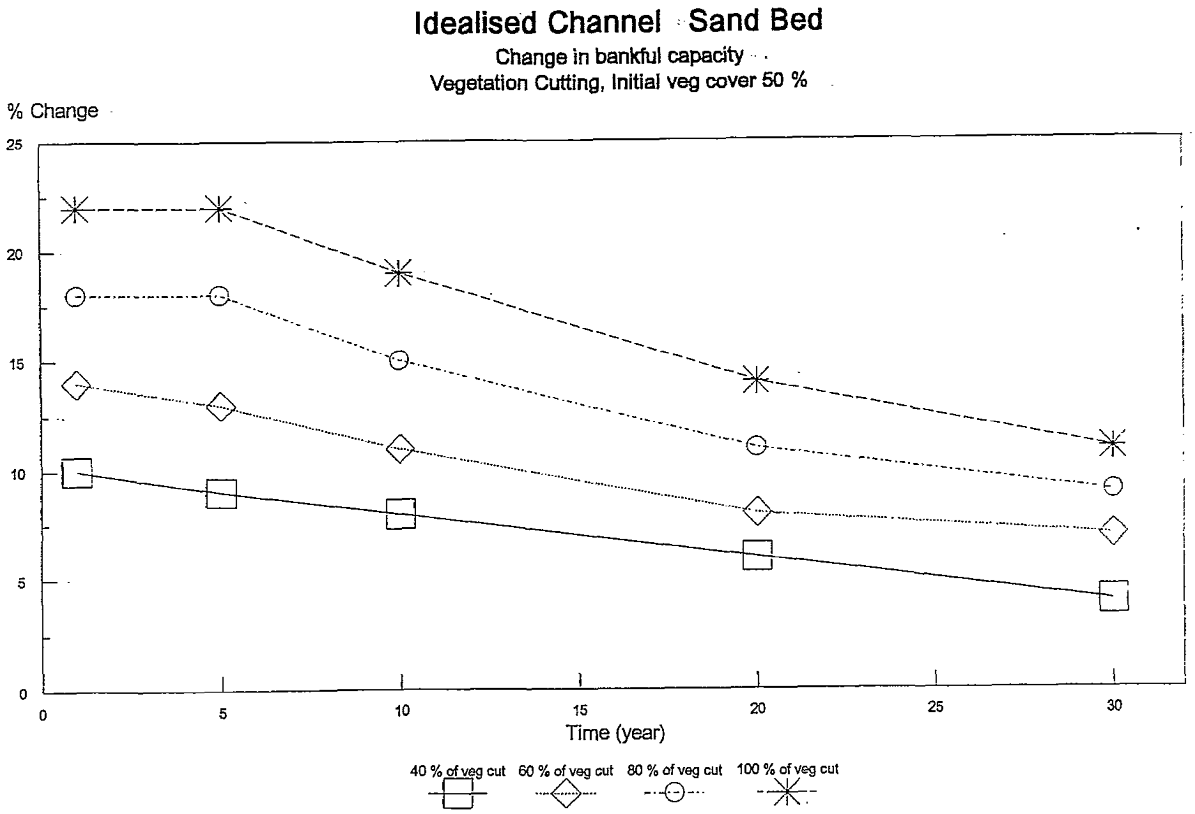

Idealised Channel Sand Bed
Change in Discharge Capacity
Deepen 5 to 40 % Mid point of maintenance
% Change
30
25
20
15
10
5
0
0
5
10
15
20
25
30
Time (year)
Deepen 5 %
Deepen 10 %
Deepen 20 %
Deepen 25 %
Deepen 40 %

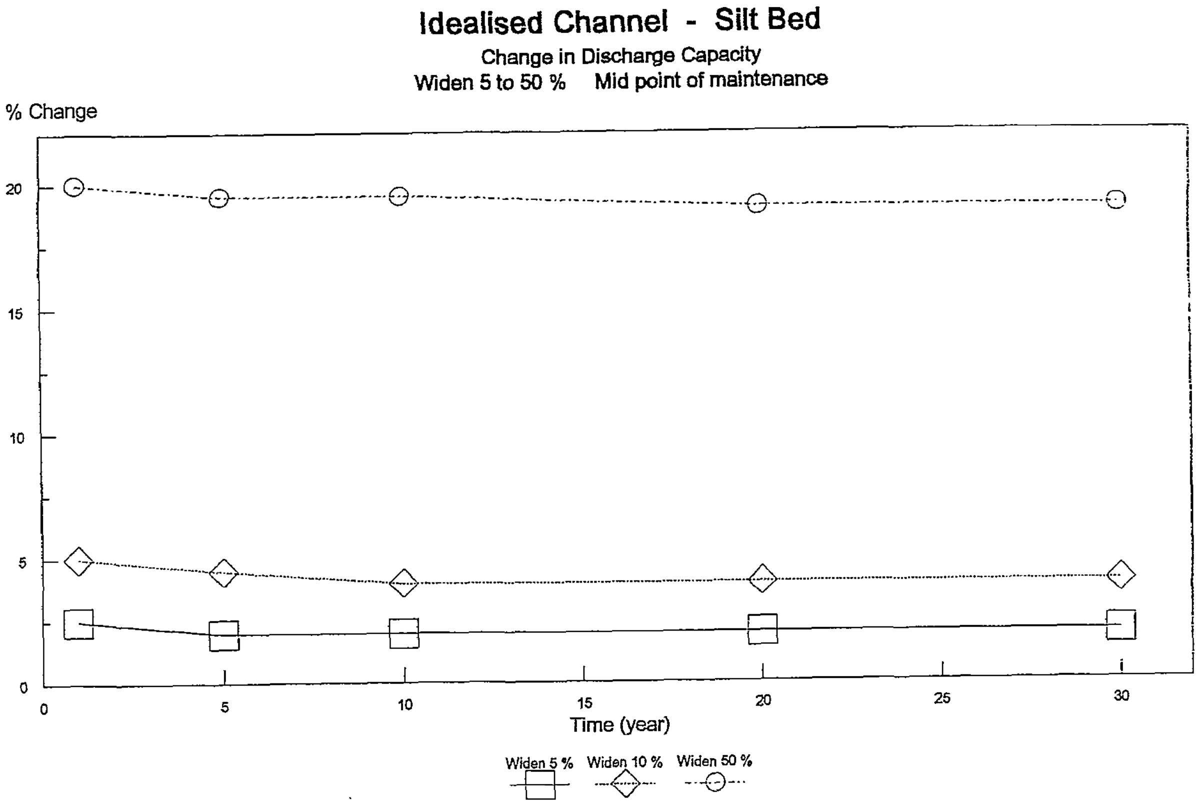


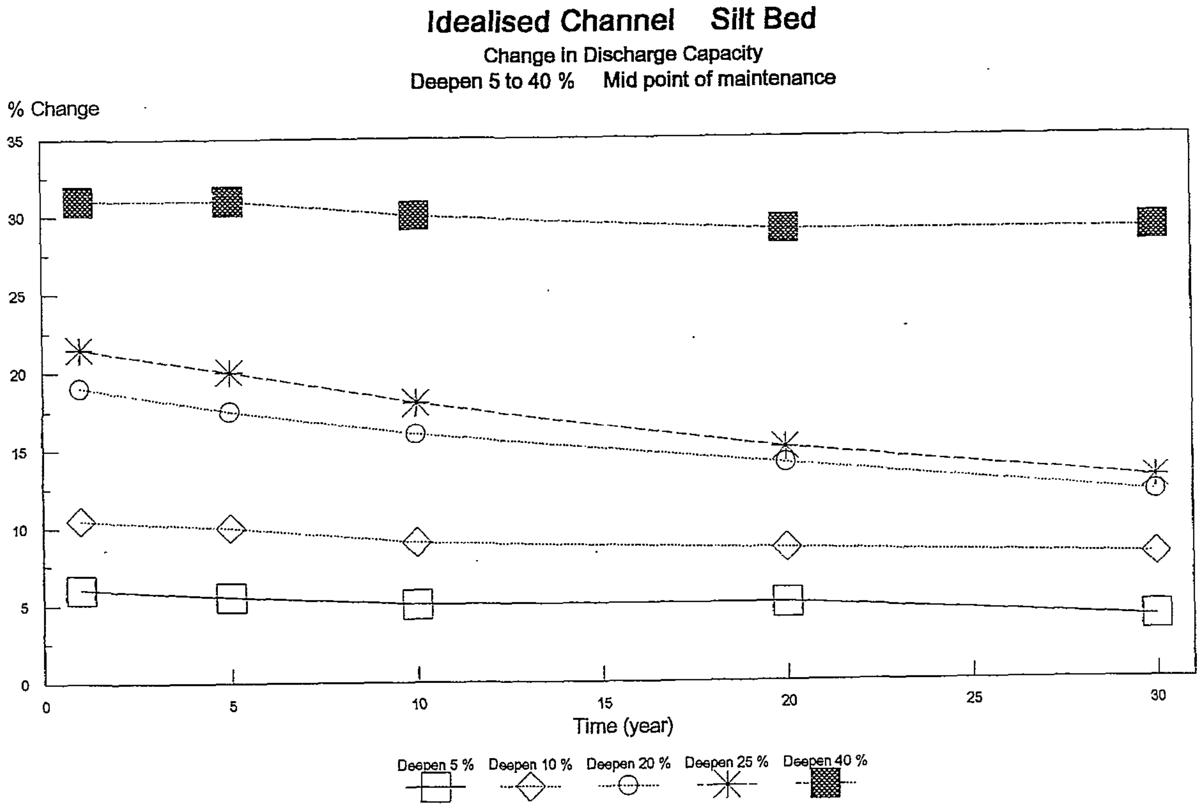
Idealised Channel Sand Bed
Change in bankful capacity
Vegetation Cutting, Initial veg cover 10 %

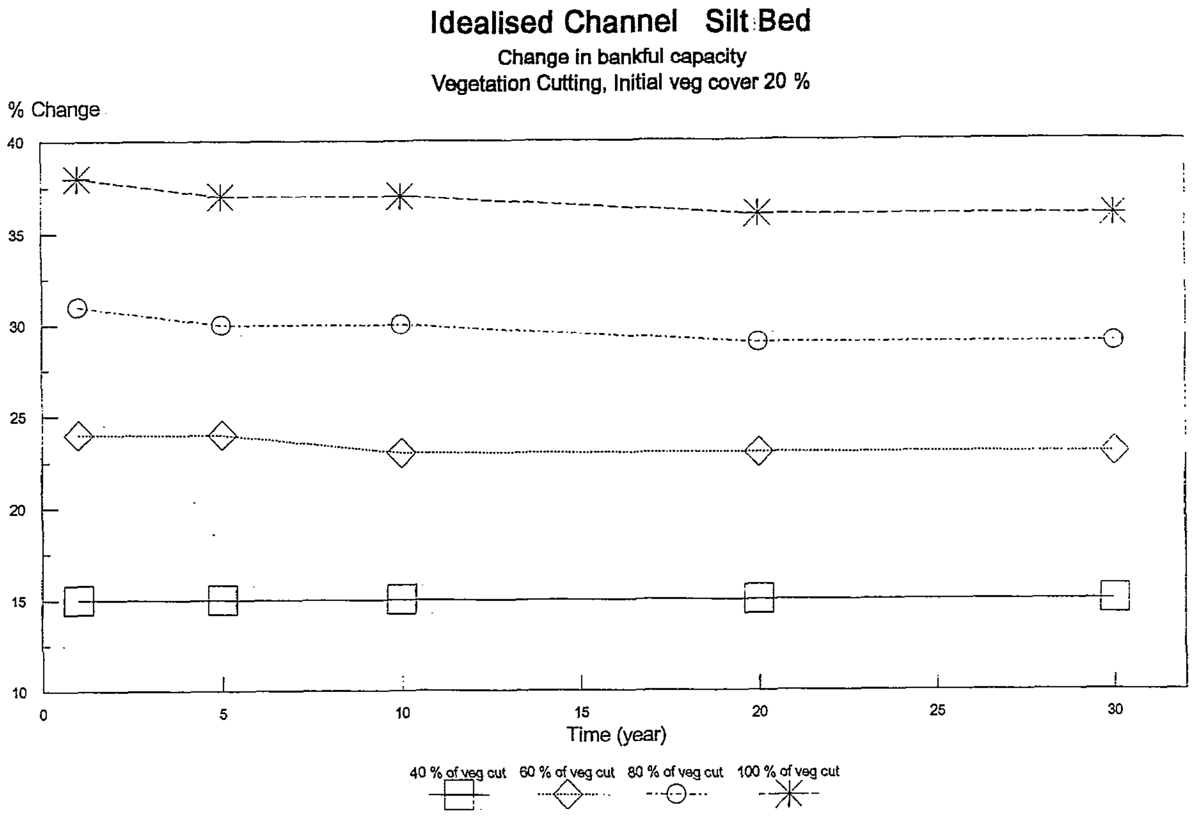


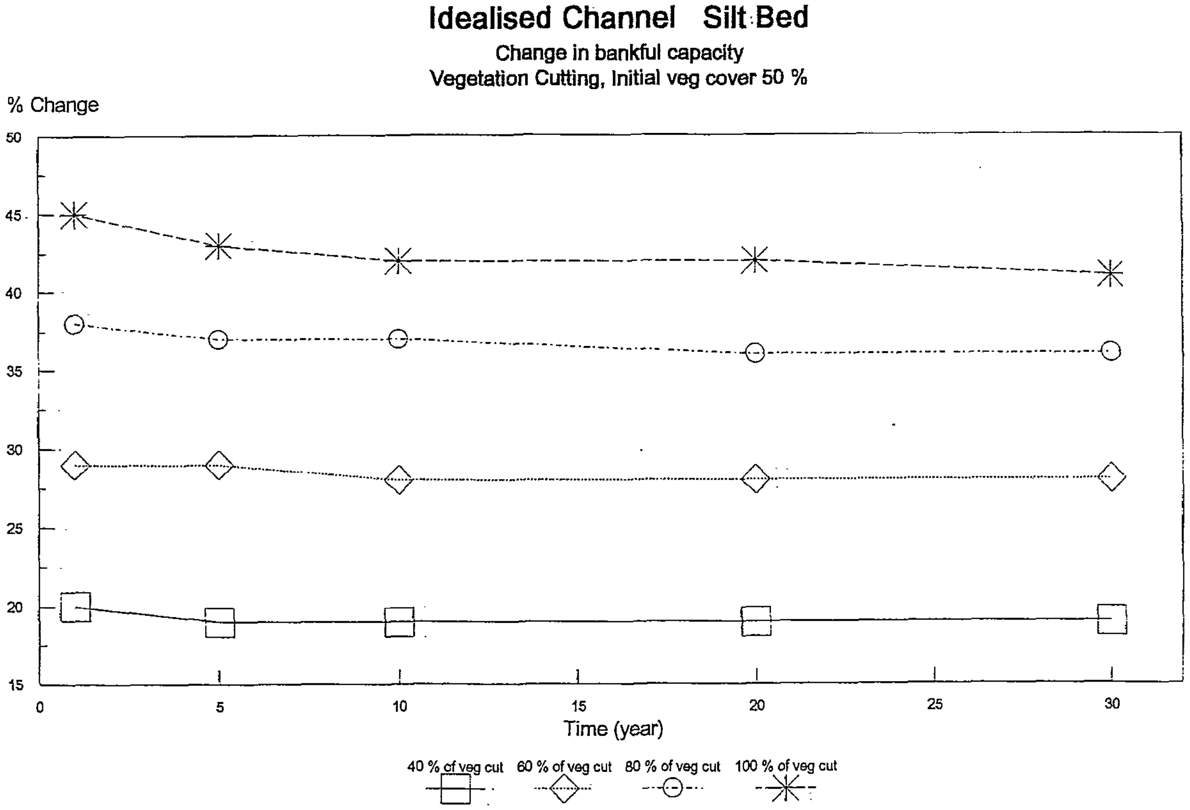
Idealised Channel Sand Bed
Change in bankful capacity
Vegetation Cutting, Initial veg cover 30 %

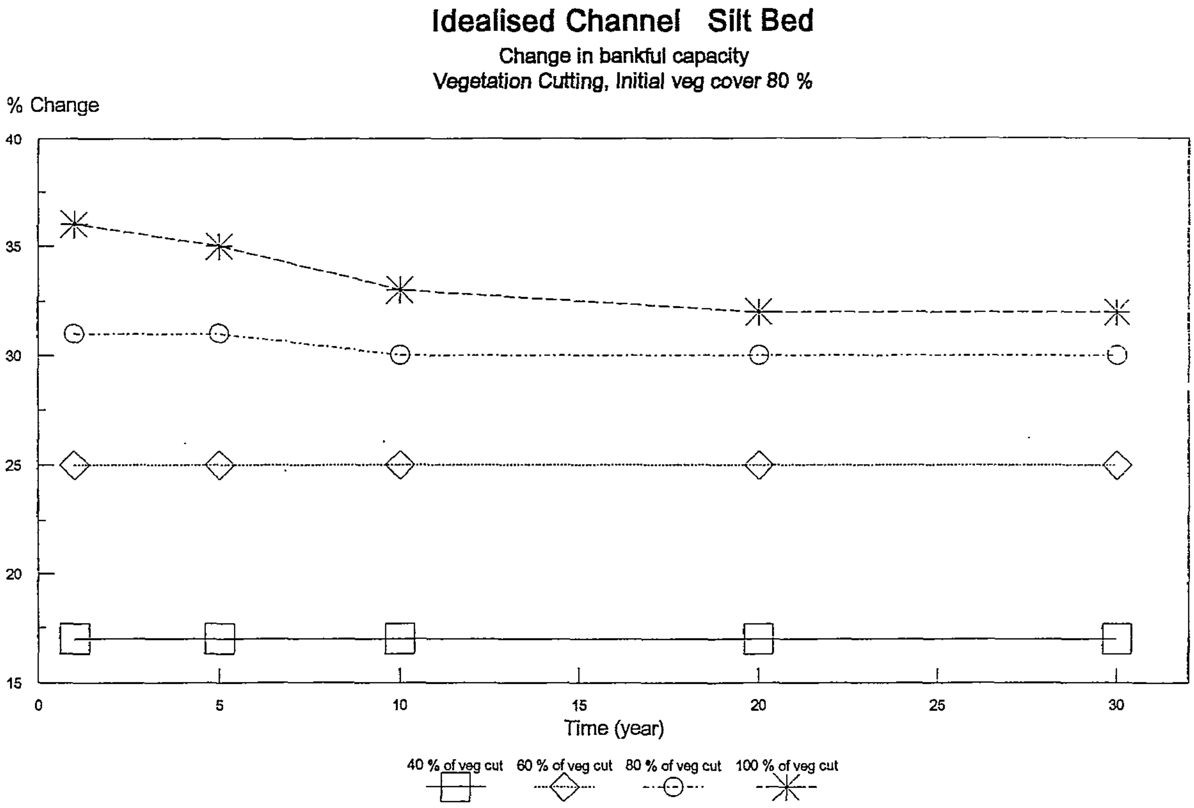

Idealised Channel Sand Bed
Change in bankful capacity
Vegetation Cutting, Initial veg cover 50 %
% Change
25
20
15
10
5
0
0
5
10
15
20
25
30
Time (year)
40 % of veg cut
60 % of veg cut
80 % of veg cut
100 % of veg cut


Idealised Channel - Silt Bed
Change in Discharge Capacity
Widen 5 to 50 % Mid point of maintenance
% Change
0
5
10
15
20
0
5
10
15
20
25
30
Time (year)
Widen 5 %
Widen 10 %
Widen 50 %


Idealised Channel Silt Bed
Change in Discharge Capacity
Deepen 5 to 40 % Mid point of maintenance
% Change
0
5
10
15
20
25
30
35
0
5
10
15
20
25
30
Time (year)
Deepen 5 %
Deepen 10 %
Deepen 20 %
Deepen 25 %
Deepen 40 %


Idealised Channel Silt Bed
Change in bankful capacity
Vegetation Cutting, Initial veg cover 20 %
% Change
40
35
30
25
20
15
10
0
5
10
15
20
25
30
Time (year)
40 % of veg cut
60 % of veg cut
80 % of veg cut
100 % of veg cut


Idealised Channel Silt Bed
Change in bankful capacity
Vegetation Cutting, Initial veg cover 50 %
% Change
50
45
40
35
30
25
20
15
0
5
10
15
20
25
30
Time (year)
40 % of veg cut
60 % of veg cut
80 % of veg cut
100 % of veg cut


Idealised Channel Silt Bed
Change in bankful capacity
Vegetation Cutting, Initial veg cover 80 %
% Change
40
35
30
25
20
15
0
5
10
15
20
25
30
Time (year)
40 % of veg cut
60 % of veg cut
80 % of veg cut
100 % of veg cut

APPENDIX IV

1. WATTON BECK

1.1 Introduction

This Appendix presents the results of the application of FDMM and the Guidelines to Watton Beck, a highland carrier in the North East of England.

1.2 Study Area

1.2.1 Channel characteristics and drainage network

Watton Beck is a spring fed river which rises in the chalk wolds to the East of Middleton-on-the-Wolds approximately 16 km north of Kingston upon Hull. The catchment area of Watton Beck, is estimated to be 27 km^2 (2700 ha). The area downstream of the spring line is estimated to cover 13.75 km^2 (1375 ha). It is this intensively drained area; both through field drains and the natural ditch system, which may benefit from maintenance (Figure 1). Above the spring line, the catchment is on the chalk wolds which are permeable and not served by a network of ditches. Field drains are unnecessary here.

The Environment Agency 'main' river total reach length is 4.5 km. Above main river is a Beverly and Holderness Internal Drainage Board (IDB) watercourse of approximately 2.9 km in length. The study reach extends from the upstream limit of the main river (GR. TA 502860 449490) to the confluence of Watton Beck with the River Hull (GR. TA 506380 447300). Two other IDB watercourses discharge into Watton Beck on the right bank.

Watton Beck discharges under gravity into the tidal River Hull on its upper reach through two flapped outfalls. The River Hull flows out into the River Humber estuary. Watton Beck is tide-locked twice a day during periods of high tide.

Watton Beck is embanked for a length of approximately 2.5 km upstream from the confluence with the River Hull and is described as a highland carrier. This section of Watton Beck does not provide a drainage function for the lowland area over which it flows. This lowland area is served by a network of IDB drains which run broadly parallel to Watton Beck and discharge into the Beverly and Barmstron Drain which is pumped into the River Hull at Wifholme Landing.

The channel of Watton Beck is typically 2.5 m deep and 3 m wide at bed level (range 2-4 m) with a predominantly clay substrate. Freeboard under conditions of mean spring flow is estimated to be 0.75 m in the non-embanked reach and 1 m within the embanked reach.

1.2.2 Catchment characteristics

This lowland catchment is predominantly rural in character. The area is well suited to the growing of cereal crops; in particular winter wheat and barley, with oilseed rape or peas used as a break crop (Jarvis et al, 1984). From a visual survey of the catchment, details on land use were obtained. Land use is dominated by cereal and oilseed crops (85%), with small areas under peas and sugar beet (2%) and extensive pasture (13%). Small areas of scrub and woodland are also present within the catchment.

The solid geology of the area is characterised by chalk which is overlain by chalky till and alluvium. Slowly permeable fine loamy soils with deposits of glaciofluvial drift are characteristic of the Holderness Soil Association (Jarvis et al, 1984). The most extensive soils are of the Holderness series, which are fine, loamy stagnogley soils (Jarvis et al, 1984). Soils of the Burlingham 2 Association dominate the head of the catchment. This Association is characterised by fine loamy soils with slowly permeable subsoil formed in chalky till. The soils of the lowland area to the south of Watton Beck are classified as belonging to the Downholland 3 Association. These humic alluvial gley soils are stoneless clays with peaty or humose upper horizons. The dominant soil type within the catchment is loamy clay.

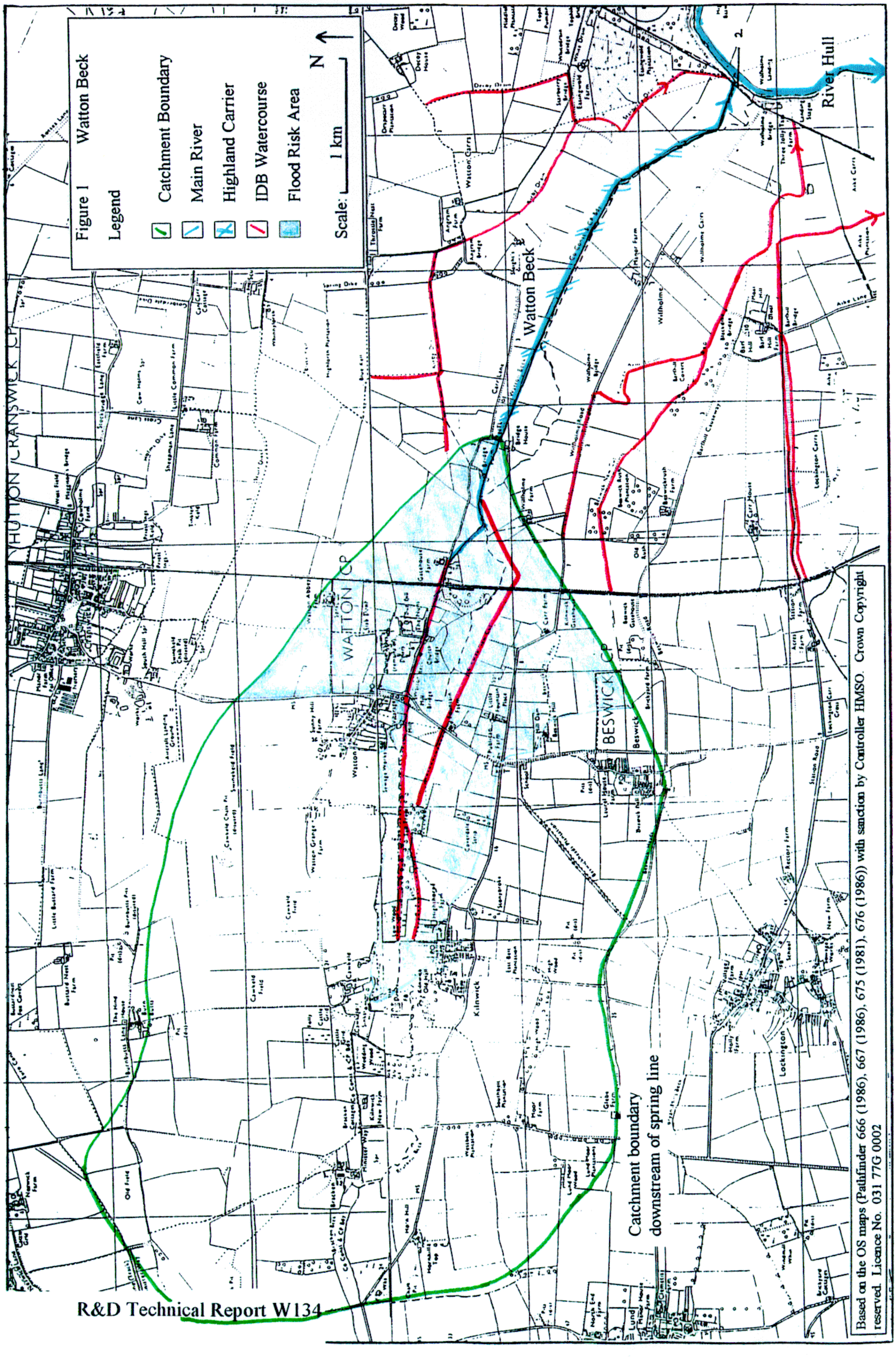


Figure 1 Watton Beck

Based on the OS maps (Pathfinder 666 (1986), 667 (1986), 675 (1981), 676 (1986)) with sanction by Controller HMSO. Crown Copyright reserved. Licence No. 031 77G 0002

1.2.3 River Maintenance

Watton Beck is subject to weedcutting twice a year. All the aquatic vegetation in channel is removed. Prior to maintenance, the channel is usually choked with emergent vegetation with *Glyceria* (Reed Sweet Grass) and *Phragmites* (Common Reed) being the dominant types. *Lemna* (Duckweed) is the dominant floating plant.

The banks are flail mown in April, mid July and in October. The timing of cutting is planned around the bird shooting season in order to avoid disturbance to nesting and breeding sites. The numbers of vermin (rats/moles) which inhabit the embankment are controlled. The channel is subject to dredging approximately once every 10 years. A depth of between 0.1 and 0.2 m of silt is removed to reach hard bed level. Aquatic rhizomes and roots in the sediment are also removed during dredging. This helps to reduce weed growth in the early years following dredging. Total annual maintenance expenditure by the Environment Agency on Watton Beck, including the highland carrier section, is estimated to be £6590 (1997/98 prices).

The IDB channels are also subject to annual weedcutting using an hydraulic excavator during September to November. All the aquatic weed is removed. Tree and bush maintenance is carried out as required. Desilting of the channel takes place on average every 10 years. Approximately 0.2 m of silt is removed to reach the solid bed level. Total maintenance expenditure on the IDB watercourses for 1997/98 is estimated to be £167. This includes a charge for desilting and tree and bush work, the costs of which have been amortised to derive an equivalent annual cost.

1.3 Application of FDMM to Watton Beck

1.3.1 Area of benefit

The area benefiting from maintenance in terms of flood alleviation is estimated to be 460 ha (Figure 1). This is termed the flood risk area. This area was derived from discussions with Environment Agency and IDB personnel. It follows the Medway Letter Line which is a line drawn 2.4 m higher than the known maximum flood extent.

1.3.2 Land use assessment

Flooding

The completed land use assessment reach summary sheets for the left and right bank are presented in at the end of this Appendix. Summary information is presented in Table 1.

Table 1 Land use assessment summary, Watton Beck

	Left Bank	Right Bank	Comment
Flood risk area (ha)	210 ha	250 ha	
Nature of flooding	fluvial	fluvial	
Effective reach length (km)	1	1	Main river within flood risk area only, excludes embanked highland carrier section
Total HE	110.87	128.85	
Flood score (HE/km)	110.87	128.85	

Note: Figures are subject to rounding

Drainage

Under the current maintenance regime, the drainage status for the whole flood risk area is described as good, therefore the drainage score is zero. The drainage benefit area is therefore 460 ha; comprising 210 ha on the left bank and 250 ha on the right bank.

1.3.3 Land use band

Table 2 Land use band, Watton Beck

	Flood Score (HE/km)	Drainage Score (HE/km)	Total	Land Use Band
Left Bank	110.87	0.0 *	110.87	A
Right Bank	128.85	0.0 *	128.85	A

Note: * the drainage status is described as good under the current maintenance situation
Figures are subject to rounding

The land use falls within land use band 'A' for both banks, which states large urban areas are at risk of flooding. This is incorrect as the area is clearly predominantly rural with large areas of agricultural land are at risk of flooding.

This error has arisen due to the very short effective reach length. The highland carrier downstream of the flood risk area provides the conduit for Watton Beck to the outfall into the River Hull. This should be included in the effective reach length. The IDB channel upstream of main river and the two IDB tributaries should also be included in the effective reach length, as these all derive benefit from maintenance on the main river. If this were the case, the land use band would be classed as 'C' on both banks. This denotes high grade agricultural land and some properties (not all agriculturally related) at risk of flooding and impeded drainage. This is a realistic classification given land use in the floodplain.

1.3.4 Determining the effect of flooding

The completed flooding assessment sheets for the left and right bank are presented at the end of this Appendix. Summary information is presented in Table 3 and 4.

The benefits associated with Scenario 1 are straight forward and relate to the representative best estimate of benefits (associated with flood alleviation) which would be lost if maintenance were discontinued. Scenario 2 represents the average annual loss of benefit assuming there is a further deterioration in channel capacity over time due to lack of maintenance and consequently larger areas are flooded. These Scenario 2 benefits have been derived by discounting the average value of incremental losses over the period from scenario 1 to year 10 to derive the present value of these average incremental losses, and adding this to the loss under Scenario 1. Further details are presented at the end of this Appendix.

Table 3 Flooding, Watton Beck

Technique	Predictive technique only. No historical records
Method of analysis	Arithmetic method
Flooded areas	Estimated by Environment Agency, actual areas flooded by the infrequent events are not documented
Annual maintenance	2 scenarios used to test sensitivity of FDMM to impact of annual flood occurring after 1 and 10 years without maintenance

Severity weighting applied to total HEs affected by flooding. 2.2 for arable, 1.5 for pasture

	Left Bank Flood Return Period (yrs)	% Area Flooded	HEs Affected	Right Bank Flood Return Period (yrs)	% Area Flooded	HEs Affected
With maintenance						
	1	0	0	1	0	0
	20	30	37.94	20	30	44.79
	50	100	126.45	50	100	149.29
Annual average number HEs affected (AAN $_{with}$)			20.48			24.18
Without maintenance						
Scenario 1	1	5	6.32	1	5	7.46
	20	50	63.23	20	50	74.65
	50	100	126.45	50	100	149.29
Annual average number HEs affected (AAN $_{without}$)			35.88			42.36
Scenario 2	1	25	31.61	1	25	37.32
	20	50	63.23	20	50	74.65
	50	100	126.45	50	100	149.29
Annual average number HEs affected (AAN $_{without}$)			47.89			56.54

The benefits (£) associated with each flooding scenario for both banks are shown in Table 4.

Table 4 Annual benefit of flood alleviation, Watton Beck

	AAN without (HE/km) (a)	AAN with (HE/km) (b)	(a) - (b)	Annual Benefit Lost (£)
Left Bank				
Scenario 1	35.88	20.48	15.40	20082
Scenario 2	47.89	20.48	27.41	25928
Right Bank				
Scenario 1	42.36	24.18	18.18	23706 *
Scenario 2	56.54	24.18	32.36	30612 *

Note: 1997/98 prices are used. Figures are subject to rounding.

* Average annual loss of benefit assuming further deterioration. Further details are presented at the end of the Appendix.

1.3.5 Determining the effect of deterioration in drainage

The completed drainage benefit assessment sheets for the left and right bank are presented at the end of this Appendix. Summary information is presented in Table 5. Under Scenario 1, the base case, the whole of the flood risk area is expected to experience bad drainage without maintenance.

As with flooding, the Scenario 2 benefits have been derived by discounting the average value of incremental losses over the period from Scenario 1 to year 10 to derive the present value of these average incremental losses, and adding this to the loss under Scenario 1. Further details are presented at the end of this Appendix.

Table 5 Drainage, Watton Beck

	Left Bank	Right Bank
Area affected by deterioration in drainage status without maintenance (ha)	210	250
Drainage status with maintenance	Good	Good
Scenario 1, base case, year 0		
Drainage status without maintenance	Bad	Bad
Annual benefit (£)	13343	15986
Total annual benefit (£) (both banks)	29329	
Scenario 2, year 10		
Drainage status without maintenance	Very bad	Very bad
Annual benefit (£)	21228	25439
Total annual benefit (£) (both banks)	46667	

Note: Figures are subject to rounding. 1997/98 prices are used .

1.3.6 Actual standard of service

Table 6 Actual standard of service provided under the current maintenance regime, Watton Beck

	Flooding (AAN $_{with}$) (HE/km) (a)	Effective Reach Length (km) (b)	Flood Score (HE/km/yr) (a/b) = (c)	Drainage Score (HE/km/yr) (d)	Total (c)+(d)
Left Bank	20.48	1	20.48	0.0 *	20.48
Right Bank	24.18	1	24.18	0.0 *	24.18
Both Banks				Average Score	22.33
				Below Target Standard	

Note: * the drainage status is described as good under the current maintenance situation, therefore the drainage score is zero . Figures are subject to rounding. 1997/98 prices are used.

1.3.7 Justification

Table 7 Total benefits of maintenance, Watton Beck

		Annual Benefit of Flood Alleviation (£)	Annual Benefit of Maintaining Drainage Status (£)	Total Annual Benefit (£)
Scenario 1	Left bank	20082	13343	
	Right bank	23706	15986	
	Total	43788	29329	73117
Scenario 2	Left bank	25928	21228	
	Right bank	30612	25439	
	Total	56540	46667	103207

Note: Figures are subject to rounding. 1997/98 prices are used.

Table 8 Benefit:cost ratio, Watton Beck

	Total Annual Benefit (£)	Total Annual Maintenance Cost (£)	Benefit:Cost Ratio
Scenario 1	73117	1883	38.83
Scenario 2	103207	1883	54.81

Note: Maintenance costs for main river within flood risk area only, excludes highland carrier. Figures are subject to rounding. 1997/98 prices are used.

1.4 Sensitivity Analysis

1.4.1 Flooding

The benefits of flooding vary according to the area inundated. The impact of different areas flooded by the annual flood occurring one and 10 years after maintenance is shown in Section 1.3.4.

1.4.2 Drainage

As the drainage benefit area is estimated to be the same as the flood risk area but not supported by historical evidence, the benefit:cost analysis was repeated assuming that 50% of the flood risk area would be subject to bad drainage in the absence of maintenance. The corresponding drainage benefits are shown in the record sheets at the end of this Appendix and the benefit:cost ratio shown in Table 9. The maintenance scheme is still justified as the benefit:cost ratio is greater than 1.0.

Table 9 Benefit : cost ratio, 50% flood risk area affected by bad drainage, Watton Beck

	Total Annual Benefit (£)	Total Annual Maintenance Cost (£)	Benefit:Cost Ratio
Scenario 1	58442	1883	31.04

Note: Maintenance costs for main river within flood risk area only, excludes highland carrier.
Figures are subject to rounding. 1997/98 prices are used.

If the areal drainage factor is applied to the flood risk area to determine the drainage benefit area, these two areas will be the same as due to the light soil and combination of natural and piped drainage system, the areal drainage factor is 1 (Table 3.8, FDMM).

1.4.3 Actual SoS

Estimates of the actual standard of service provided are sensitive to the effective reach length used, as shown in Table 10. As the IDB watercourse upstream of main river derives benefit from maintenance on main river, and as it is wholly included within the flood risk area of the main river, the IDB watercourse should ideally be included in the calculation of the effective reach length. Similarly, the two IDB tributaries which also lie wholly within the flood risk area, could be included in the calculation of effective reach length. As these are not classed as main river, however, FDMM excludes them from the analysis.

Table 10 Sensitivity analysis: effective reach length and reach status, Watton Beck

Ban	Flooding (HE/km) (a)	Effective Reach Length (km) (b)	Flood Score (HE/km/yr) (a/b) = (c)	Drainage Score (HE/km/yr) (d)	Total (c)+(d)	Reach Status
Effective reach comprises: main river only						
LB	20.48	1	20.48	0.0 *	20.48	BTS
RB	24.18	1	24.18	0.0 *	24.18	BTS
				Average	22.33	BTS
Effective reach comprises: main river and IDB watercourse upstream of main river						
LB	20.48	3.9	5.25	0.0 *	5.25	BTS
RB	24.18	3.9	6.20	0.0 *	6.20	BTS
				Average	5.72	BTS
Effective reach comprises: main river and highland carrier						
LB	20.48	3.5	5.85	0.0 *	5.85	BTS
RB	24.18	3.5	6.91	0.0 *	6.91	BTS
				Average	6.38	BTS
Effective reach comprises: main river, IDB watercourse upstream of main river, IDB tributaries and highland carrier						
LB	20.48	6.4	3.20	0.0 *	3.20	BTS
RB	24.18	13.1	1.85	0.0 *	1.85	BTS
				Average	2.52	BTS

Note: * the drainage status is described as good under the current maintenance situation, therefore the drainage score is zero. Figures are subject to rounding. 1997/98 prices are used.

The highland carrier which provides the outfall of Watton Beck into the River Hull does not provide a service to the land through which it flows, but it conveys water from the upper reaches of the catchment. Technically, this should be included in calculation of the effective reach length. The number of HEs which would be inundated if the highland carrier were breached should also be included in the analysis of the SoS.

1.4.4 Maintenance costs

In accordance with FDMM, maintenance expenditure has been increased by 15% and the benefits reduced by 15% in order to check the sensitivity of assumptions made on the benefit:cost ratio. The results of this are shown in Table 11 using the average benefits of Scenario 1, 2 and 3. Due to the high benefits and low maintenance costs, the maintenance regime would be justified even if costs increased and benefits reduced by 15%.

If the IDB watercourses and highland carrier are included in the analysis of effective reach length, the maintenance costs associated with these channels should be included in the benefit:cost equation. Sensitivity of the benefit:cost ratio to these various maintenance costs is shown in Table 11. The results show that the benefit:cost ratio is sensitive to assumptions made regarding maintenance costs.

The maintenance costs on the highland carrier should be included in the benefit:cost analysis as this maintenance provides benefits for the main river upstream. Provision for this, however, is not made within FDMM. Further details on this are presented in Section 1.4.5.

Table 11 Sensitivity analysis: benefit : cost ratio, Watton Beck

Total Annual Benefit (£)	Total Annual Maintenance Cost (£)	Benefit:Cost Ratio
Maintenance costs increased by 15%		
73117	2165	33.77
Benefits reduced by 15%		
62149	1883	33.00
Maintenance costs increased by 15%, benefits reduced by 15%		
62149	2165	28.70

Note: Maintenance costs for main river within flood risk area only, excludes highland carrier. Figures are subject to rounding. 1997/98 prices are used.

As Watton Beck discharges into the River Hull and derives benefit from maintenance on it, a proportion of the maintenance expenditure on the River Hull should be included in the costs for Watton Beck. Fluvial flow into the River Hull from Watton Beck accounts for approximately 1% of total flow. The proportion of maintenance expenditure on the River Hull which may be associated with Watton Beck is therefore £202 (1997/98 prices) which is 1% of maintenance costs on the River Hull.

Sensitivity of the benefit:cost ratio to maintenance expenditure is shown in Table 12. The results show that the benefit:cost ratio is sensitive to assumptions made regarding maintenance costs, although in this case study, the benefit:cost ratios remain favourable.

Table 12 ***Sensitivity of benefit:cost ratio to maintenance costs, Watton Beck***

Total Annual Benefit (£)	Total Annual Maintenance Cost (£)	Benefit:Cost Ratio
Maintenance costs for Watton Beck, main river within flood risk area only		
73117	1883	38.83
Maintenance costs for Watton Beck main river within flood risk area only and IDB watercourses		
73117	2050	35.66
Maintenance costs for Watton Beck including embanked highland carrier section		
73117	6590	11.10
Maintenance costs for Watton Beck, including highland carrier and proportion of costs for River Hull		
73117	6792	10.77
Maintenance costs for Watton Beck including highland carrier, IDB watercourses and proportion of costs for River Hull		
73117	6959	10.51

Note: Figures are subject to rounding. 1997/98 prices are used.

1.4.5 Benefits

If the maintenance costs of the IDB watercourses, highland carrier and the River Hull are taken into account in the benefit:cost equation, the benefits of this maintenance should also be considered.

The highland carrier provides the conduit for Watton Beck over a lowland area to the River Hull into which it discharges. Maintenance of this highland carrier therefore provides a benefit for the main river upstream. If maintenance were not carried out on the highland carrier, channel capacity may be reduced with a concomitant deterioration in drainage status upstream and increase in flooding.

The benefits provided by the highland carrier also relate to flood protection. If the maintenance were not carried out and the banks were breached, a large part of the lowland drainage area may flood. The exact area affected, however, will depend on many factors such as the location of the breach, time taken to repair it, discharge and topography. Detailed modelling would be required to accurately predict the area affected by a flood event of a particular return period, with a breach at a specific point. Such detailed analysis is not usually possible and an estimate of benefits may need to be made. Similarly, it is likely to be difficult to determine the benefits derived from the proportion of maintenance on the River Hull which are attributed to Watton Beck. Estimation of these benefits will, however, reduce the accuracy of the benefit:cost analysis. It is recommended that the type of these additional benefits is noted and only if the benefits of maintenance appear to be marginal, then an estimate of these benefits is made.

1.5 Application of the Guidelines to Watton Beck

1.5.1 Introduction

The following sections present the results of the application of the Guidelines to Watton Beck. The same data are used as in the application of FDMM in order that results from the two methods may be compared. The completed record sheets and tables/figures required in the use of the Guidelines are presented at the end of this Appendix.

1.5.2 General information

Table 13 General information, Watton Beck

Parameter		Comment
Dominant substrate	Clay	
Floodplain topography	Rising (>1%)	
Catchment size	Large (>2500 ha)	
Benefit area (ha)	460	Same as total flood risk area. Left and right banks are combined.
Land use type	Cereal/oilseed rotation (LUT 5)	
Dominant soil type	Loamy clay	

1.5.3 Design standard (maintained condition)

Table 14 With maintenance channel parameters, drainage status and net return

Parameter		Comment
Average bed width (m)	3	
Average channel depth (m)	2.5	
Freeboard under mean spring flow (m)	0.75	
Watertable depth (m)	0.5	Using Figure 2.6 in main text
Drainage status	Good	Using Figure 2.6 in main text
Economic net return (£/ha)	329	1997/98 prices
Economic net return (£)	151340	1997/98 prices

Note: Figures are subject to rounding. 1997/98 prices are used.

Annual flood costs were identified using the Guidelines for the cereal/oilseed rotation under good drainage, for events with a return period of 1, 20 and 50 years. The same flooded areas and return periods were used as in FDMM. The flood costs corresponding with these return periods are shown in Table 15. It is assumed that these costs are additive. Total flood costs for the 'with' maintenance situation are £1794 (1997/98 prices).

Table 15 With maintenance flood costs, Watton Beck

Flood Return Period	Area Flooded	Area Flooded	Annual Flood Cost	
(yr)	(%)	(ha)	(£/ha)	(£)
1	0	0	0	0
20	30	138	3	414
50	100	460	3	1380
			Total	1794

Note: Figures are subject to rounding. 1997/98 prices are used.

The value of the benefit area under the current maintenance regime is calculated by subtracting the flood costs from the net return, as shown in Table 16.

Table 16 Design standard, value of benefit area, Watton Beck

Total Net Return (£) (a)	Total Flood Cost (£) (b)	Benefit Area Value (£) (a-b)
151340	1794	149546

Note: Figures are subject to rounding. 1997/98 prices are used.

1.5.4 Maintenance regime

Table 17 Impact of maintenance on freeboard, Watton Beck

Parameter		Comment
Increase in bed width	50%, 1.5 m	
Increase in channel depth	8%, 0.2 m	
Impact of widening on freeboard	9%	Using Table 2.8 in main text
Impact of deepening on freeboard	3.5%	Using Table 2.8 in main text
Total impact on freeboard	12.5%	

1.5.5 Do-nothing (without maintenance)

Drainage status

The change in freeboard as a consequence of maintenance is used to determine the watertable depth and the corresponding drainage status which would prevail in the absence of maintenance. Assuming a freeboard of 0.66 m without maintenance, using Figure 2.6 in the main text, the without maintenance drainage status is assessed as bad. Under Scenario 2, the drainage status is expected to deteriorate from good to very bad.

Economic net return

Using the dominant land use type of a cereal/oilseed rotation and bad drainage, the economic net return is calculated to be £263 /ha (1997/98 economic prices) (Scenario 1). The total economic net return for the whole benefit area is therefore £120980 (1997/98 prices).

Under Scenario 2, the loss associated with the extra deterioration to very bad drainage is £47203. If this is subtracted from the net return with maintenance, the net return without maintenance under Scenario 2 is £104137 (1997/98 prices). These Scenario 2 figures have been derived following the same approach as for flooding. Further details are presented at the end of this Appendix.

Flood costs

Annual flood costs were identified using the Guidelines for the cereal/oilseed rotation under bad drainage, for events with the same return periods as under the 'with' maintenance situation. The same flooded areas and return periods were used as in FDMM.

The flood costs corresponding to the return periods are shown in the record sheets at the end of this Appendix. It is assumed that these costs are additive. Under Scenario 1 (year 0), total flood costs in the first year of no maintenance are £2116 (1997/98 prices). Under Scenario 2 (year 10), flood costs are £3216 (1997/98 prices).

Value of benefit area without maintenance

The value of the benefit area without maintenance is calculated by subtracting the flood costs from the net return, as shown in Table 18.

Table 18 Without maintenance value of benefit area, Watton Beck

	Total Net Return (£) (a)	Total Flood Cost (£) (b)	Benefit Area Value (£) (a-b)
Scenario 1	120980	2116	118864
Scenario 2	104137	3216	100921

Note: Figures are subject to rounding. 1997/98 prices are used.

1.5.6 Maintenance costs

The total annual maintenance expenditure on Watton Beck, excluding the highland carrier, is £1883 (1997/98 prices).

1.5.7 Benefit of maintenance

The difference in value of the benefit area 'with' and 'without' maintenance is used to determine the benefit of maintenance. From the figures presented in Tables 16 and 18, the benefit of maintenance is calculated to be £30682 for Scenario 1 and £48625 for Scenario 2 (19997/98 prices).

1.5.8 Justification

The net benefit of maintenance is greater than the annual maintenance expenditure, therefore the maintenance regime is justified. The benefit:cost ratio is 16.29 for Scenario 1 and 25.82 for Scenario 2.

1.6 Sensitivity Analysis

1.6.1 Flooding

As previously discussed (Section 1.3.4), the benefits of flooding vary according to the area inundated. Some sensitivity analysis has been undertaken to determine the impact of different areas flooded by the annual flood occurring one and 10 years after maintenance.

1.6.2 Maintenance costs

The benefits of maintenance are sensitive to assumptions made regarding maintenance expenditure. In the preceding analysis, maintenance expenditure for the main river only, excluding the highland carrier has been taken into account.

As in Section 1.4.4, the benefit:cost ratios have been calculated for various maintenance expenditure scenarios. The results of this analysis are shown in Table 20.

Table 20 Sensitivity of benefit:cost ratio to maintenance costs, Watton Beck

Total Annual Benefit (£)	Total Annual Maintenance Cost (£)	Benefit:Cost Ratio
1. Maintenance costs for Watton Beck, main river in flood risk area only		
30682	1883	16.29
2. Maintenance costs for Watton Beck including highland carrier		
30682	6590	4.66
3. Maintenance costs for Watton Beck, including the highland carrier and IDB watercourses		
30682	6757	4.54
4. Maintenance costs for Watton Beck, including the highland carrier and proportion of costs on the R. Hull		
30682	6792	4.52
5. Maintenance costs for Watton Beck, including the highland carrier, IDB watercourses and proportion of costs on R. Hull		
30682	6959	4.41

Note: Figures are subject to rounding. 1997/98 prices are used.

WATTON BECK

Order of record sheets presented in the following pages:

FDMM

Annual maintenance costs

Land use assessment: reach summary

Flooding

Drainage benefits

Agricultural benefits only: Land use assessment - reach summary

Agricultural benefits only: Flooding

GUIDELINES

General information

Design standard

Maintenance regime

'Do-nothing' - Without maintenance

Maintenance expenditure and benefits of maintenance

ANNUAL MAINTENANCE COSTS

Watton Beck
1997/98 prices

Element	Annual Maintenance Cost (£)
Main river within flood risk area only	1883
Highland carrier section only	4707
Total costs on main river	6590
Proportion of costs on River Hull	202
Internal Drainage Board watercourses	167

Source: Environment Agency (North East Region) and Beverly & Holderness IDB

Note: All maintenance costs relate to annual costs, in 1997 prices.
The proportion of maintenance costs on the River Hull which may be associated with Watton Beck is based on the percentage of total fluvial flow into the River Hull from Watton Beck.
1 % of the total fluvial flow in River Hull is derived from Watton Beck, therefore, 1 % of maintenance costs on the River Hull are associated with Watton Beck. (1% of £20179).

LAND USE ASSESSMENT : REACH SUMMARY

Watercourse	**Watton Beck**
Bank	**Left Bank**
OS Map	Pathfinder 675/676/666/667
Flood risk area (ha)	210
Effective reach length (km)	1

Land Use Factor	Unit	Number or area (a)	House Equivalents HE/unit (b)		Total HE (a) x (b)	
House	Number	*3*	1.00		*3*	
Garden / allotments	Number	*3*	0.04		*0.12*	
NRP - Manufacturing	Area (m^2)		0.030		*0*	
NRP - Distribution	Area (m^2)		0.054		*0*	
NRP - Leisure	Area (m^2)		0.032		*0*	
N R P - Offices	Area (m^2)	*25*	0.033		*0.825*	
N R P - Retail	Area (m^2)		0.035		*0*	
N R P - Agricultural	Area (m^2)	*2500*	0.010		*25*	
C Roads	Number	*2*	2.7		*5.4*	
B Roads	Number		6.3		*0*	
A Roads (non trunk)	Number		15.9		*0*	
A Roads (trunk)	Number		31.7		*0*	
Motorway	Number		63.5		*0*	
Railway	Number	*1*	63.5		*63.5*	
			Flooding	Drainage	Flooding	Drainage **
Forestry and scrub *	per 100 ha		0.02	0.0		
Extensive pasture *	per 100 ha	*0.042*	1.3	1.1	*0.0546*	*0*
Intensive pasture *	per 100 ha		3	4.5		
Extensive arable *	per 100 ha	*2.058*	6.3	3.6	*12.9654*	*0*
Intensive arable *	per 100 ha		44.1	9.7		
Formal parks	Number		0.6		*0*	
Golf / race courses	Number		0.7		*0*	
Playing field	Number		0.1		*0*	
Special parks	Number		9.3		*0*	
Total HE (c) *					*110.87*	
HE/km ((c) / effective reach length)					*110.87*	

Note
* Flooding / drainage scores to be summed ** Apply areal drainage factor if required
HE values are at 1991 base

LAND USE ASSESSMENT : REACH SUMMARY

Watercourse	**Watton Beck**
Bank	**Right Bank**
OS Map	Pathfinder 675/676/666/667
Flood risk area (ha)	250
Effective reach length (km)	1

Land Use Factor	Unit	Number or area (a)	House Equivalents HE/unit (b)		Total HE (a) x (b)	
House	Number	*16*	1.00		*16*	
Garden / allotments	Number	*16*	0.04		*0.64*	
NRP - Manufacturing	Area (m^2)		0.030		*0*	
NRP - Distribution	Area (m^2)		0.054		*0*	
NRP - Leisure	Area (m^2)		0.032		*0*	
N R P - Offices	Area (m^2)		0.033		*0*	
N R P - Retail	Area (m^2)		0.035		*0*	
N R P - Agricultural	Area (m^2)	*2625*	0.010		*26.25*	
C Roads	Number	*2*	2.7		*5.4*	
B Roads	Number		6.3		*0*	
A Roads (non trunk)	Number		15.9		*0*	
A Roads (trunk)	Number		31.7		*0*	
Motorway	Number		63.5		*0*	
Railway	Number	*1*	63.5		*63.5*	
			Flooding	Drainage	Flooding	Drainage **
Forestry and scrub *	per 100 ha	*0.0125*	0.02	0.0	*0.00025*	*0*
Extensive pasture *	per 100 ha	*0.025*	1.3	1.1	*0.0325*	*0*
Intensive pasture *	per 100 ha		3	4.5		
Extensive arable *	per 100 ha	*2.4225*	6.3	3.6	*15.26175*	*0*
Intensive arable *	per 100 ha	*0.04*	44.1	9.7	*1.764*	
Formal parks	Number		0.6		*0*	
Golf / race courses	Number		0.7		*0*	
Playing field	Number		0.1		*0*	
Special parks	Number		9.3		*0*	
				Total HE (c) *	*128.85*	
				HE/km ((c) / effective reach length)	*128.85*	

Note

* Flooding / drainage scores to be summed

HE values are at 1991 base

** Apply areal drainage factor if required

FLOODING

Watercourse	**Watton Beck**
Bank	**Left Bank**
Flood risk area (ha)	210
Effective reach length (km)	1

With maintenance - current situation

Flood Return Period (years)	Probability	Nr. HEs Affected	Probability Interval (a)	Average Nr. HEs Affected (b)	(a) x (b)
1	1	0.00			
no flooding			0.95	18.97	18.02
20	0.05	37.94			
30 % flooded			0.03	82.19	2.47
50	0.02	126.45			
100 % flooded					
Annual Average Number HEs affected with maintenance (AAN$_{\text{with}}$)					20.48

Scenario 1 - without maintenance

Impact of annual flood after 1 year without maintenance

Flood Return Period (years)	Probability	Nr. HEs Affected	Probability Interval (a)	Average Nr. HEs Affected (b)	(a) x (b)
1	1	6.32			
5 % flooded			0.95	34.77	33.04
20	0.05	63.23			
50 % flooded			0.03	94.84	2.85
50	0.02	126.45			
100 % flooded					
Annual Average Number HEs affected without maintenance (AAN$_{\text{without}}$)					35.88

Scenario 2 - without maintenance

Impact of annual flood after 10 years without maintenance

Flood Return Period (years)	Probability	Nr. HEs Affected	Probability Interval (a)	Average Nr. HEs Affected (b)	(a) x (b)
1	1	31.61			
25 % flooded			0.95	47.42	45.05
20	0.05	63.23			
50 % flooded			0.03	94.84	2.85
50	0.02	126.45			
100 % flooded					
Annual Average Number HEs affected without maintenance (AAN$_{\text{without}}$)					47.89

Summary: flooding **Left Bank**	AAN$_{\text{without}}$ (a)	AAN$_{\text{with}}$ (b)	(a) - (b)	Benefit (£)
Scenario 1, year 0	35.88	20.48	15.40	20075
Scenario 2, year 10	47.89	20.48	27.41	35740
Value of one HE (£) *	1304			

* 1997/98 price

Note: Severity weightings have been applied to HEs affected by flooding	arable	2.2
	pasture	1.5

FLOODING

Watercourse	**Watton Beck**
Bank	**Right Bank**
Flood risk area (ha)	250
Effective reach length (km)	1

With maintenance - current situation

Flood Return Period (years)	Probability	Nr. HEs Affected	Probability Interval (a)	Average Nr. HEs Affected (b)	(a) x (b)
1	1	0.00			
no flooding			0.95	22.39	21.27
20	0.05	44.79			
30 % flooded			0.03	97.04	2.91
50	0.02	149.29			
100 % flooded					
		Annual Average Number HEs affected with maintenance (AAN_{with})			24.18

Scenario 1 - without maintenance

Impact of annual flood after 1 year without maintenance

Flood Return Period (years)	Probability	Nr. HEs Affected	Probability Interval (a)	Average Nr. HEs Affected (b)	(a) x (b)
1	1	7.46			
5 % flooded			0.95	41.05	39.00
20	0.05	74.65			
50 % flooded			0.03	111.97	3.36
50	0.02	149.29			
100 % flooded					
		Annual Average Number HEs affected without maintenance ($\text{AAN}_{\text{without}}$)			42.36

Scenario 2 - without maintenance

Impact of annual flood after 10 years without maintenance

Flood Return Period (years)	Probability	Nr. HEs Affected	Probability Interval (a)	Average Nr. HEs Affected (b)	(a) x (b)
1	1	37.32			
25 % flooded			0.95	55.98	53.18
20	0.05	74.65			
50 % flooded			0.03	111.97	3.36
50	0.02	149.29			
100 % flooded					
		Annual Average Number HEs affected without maintenance ($\text{AAN}_{\text{without}}$)			56.54

Summary: flooding **Right Bank**	$\text{AAN}_{\text{without}}$ (a)	AAN_{with} (b)	(a) - (b)	Benefit (£)
Scenario 1, year 0	42.36	24.18	18.18	23702
Scenario 2, year 10	56.54	24.18	32.36	42196
Value of one HE (£) *	1304			

* 1997/98 price

Note: Severity weightings have been applied to HEs affected by flooding

arable	2.2
pasture	1.5

FDMM

WATTON BECK

Estimation of Benefits from Flooding assuming further deterioration in subsequent years

		Left Bank £	Right Bank £
Benefit lost in year 0	a	20075	23702
Benefit lost in year 10	b	35740	42196
Incremental loss over 10 years	(b-a) = c	15665	18494
Average value of incremental loss (loss in year 5)	(c/2) = d	7832	9247
Discount factor at 6% (year 5)	e	0.747	0.747
Present value of average incremental loss	(d*e) = f	5853	6910
Average annual loss assuming further deterioration	f + a	25928	30612
Total for both banks			56540

1997/98 prices are used. Figures are subject to rounding.

DRAINAGE BENEFITS

Scenario 1, Year 0

Watercourse	**Watton Beck**
Bank	**Left Bank**
Drainage benefit area (ha)	210

Land use type	Extensive pasture	Extensive arable
With maintenance drainage status	Good	Good
Without maintenance drainage status	Bad	Bad
Area affected (ha)	4.2	205.8
Annual benefit (£/ha) *	-8	65
Total benefit/land use (£) *	-33.6	1337.7
Total benefit (£) *	13343	

* 1997 economic prices

Watercourse	**Watton Beck**
Bank	**Right Bank**
Drainage benefit area (ha)	250

Land use type	Extensive pasture	Extensive arable	Intensive arable	Forestry & scrub
With maintenance drainage status	Good	Good	Good	Good
Without maintenance drainage status	Bad	Bad	Bad	Bad
Area affected (ha)	2.5	242.25	4	1.25
Annual benefit (£/ha) *	-8	65	65	0
Total benefit/land use (£) *	-20	15746	260	0
Total benefit (£) *	15986			

* 1997/98 economic prices are used. Figures are subject to rounding.

Note

If the drainage benefit area is not known, multiply the flood risk area by the appropriate areal drainage factor, according to soil type and drainage system.

DRAINAGE BENEFITS
Scenario 2, Year 10

Watercourse	**Watton Beck**
Bank	**Left Bank**
Drainage benefit area (ha)	210

Land use type	Extensive pasture	Extensive arable
With maintenance drainage status	Good	Good
Without maintenance drainage status	Very bad	Very bad
Area affected (ha)	4.2	205.8
Annual benefit (£/ha) *	-30	168
Total benefit/land use (£) *	-126	34574.4
Total benefit (£) *	34448	

* 1997 economic prices

Watercourse	**Watton Beck**
Bank	**Right Bank**
Drainage benefit area (ha)	250

Land use type	Extensive pasture	Extensive arable	Intensive arable	Forestry & scrub
With maintenance drainage status	Good	Good	Good	Good
Without maintenance drainage status	Very bad	Very bad	Very bad	Very bad
Area affected (ha)	2.5	242.25	4	1.25
Annual benefit (£/ha) *	-30	168	168	0
Total benefit/land use (£) *	-75	40698	672	0
Total benefit (£) *	41295			

* 1997/98 economic prices are used. Figures are subject to rounding.

Note

If the drainage benefit area is not known, multiply the flood risk area by the appropriate areal drainage factor, according to soil type and drainage system.

FDMM
Watton Beck
Estimation of Drainage Benefits assuming further deterioration in subsequent years

		Left Bank £	Right Bank £
Benefit lost in year 0 (Good to bad drainage)	(a)	13343	15986
Benefit lost in year 10 (Good to very bad drainage)	(b)	34448	41295
Incremental loss over 10 years	(b)-(a) = (c)	21105	25309
Average value of incremental loss (loss in year 5)		10553	12655
Discount factor at 6% (year 5)	(e)	0.747	0.747
Present value of average incremental loss	(d) x (e) = (f)	7885	9453
Average annual loss assuming further deterioration	(f) + (a)	21228	25439
Total for both banks			46667

1997/98 prices are used. Figures are subject to rounding.

Sensitivity analysis
Assuming 50 % of whole flood risk area is prone to bad drainage without maintenance

DRAINAGE BENEFITS

Watercourse	**Watton Beck**	
Bank	**Left Bank**	
Drainage benefit area (ha)	105	
Land use type	Extensive pasture	Extensive arable
With maintenance drainage status	Good	Good
Without maintenance drainage status	Bad	Bad
Area affected (ha)	2.1	102.9
Annual benefit (£/ha) *	-8	65
Total benefit/land use (£) *	-16.8	6688.5
Total benefit (£) *	6672	

* 1997 economic prices

Watercourse	**Watton Beck**			
Bank	**Right Bank**			
Drainage benefit area (ha)	125			
Land use type	Extensive pasture	Extensive arable	Intensive arable	Forestry & scrub
With maintenance drainage status	Good	Good	Good	Good
Without maintenance drainage status	Bad	Bad	Bad	Bad
Area affected (ha)	1.25	121.125	2	0.62
Annual benefit (£/ha) *	-8	65	65	0
Total benefit/land use (£) *	-10	7873	130	0
Total benefit (£) *	7993			

* 1997 economic prices

Note
If the drainage benefit area is not known, multiply the flood risk area by the appropriate areal drainage factor, according to soil type and drainage system.

AGRICULTURAL BENEFITS ONLY
LAND USE ASSESSMENT : REACH SUMMARY

Watercourse	**Watton Beck**
Bank	**Left Bank**
OS Map	Pathfinder 675/676/666/667
Flood risk area (ha)	210
Effective reach length (km)	1

Land Use Factor	Unit	Number or area (a)	House Equivalents HE/unit (b)		Total HE (a) x (b)	
House	Number		1.00		*0*	
Garden / allotments	Number		0.04		*0*	
NRP - Manufacturing	Area (m^2)		0.030		*0*	
NRP - Distribution	Area (m^2)		0.054		*0*	
NRP - Leisure	Area (m^2)		0.032		*0*	
N R P - Offices	Area (m^2)		0.033		*0*	
N R P - Retail	Area (m^2)		0.035		*0*	
N R P - Agricultural	Area (m^2)		0.010		*0*	
C Roads	Number		2.7		*0*	
B Roads	Number		6.3		*0*	
A Roads (non trunk)	Number		15.9		*0*	
A Roads (trunk)	Number		31.7		*0*	
Motorway	Number		63.5		*0*	
Railway	Number		63.5		*0*	
			Flooding	Drainage	Flooding	Drainage **
Forestry and scrub *	per 100 ha		0.02	0.0		
Extensive pasture *	per 100 ha	*0.042*	1.3	1.1	*0.0546*	*0*
Intensive pasture *	per 100 ha		3	4.5		
Extensive arable *	per 100 ha	*2.058*	6.3	3.6	*12.9654*	*0*
Intensive arable *	per 100 ha		44.1	9.7		
Formal parks	Number		0.6		*0*	
Golf / race courses	Number		0.7		*0*	
Playing field	Number		0.1		*0*	
Special parks	Number		9.3		*0*	
Total HE (c) *					*13.02*	
HE/km ((c) / effective reach length)					*13.02*	

Note

* Flooding / drainage scores to be summed

** Apply areal drainage factor if required

HE values are at 1991 base

AGRICULTURAL BENEFITS ONLY
LAND USE ASSESSMENT : REACH SUMMARY

Watercourse	**Watton Beck**
Bank	**Right Bank**
OS Map	Pathfinder 675/676/666/667
Flood risk area (ha)	250
Effective reach length (km)	1

Land Use Factor	Unit	Number or area (a)	House Equivalents HE/unit (b)		Total HE (a) x (b)	
House	Number		1.00		*0*	
Garden / allotments	Number		0.04		*0*	
NRP - Manufacturing	Area (m^2)		0.030		*0*	
NRP - Distribution	Area (m^2)		0.054		*0*	
NRP - Leisure	Area (m^2)		0.032		*0*	
N R P - Offices	Area (m^2)		0.033		*0*	
N R P - Retail	Area (m^2)		0.035		*0*	
N R P - Agricultural	Area (m^2)		0.010		*0*	
C Roads	Number		2.7		*0*	
B Roads	Number		6.3		*0*	
A Roads (non trunk)	Number		15.9		*0*	
A Roads (trunk)	Number		31.7		*0*	
Motorway	Number		63.5		*0*	
Railway	Number		63.5		*0*	
			Flooding	Drainage	Flooding	Drainage **
Forestry and scrub *	per 100 ha	*0.0125*	0.02	0.0	*0.00025*	*0*
Extensive pasture *	per 100 ha	*0.025*	1.3	1.1	*0.0325*	*0*
Intensive pasture *	per 100 ha		3	4.5		
Extensive arable *	per 100 ha	*2.4225*	6.3	3.6	*15.26175*	*0*
Intensive arable *	per 100 ha	*0.04*	44.1	9.7	*1.764*	
Formal parks	Number		0.6		*0*	
Golf / race courses	Number		0.7		*0*	
Playing field	Number		0.1		*0*	
Special parks	Number		9.3		*0*	
Total HE (c) *					*17.06*	
HE/km ((c) / effective reach length)					*17.06*	

Note
* Flooding / drainage scores to be summed ** Apply areal drainage factor if required
HE values are at 1991 base

AGRICULTURAL BENEFITS ONLY
FLOODING

Watercourse	**Watton Beck**
Bank	**Left Bank**
Flood risk area (ha)	210
Effective reach length (km)	1

With maintenance - current situation

Flood Return Period (years)	Probability	Nr. HEs Affected	Probability Interval (a)	Average Nr. HEs Affected (b)	(a) x (b)
1	1	0.00			
no flooding			0.95	4.29	4.08
20	0.05	8.58			
30 % flooded			0.03	18.60	0.56
50	0.02	28.61			
100 % flooded					
	Annual Average Number HEs affected with maintenance (AAN_{with})				4.63

Scenario 1 - without maintenance

Impact of annual flood after 1 year without maintenance

Flood Return Period (years)	Probability	Nr. HEs Affected	Probability Interval (a)	Average Nr. HEs Affected (b)	(a) x (b)
1	1	1.43			
5 % flooded			0.95	7.87	7.47
20	0.05	14.31			
50 % flooded			0.03	21.46	0.64
50	0.02	28.61			
100 % flooded					
	Annual Average Number HEs affected without maintenance ($AAN_{without}$)				8.12

Scenario 2 - without maintenance

Impact of annual flood after 10 years without maintenance

Flood Return Period (years)	Probability	Nr. HEs Affected	Probability Interval (a)	Average Nr. HEs Affected (b)	(a) x (b)
1	1	7.15			
25 % flooded			0.95	10.73	10.19
20	0.05	14.31			
50 % flooded			0.03	21.46	0.64
50	0.02	28.61			
100 % flooded					
	Annual Average Number HEs affected without maintenance ($AAN_{without}$)				10.84

Summary: flooding **Left Bank**	$AAN_{without}$ (a)	AAN_{with} (b)	(a) - (b)	Benefit (£)
Scenario 1, year 0	8.12	4.63	3.48	4542
Scenario 2, year 10	10.84	4.63	6.20	8086
Value of one HE (£) *	1304		Average	

* 1997/98 price

Note: Severity weightings have been applied to HEs affected by flood	arable	2.2
	pasture	1.5

AGRICULTURAL BENEFITS ONLY
FLOODING

Watercourse	**Watton Beck**
Bank	**Right Bank**
Flood risk area (ha)	250
Effective reach length (km)	1

With maintenance - current situation

Flood Return Period (years)	Probability	Nr. HEs Affected	Probability Interval (a)	Average Nr. HEs Affected (b)	(a) x (b)
1	1	0.00			
no flooding			0.95	5.63	5.35
20	0.05	11.25			
30 % flooded			0.03	24.38	0.73
50	0.02	37.51			
100 % flooded					
Annual Average Number HEs affected with maintenance (AAN$_{\text{with}}$)					6.08

Scenario 1 - without maintenance

Impact of annual flood after 1 year without maintenance

Flood Return Period (years)	Probability	Nr. HEs Affected	Probability Interval (a)	Average Nr. HEs Affected (b)	(a) x (b)
1	1	1.88			
5 % flooded			0.95	10.32	9.80
20	0.05	18.76			
50 % flooded			0.03	28.13	0.84
50	0.02	37.51			
100 % flooded					
Annual Average Number HEs affected without maintenance (AAN$_{\text{without}}$)					10.64

Scenario 2 - without maintenance

Impact of annual flood after 10 years without maintenance

Flood Return Period (years)	Probability	Nr. HEs Affected	Probability Interval (a)	Average Nr. HEs Affected (b)	(a) x (b)
1	1	9.38			
25 % flooded			0.95	14.07	13.36
20	0.05	18.76			
50 % flooded			0.03	28.13	0.84
50	0.02	37.51			
100 % flooded					
Annual Average Number HEs affected without maintenance (AAN$_{\text{without}}$)					14.21

Summary: flooding **Right Bank**	AAN$_{\text{without}}$ (a)	AAN$_{\text{with}}$ (b)	(a) - (b)	Benefit (£)
Scenario 1, year 0	10.64	6.08	4.57	5955
Scenario 2, year 10	14.21	6.08	8.13	10602
Value of one HE (£) *	1304			Average

* 1997/98 price

Note: Severity weightings have been applied to HEs affected by flo	arable	2.2
	pasture	1.5

AGRICULTURAL BENEFITS ONLY WATTON BECK

Estimation of Benefits from Flooding assuming further deterioration in subsequent years

		Left Bank £	Right Bank £
Benefit lost in year 0	(a)	4542	5955
Benefit lost in year 10	(b)	8086	10602
Incremental loss over 10 years	(a)-(b) = (c)	3544	4647
Average value of incremental loss (loss in year 5)	(c)/2 = (d)	1772	2323
Discount factor at 6% (year 5)	(e)	0.747	0.747
Present value of average incremental loss	d) x (e) = (f)	1324	1736
Average annual loss assuming further deterioration	(f) + (a)	5866	7691
Total for both banks			13558

1997/98 prices are used. Figures are subject to rounding.

GENERAL INFORMATION

River — 1a **WATTON BECK**

Reach Code — 1b **01**

Reach Length (km) — 2 **1**

Dominant Substrate Type:-
Gravel, Sand or Silt
(Treat clay as silt) — 3 **CLAY**

Floodplain -
Rising (>1 %) or Flat (< 1 %) — 4 **RISING**

Catchment Size
Large (> 25 sq. km)
Small (< 25 sq. km) — 5 **LARGE**

Benefit Area (ha)
(Area deriving benefit from maintenance) — 6 **460**

Dominant Land Use Type (LUT)
(Table 1) — 7 **CEREAL/OILS (5)**

Dominant Soil Type — 9 **LOAMY CLAY**

Varied Land Use Types (LUT)
(Table 1)

LUT	7 % Benefit Are as decimal	8a Does the LUT flood ?	8b If yes, % that floods (as decimal)
1 Ext grass			
2 Int grass			
3 Grass/arable			
4 All cereals			
5 Cereal/oil seed			
6 Cereal/root			
7 Horticulture			
8 Other			

Note: All table numbers and references relate to R&D Note 511, Guidelines for the Justification of River Maintenance

DESIGN STANDARD

Average Bed Width (m) — 10: **3**

Average Channel Depth (m) — 11: **2.5**

% Weed Cover (In channel, submerged & floating weed) — 12: **0** (Emergent vegetation only)

Freeboard (m) — 13: **0.75**

Watertable Depth (m) *(Box 4, 9, 13 & Figure 1 or 2)* — 14: **0.5**

Drainage Status *(Box 14 & Table 4)* — 15: **GOOD**

Economic Net Return *(Table 5, using Box 7 & Box 15)*

			16
For either :-	Dominant land use	(£/ha)	**329**
		(£)	**151340**
or :-	Varied land use	(£/ha)	
		(£)	

LUT	16a Net Return (£/ha)	16b Weighted Net Return
1		
2		
3		
4		
5		
6		
7		

Bankful discharge (Qbf) (cumecs) — 17:

* Regional Growth Curve Area *(Figure 3)* — 18:

* Mean Annual Flood (Q bar) (cumecs) — 19:

* Qbf/Q bar (cumecs) *(Box 17 / Box 19)* — 20:

* Flooding Envelopes
* % BA with different flood return periods (years)
(Table 6 or 7, boxes 5, 7, 15)

FRP (yr)	21 % area of each LUT that floods	21a Flooded Area (ha)	22 Flood Cost (£/ha)	22a Total Flood Cost (£) *(Box 21a * box 22)*
0	**0**	**0**	**0**	**0**
1 - 2	**0**	**0**	**0**	**0**
3 - 5				
6 - 10				
> 10 (20 yr)	**30**	**138**	**3**	**414**
(50 yr)	**100**	**460**	**3**	**1380**
			Total	**1794**

* *Not necessary unless detailed information and assessment is required*

Flood Return Period (years) — 23: **AS ABOVE**

Total Flood Cost (£) — 24: **1794**

Design Net Return Less Flood Cost *(Box 16 - box 24)* (£) — 24a: **149546**

Note: All table numbers and references relate to R&D Note 511, Guidelines for the Justification of River Maintenance

MAINTENANCE REGIME

	25a (m)	25b (%)
Widening, change in width, expressed in metres and as a % , (including cutting of banks and emergent vegetation)	1.5	50
	26a (m)	26b (%)
Deepening, change in depth, expressed in metres and as a %	0.2	8
		27
Weed cutting, % cover removed (Submerged & floating weed)		
	28a (m)	28b (%)
Change in freeboard, expressed in metres and as a % (Table 8 - 15, & boxes 25, 26, 27)	0.094	12.5
	29a (m)	29b (%)
Change in Qbf , expressed in metres and as a % (Table 8 - 15, & boxes 25, 26, 27)		

Note: All table numbers and references relate to R&D Note 511, Guidelines for the Justification of River Maintenance

"DO NOTHING" (WITHOUT MAINTENANCE)

W/o Maintenance Width (m)
(Box 10 - box 25a)
30: **1.5**

W/o Maintenance Depth (m)
(Box 11 - box 26a)
31: **2.3**

W/o Maintenance Freeboard (m)
(Box 13 - box 28a)
32: **0.66**

W/o Maintenance Watertable Depth (m)
(Box 4, 9, 32, Table 3, Figure 1 or 2)
33: **0.42**

W/o Maintenance Drainage Status
(Table 4, box 33)
34: Scenario 1 **BAD**
Scenario 2 **VERY BAD**

Economic Net Return (W/o maintenance)
(Table 5, box 8, 34)

For either :-

35		Scenario 1	Scenario 2
Dominant land use	(£/ha)	**263**	**165**
	£	**120980**	**75900**

or :-

Varied land use	(£/ha)		
	£		

LUT	35b Net Return (£/ha)	35a Weighted Net Return
1		
2		
3		
4		
5		
6		
7		

W/o Maintenance bankful discharge (Qbf) (cumecs)
(Box 17 - box 29)
36:

* W/o Maintenance Qbf/Q bar (cumecs)
(Box 36 / box 19)
37:

SCENARIO 1 (Year 0)

* Flooding Envelopes
* % BA with different flood return periods (years)
(Table 6 or 7, boxes 5, 7, 34)

FRP (yr.)	38 % area of each LUT that floods	38a Flooded Area (ha)	39 Flood Cost (£/ha)	39a Total Flood Cost (£) *(Box 38a * box 39)*
0				
<1				
1 - 2	**5**	**23**	**32**	**736**
3 - 5				
6 - 10				
> 10 (20 yr)	**50**	**230**	**2**	**460**
> 10 (50 yr)	**100**	**460**	**2**	**920**
			Total	**2116**

SCENARIO 2 (Year 10)

FRP (yr.)				
0				
<1				
1 - 2	**25**	**115**	**32**	**3680**
3 - 5				
6 - 10				
> 10 (20 yr)	**50**	**230**	**2**	**460**
> 10 (50 yr)	**100**	**460**	**2**	**920**
			Total	**5060**

Estimation of loss assuming further deterioration in subsequent years

		Drainage	**Flooding**
Loss without maintenance in year 0 (£)	a	30360	2116
Loss without maintenance in year 10 (£)	b	75440	5060
Incremental loss over 10 years (£)	(b-a) = c	45080	2944
Average value of incremental loss (loss in year 5) (£)	(c/2) = d	22540	1472
Discount factor at 6% (year 5) (£)	e	0.747	0.747
Present value of average incremental loss (£)	(d x e) = f	16843	1100
Average annual loss assuming further deterioration (£)	f + a	47203	3216

W/o Maintenance FRP (years)
40: **AS ABOVE**

Total Average Flood Cost (£)
41: **2116** Scenario 1 **3216** Scenario 2

Do-nothing
Net Return Less Flood Cost (£)
(Box 35 - box 41)
41a: **118864** Scenario 1 **100921** Scenario 2

Note: All table numbers and references relate to R&D Note 511, Guidelines for the Justification of River Maintenance

MAINTENANCE EXPENDITURE

	42	43	44	45	46	47
Maintenance Activity	Unit Cost (£)	No. of Units (specify)	Cost/Reach/ Activity (£)	Interval Between Maintenance Activities (years)	Amortisation Value at 6 % Discount Rate *(Box 45, Table 18)*	Annual Cost (£) *(Box 44 * box 46)*
Weedcutting and desilting						**1883**

	Total annual cost/reach (£)	*(Sum box 47)*		48	**1883**		
	Benefit Area (ha)	*(Box 6)*		49	**460**		
	Total annual maintenance cost/ha	*(Box 48 / box 49)*		50	**4**		

BENEFITS OF MAINTENANCE

Design Standard (With maintenance)	Net return less flood costs	*(Box 24a)*	(£)	51	**149546**			
Do Nothing (Without maintenance)	Net return less flood costs	*(Box 41a)*	(£)	52	**118864**	Scenario 1	**100921**	Scenario 2
Change in Net Benefit Due to Maintenance		*(Box 51 - box 52)*	(£)	53	**30682**	Scenario 1	**48625**	Scenario 2
Net Benefit of Maintenance	Change in net benefit-total annual maintenance costs	*(Box 53 - box 49 or 50)*	(£)	54	**28799**	Scenario 1	**46742**	Scenario 2
	Benefit : cost ratio	*(Box 53/box 48)*			**16.29**	Scenario 1	**25.82**	Scenario 2

Note: All table numbers and references relate to R&D Note 511, Guidelines for the Justification of River Maintenance

APPENDIX V

1. WINESTEAD DRAIN

1.1 Introduction

This Appendix presents the results of the application of FDMM and the Guidelines to Winestead Drain, a pumped watercourse in the North East of England.

1.2 Study Area

1.2.1 Channel characteristics and drainage network

Winestead Drain rises to the east of Withernsea, approximately 17 km east of Kingston upon Hull. The catchment area of Winestead Drain is estimated to be 54 km^2 (5400 ha). This lowland catchment is intensively drained both through field drains and the natural ditch system.

The Environment Agency 'main' river reach length is 7.3 km. Above main river is an Internal Drainage Board (IDB) watercourse of approximately 6.1 km in length (Figure 1). Two pumping stations are used to control water levels in the main river and IDB watercourse. Both these pumping stations are owned and operated by the Environment Agency,

The Booster Pumping Station (3 pumps) at the head of main river (GR. TA 530050 423400) pumps land drainage water from the IDB watercourse up into the main river which is at a higher level. The capacity of each pump is 1130 litres/second. The pumps usually operate automatically, and are triggered when the water level in the pump well reaches the threshold (0.15-0.6 m). This threshold varies according to the season (winter or summer) and cost of pumping at various time of the day.

The Outstrays Pumping Station (2 pumps) provides the outfall of Winestead Drain into the estuary of the River Humber. Each pump is triggered automatically through no-flote electrodes suspended in the sump and has a capacity of 3760 litres/second. Time switches are fitted to ensure that the pumps only operate in "off-peak" periods; except during an emergency when the pumps may be operated manually or the timing mechanism overridden.

The channel of Winestead Drain is typically 3.8 m deep (range 5.2-3.2 m) and 6.5 m wide at bed level (range 2-12 m). The dominant substrate is clay. Average freeboard under conditions of mean spring flow is estimated to be 1.5 m. The outfalls of the field drains into Winestead Drain are characteristically at a depth of 2 to 2.5 m. Such a depth is needed to provide a sufficient gradient for the pipes to discharge into the river because the floodplain commonly falls away from the channel.

The study reach extends from the upstream limit of the main river (Booster Pumping Station) to the pumped outfall of Winestead Drain into the Humber Estuary at Outstrays Pumping Station (TA 533500 418495).

1.2.2 Catchment characteristics

This lowland catchment is predominantly rural in character. The catchment is well suited to the growing of cereal crops; in particular winter wheat and barley. Oilseed rape, peas and beans are used as a break crop (Jarvis et al, 1984). From a visual survey of the catchment, details on land use were obtained. Land use is dominated by cereal and oilseed crops (85%), with small areas under beans and oilseed rape (10%). Small areas of scrub and woodland (1%) and pasture (4%) are also found within the catchment.

The solid geology of the area is characterised by chalk which is overlain by alluvium and chalky till. The Holderness Soil Association is characteristic of the catchment (Jarvis et al, 1984). The most extensive soil are of the Holderness series, which are fine, loamy stagnogley soils (Jarvis et al, 1984). Soils of the Burlingham 2 Association dominate the sloping land towards the edge of the floodplain. This Association is characterised by fine loamy soils with slowly permeable subsoil formed in chalky till. The floodplain of the IDB channel and on the right bank of the main river, is characterised by soils of the Wallasea 1 Association. These marine alluvial gley soils rely on arterial drainage to prevent waterlogging. The soils of the floodplain on the left bank of main river consist of the Newchurch 2 Association. Artificial drainage and pumping is necessary to control the groundwater levels in these clay soils.

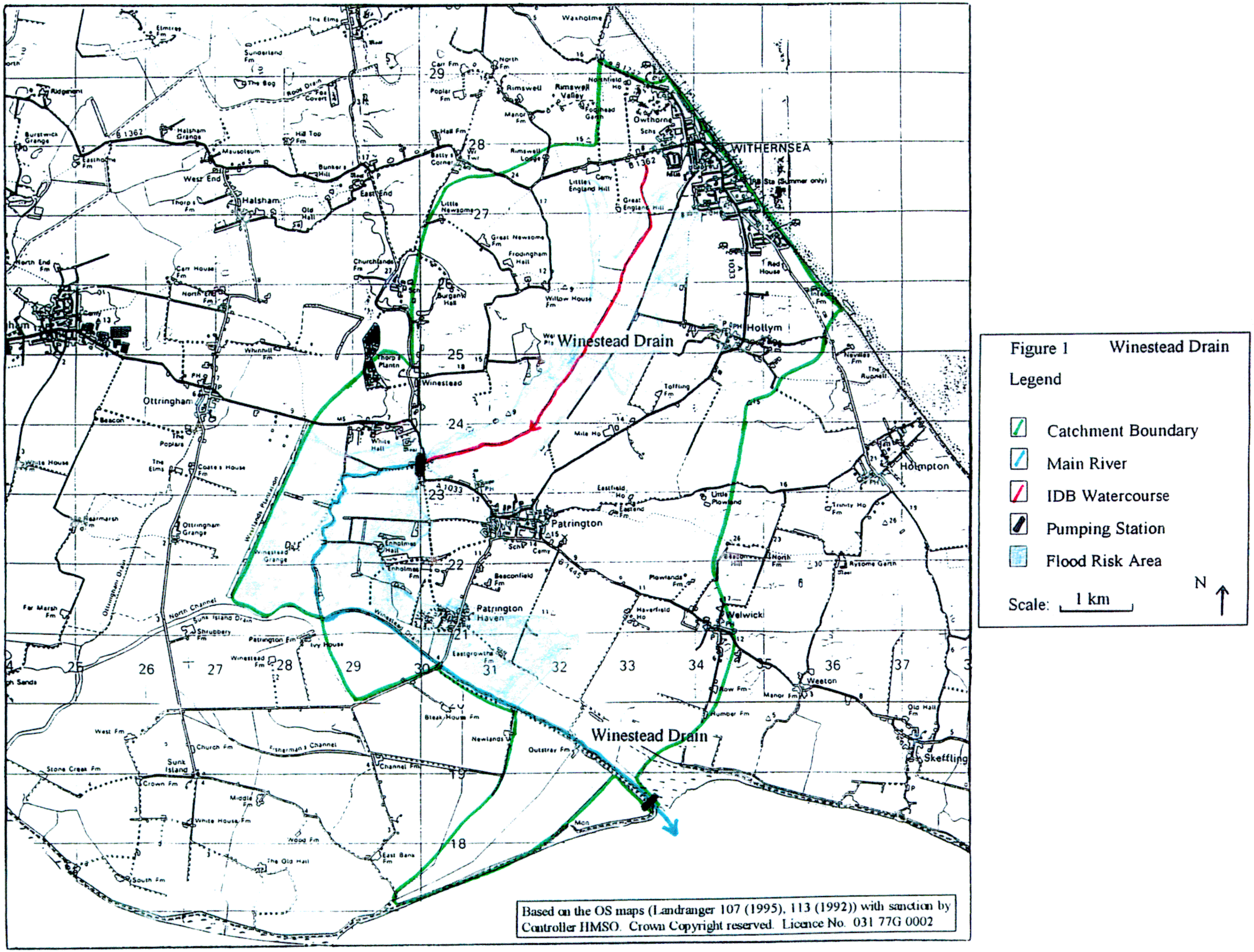


Figure 1 Winestead Drain

Legend

- 🟩 Catchment Boundary
- 🟦 Main River
- 🟥 IDB Watercourse
- ■ Pumping Station
- ▨ Flood Risk Area

Scale: 1 km

N ↑

Based on the OS maps (Landranger 107 (1995), 113 (1992)) with sanction by Controller HMSO. Crown Copyright reserved. Licence No. 031 77G 0002

1.2.3 River Maintenance

Winestead Drain is subject to annual weedcutting, twice a year, using a weed boat. Approximately 80% of the channel aquatic vegetation is removed. A fringe of uncut vegetation is left down opposite margins, alternating approximately every 50 m, the purpose being to encourage wildlife.

Prior to maintenance, the channel is usually choked with emergent vegetation with 100% of the water surface covered by plants. *Glyceria* (Reed Sweet Grass) and *Phragmites* (Common Reed) are the dominant types. The banks are flail mown twice a year. Alternate stretches of bank are cut in order to encourage habitats favourable to wildlife. Algae is commonly found within the IDB watercourse.

The channel has been subject to dredging approximately once every 10 years. A depth of between 0.15 and 0.3 m of silt is removed to reach hard bed level. Aquatic rhizomes and roots in the sediment are also removed during dredging which helps to reduce weed growth in the early years of the scheme life. In the future, sonar will be used to determine whether dredging is required.

Total annual maintenance expenditure by the Environment Agency on Winestead Drain is estimated to be £42939 (1997/98 prices). This includes a charge for maintenance of the pumps and electricity running costs. Pumping costs can vary considerably according to factors such as season, time of pumping, number of pumps in use, and length of time and frequency of operation. For the purpose of this analysis, the pumping costs for the financial year 1996/97 are used, inflated to 1997/98 prices. This is the most recent complete year for which pumping station expenditure is available. Costs for channel maintenance only are estimated to be £6075 (1997/98 prices).

Above main river is a Winestead Drain Internal Drainage Board (IDB) watercourse of approximately 6.1 km in length. Water from this channel is pumped into the main river at the Booster Pumping Station.

This IDB channel is subject to annual weedcutting. Approximately 70% of the aquatic weed is removed in a strip down the centre of the channel. Dredging of the channel takes place on average every 10 years. Between 0.3 m and 0.6 m of silt is removed to reach the solid bed level. Total annual maintenance expenditure on the IDB watercourse is estimated to be £3433 in 1997/98. This includes a charge for dredging which has been amortised to derive an equivalent annual cost.

1.3 Application of FDMM to Winestead Drain

1.3.1 Area of benefit

The area benefiting from maintenance in terms of flood alleviation is estimated to be 729 ha. This is termed the flood risk area (Figure 1). This area was delineated during discussions with the Environment Agency and IDB personnel and is based on the drainage board boundary.

1.3.2 Land use assessment

Flooding

The completed land use assessment reach summary sheets for the left and right bank are presented at the end of this Appendix. Summary information is presented in Table 1.

Table 1 Land use assessment summary, Winestead Drain

	Left Bank	Right Bank	Comment
Flood risk area (ha)	460	269	
Nature of flooding	fluvial	fluvial	
Effective reach length (km)	7.3	7.3	Main river only
Total HE	190.91	20.64	
Flood score (HE/km)	26.15	2.83	

Drainage

Under the current maintenance regime, the drainage status for the whole flood risk area is described as good, therefore the drainage score is zero. The drainage benefit area is thus 460 ha on the left bank and 269 ha on the right bank.

1.3.3 Land use band

Table 2 Land use band, Winestead Drain

	Flood Value (HE/km)	Drainage Value (HE/km)	Total	Land Use Band
Left Bank	26.15	0.0 *	26.15	B
Right Bank	2.83	0.0 *	2.83	D

Note: * the drainage status is described as good under the current maintenance situation. Figures are subject to rounding.

1.3.4 Determining the effect of flooding

The completed flooding assessment sheets for the left and right bank are presented at the end of this Appendix Summary information is presented in Table 3 and 4.

Table 3 Flooding, Winestead Drain

Technique	Predictive technique only. No historical records
Method of analysis	Arithmetic method
Flooded areas	Estimated by Environment Agency, actual areas flooded by the infrequent events are not documented

Severity weighting applied to total HEs affected by flooding: 2.2 for arable, 1.5 for pasture

	Left Bank			Right Bank		
	Flood Return Period (yrs)	% Area Flooded	HEs Affected	Flood Return Period (yrs)	% Area Flooded	HEs Affected
With maintenance	1	0	0	1	0	0
	50	30	67.61	50	30	12.28
	100	100	225.37	100	100	40.95
Without maintenance	1	5	11.27	1	5	2.05
	50	100	225.37	50	100	40.93
	100	100	225.37	100	100	40.93

Note: Figures are subject to rounding.

Table 4 Annual benefit of flood alleviation, Winestead Drain

	AAN $_{\text{without}}$ (HE/km) (a)	AAN $_{\text{with}}$ (HE/km) (b)	(a) - (b)	Benefit (£)
Left Bank	118.21	34.59	83.62	109040
Right Bank	21.47	6.28	15.19	19808
Total				128849

Note: Figures are subject to rounding. 1997/98 prices are used.

1.3.5 Determining the effect of deterioration in drainage

For the purpose of this analysis, it is assumed that without channel maintenance and pumping, the drainage status of whole flood risk area on each bank will deteriorate from a good to bad drainage condition. The associated drainage benefits are therefore £47213. Further details are presented at the end of this Appendix.

1.3.6 Actual standard of service

Table 5 Actual SoS provided under the current maintenance regime, Winestead Drain

	Flooding (AAN $_{with}$) (HE/km) (a)	Effective Reach Length (km) (b)	Flood Score (HE/km/yr) (a/b) = (c)	Drainage Score (HE/km/yr) (d)	Total (c)+(d)
Left Bank	34.59	7.3	4.7	0.0 *	4.7
Right Bank	6.28	7.3	0.9	0.0 *	0.9
Both Banks				Average Score	2.8
				Below Target Standard	

Note: * the drainage status is described as good under the current maintenance situation, therefore the drainage score is zero. Figures are subject to rounding.

1.3.7 Justification

Table 6 Total benefits of maintenance, Winestead Drain

Annual Benefit of Flood Alleviation (£)	Annual Benefit of Maintaining Drainage Status (£)	Total Annual Benefit (£)	Total Annual Maintenance Cost (£)	Benefit:Cost Ratio (Agricultural + Urban)	Benefit:Cost Ratio (Agricultural Only)
1288449	47213	176062	42939	4.10	2.24

Note: Figures are subject to rounding. 1997/98 prices are used.

1.4 Sensitivity Analysis

1.4.1 Actual SoS

Estimates of the actual standard of service provided are sensitive to the effective reach length used. As shown in Table 7, different effective reach lengths can affect the reach status.

As the IDB watercourse upstream of main river derives benefit from maintenance on main river, in particular from operation and maintenance of the Booster Pumping Station, this watercourse should ideally be included in the calculation of the effective reach length. If this is the case, however, the HEs in the benefit area associated with this IDB channel should also be included in the analysis. Under the present analysis, these additional HEs have not been included. In this instance, however, inclusion of the IDB watercourse in calculation of the effective reach length does not effect the reach status.

Table 7 Sensitivity analysis: effective reach length and reach status, Winestead Drain

Bank	Flooding (HE/km) (a)	Effective Reach Length (km) (b)	Flood Score (HE/km/yr) (a/b) = (c)	Drainage Score (HE/km/yr) (d)	Total (c)+(d)	Reach Status
Effective reach comprises: main river only						
LB	34.59	7.3	4.7	0.0 *	4.7	BTS
RB	6.28	7.3	0.9	0.0 *	0.9	OTS
				Average	2.8	BTS
Effective reach comprises: main river and IDB watercourse						
LB	34.59	13.4	2.6	0.0 *	2.6	BTS
RB	6.28	13.4	0.5	0.0 *	0.5	OTS
				Average	1.6	BTS

Note: * the drainage status is described as good under the current maintenance situation, therefore the drainage score is zero. Figures are subject to rounding. BTS = Below target, OTS = On target.

1.4.2 Maintenance costs and benefits

In accordance with FDMM, maintenance expenditure has been increased by 15% and the benefits reduced by 15% in order to check the sensitivity of assumptions made on the benefit:cost ratio. The results of this are shown in Table 8. Results show that the benefit:cost ratio is insensitive to the assumptions made regarding benefits and costs, due to the large benefits.

Table 8 Sensitivity analysis: benefit : cost ratio, Winestead Drain

Total Annual Benefit (£)	Total Maintenance Cost (£)	Benefit:Cost Ratio
Maintenance costs increased by 15%		
176062	49380	3.57
Benefits reduced by 15%		
149653	42939	3.49
Maintenance costs increased by 15% and benefits reduced by 15%		
149653	49380	3.03

Note: Maintenance costs are for main river only (channel maintenance and pumping) Figures are subject to rounding. 1997/98 prices are used.

1.4.3 Without maintenance scenarios

In the previous analysis, the benefits of maintenance are derived by comparing the total benefits provided by channel maintenance and pumping with the 'do-nothing' option for the main river only. The IDB watercourse upstream of the main river has been excluded form the analysis, in accordance with FDMM. This IDB watercourse, however, benefits from maintenance and pumping on the main river and in order to determine total benefits and costs, this watercourse and associated benefit area should be included within the analysis. Sensitivity analysis to determine the impact of including the IDB watercourse and benefit area in the analysis, and, the benefits associated with channel maintenance only and pumping only has been carried out. Further details of each scenario are provided in the following sections.

Scenario 1

Scenario 1 compares the total benefits (flooding and drainage) associated with channel maintenance and pumping on the main river and IDB watercourse with the 'do-nothing' option. These total benefits and costs are summarised in Table 9. The same assumptions are made regarding the impacts of no maintenance on the IDB benefit area as for the main river. Further details are presented at the end of this Appendix.

If the benefits and costs associated with the IDB watercourse are included in the analysis, the current maintenance scheme is still justified for the assumptions made. The benefit:cost ratio is larger than if the IDB costs and benefits are excluded from the analysis. This is because the costs associated with the IDB channel are small whereas the benefits are significant. These benefits are largely the result of operation of the Booster Pumping Station.

Table 9 Scenario 1, benefit:cost analysis, channel maintenance and pumping

Annual Flooding Benefits (£)	Annual Drainage Benefits (£)	Total Annual Benefits (£)	Annual Maintenance Costs (£)	Benefit:Cost Ratio (Agricultural + Urban)
Main River				
128849	47213	176062	42939	
IDB Watercourse				
40920	31603	40920	3433	
Total		248584	46372	5.36

Note: Figures are subject to rounding. 1997/98 prices are used.

Scenario 1A

The Booster Pumping Station at head of main river pumps water from the IDB channel up into the main river which is at a higher level. The main river itself derives no benefit from this pumping station. In effect, operation of the Booster Pumping Station may necessitate increased use of the Outstrays Pumping Station, which provides the outfall of Winestead Drain, in order to remove this additional water.

Scenario 1A compares the benefits associated with channel maintenance and pumping on the main river only, and the associated costs, with the 'do-nothing' option. The costs associated with the Booster Pumping Station at the head of main river on Winestead Drain are therefore omitted from the analysis on the grounds that this delivers benefits to areas beyond the study reach. As shown in Table 10, exclusion of the Booster Pumping Station costs increases the benefit:cost ratio.

Table 10 Scenario 1A, benefit:cost analysis, main river only, excluding Booster pumping station

Annual Flooding Benefits (£)	Annual Drainage Benefits (£)	Total Annual Benefits (£)	Annual Maintenance Costs (£)	Benefit:Cost Ratio (Agricultural + Urban)
Main River				
128849	47213	176062	26678	6.60

Note: Figures are subject to rounding. 1997/98 prices are used.

Scenario 1B

Scenario 1B compares the benefits associated with channel maintenance and pumping on the IDB watercourse only, with the 'do-nothing' option, as shown in Table 11. As the IDB watercourse and associated benefit area benefits from operation of the Booster Pumping Station, the cost associated with this should ideally be included in the equation. Table 11 shows that even if these pumping costs are included in the analysis, maintenance on the IDB watercourse is still justified given the assumptions made, due to the large benefits provided by pumping.

Table 11 Scenario 1B, benefit:cost analysis, IDB watercourse, including Booster pumping station

Annual Flooding Benefits (£)	Annual Drainage Benefits (£)	Total Annual Benefits (£)	Annual Maintenance Costs (£)	Benefit:Cost Ratio (Agricultural + Urban)
IDB Watercourse				
31603	40920	72523	19694	3.68

Note: Figures are subject to rounding. 1997/98 prices are used.

Scenario 2

Scenario 2 assumes that Winestead Drain is subject to channel maintenance only and that all pumping is discontinued. It is assumed that flooding will become more frequent and that a larger area will be affected than if pumping were to continue. It is assumed that a good drainage status will prevail over 25% of the flood risk area of the main river and IDB watercourse and that the remaining 75% of the area will experience bad drainage. Further details are presented at the end of this Appendix and in Table 12.

Table 12 Scenario 2, benefits of channel maintenance only, compared with the 'do-nothing' option

Annual Flooding Benefits (£)	Annual Drainage Benefits (£)	Total Annual Benefits (£)	Annual Maintenance Costs (£)	Benefit:Cost Ratio (Agricultural + Urban)
Main River				
861	11933	12794	6075	
IDB Watercourse				
273	7901	8174	3433	
Total		20968	9508	2.21

Note: Figures are subject to rounding. 1997/98 prices are used.

Scenario 3

Scenario 3 assumes that Winestead Drain is subject to pumping only and that channel maintenance is discontinued. It is assumed that flooding will become more frequent and that a larger area will be affected that if channel maintenance were to continue. It is assumed that a good drainage status will prevail over 75% of the flood risk area of the main river and IDB watercourse and that the remaining 25% of the area will experience bad drainage. Further details are presented at the end of this Appendix and in Table 13.

Table 13 Scenario 3, benefits of pumping only, compared with the 'do-nothing' option

Annual Flooding Benefits (£)	Annual Drainage Benefits (£)	Total Annual Benefits (£)	Annual Maintenance Costs (£)	Benefit:Cost Ratio (Agricultural + Urban)
Main River				
108245	35453	143698	36864	
IDB Watercourse				
273	23702	23976	0	
Total		167673	36864	4.55

Note: Figures are subject to rounding. 1997/98 prices are used.

Analysis of Scenario 2 and 3 confirms that channel maintenance and pumping complement each other. Channel maintenance sustains the operation of the pumping scheme through preventing a build up of vegetation and sediment in the channel and by preventing the blockage of field drainage pipe outfalls. Without channel maintenance, the resultant restrictions in capacity will cause channel water levels and hence field watertable levels to rise. Whilst the pumps may operate more frequently to counteract this, retained water levels are still expected to remain higher than that of a maintained channel. The effectiveness of the pumps will be reduced as they will exert less drawdown than if the channel were kept clear and pumping costs may therefore increase. Without pumping, much of the area would flood and become waterlogged. It is likely that a change in land use will occur and that some arable areas will revert to grassland.

1.5 Application of the Guidelines to Winestead Drain

1.5.1 Introduction

The following sections present the results of the application of the Guidelines to Winestead Drain. The same data are used as in the application of FDMM in order that results from the two methods may be compared. The completed record sheets and tables/figures required in the use of the Guidelines are presented at the end of this Appendix.

1.5.2 General information

Table 14 General information, Winestead Drain

Parameter		Comment
Dominant substrate	Clay	
Floodplain topography	Flat (<1%)	
Catchment size	Large (>2500 ha)	
Benefit area (ha)	729	Same as total flood risk area. Left and right banks are combined.
Land use type	Cereal/oilseed rotation (LUT 5)	
Dominant soil type	Loamy clay	

1.5.3 Design standard (maintained condition)

Table 15 With maintenance channel parameters, drainage status and net return

Parameter		Comment
Average bed width (m)	6.5	
Average channel depth (m)	3.8	
Freeboard under mean spring flow (m)	2.5	
Watertable depth (m)	1.25	Using Figure 2.6 in main text
Drainage status	Good	Using Figure 2.6 in main text
Economic net return (£/ha)	329	1997/98 prices
Economic net return (£)	239841	1997/98 prices

Note: Figures are subject to rounding. 1997/98 prices are used.

Annual flood costs were identified using the Guidelines for the cereal/oilseed rotation under good drainage, for events with a return period of 50 and 100 years. The same flooded areas and return periods were used as in FDMM. The flood costs corresponding with these return periods are shown in Table 16. It is assumed that these costs are additive. Total flood costs for the 'with' maintenance situation are £2843 (1997/98 prices).

Table 16 With maintenance flood costs, Winestead Drain

Flood Return Period (yr)	Area Flooded (%)	Area Flooded (ha)	Annual Flood Cost * (£/ha)	Annual Flood Cost * (£)
50	30	219	3	656
100	100	729	3	2187
			Total	2843

Note: Figures are subject to rounding. 1997/98 prices are used.

The value of the benefit area under the current maintenance regime is calculated by subtracting the flood costs from the net return, as shown in Table 17.

Table 17 Design standard, value of benefit area, Winestead Drain

Total Net Return (£) (a)	Total Flood Cost (£) (b)	Benefit Area Value (£) (a-b)
239841	2843	236998

Note: Figures are subject to rounding. 1997/98 prices are used.

1.5.4 Maintenance regime

Details on the maintenance regime are not required in the case of Winestead Drain as the watercourse is pumped.

1.5.5 Do-nothing (without maintenance)

Drainage status

In the absence of channel maintenance and pumping, the drainage status is expected to deteriorate by one class from good to bad. In this instance, the freeboard:watertable graphs are not used as these are not applicable to pumped situations.

Economic net return

Using the dominant land use type of a cereal/oilseed rotation and bad drainage, the economic net return is calculated to be £263 /ha (1997/98 economic prices). The total economic net return for the whole benefit area is therefore £191727 (1997/98 prices).

Flood costs

Annual flood costs were identified using the Guidelines for dominant land use of cereal/oilseed rotation under bad drainage, for events with the same return periods as under the 'with' maintenance situation. The same flooded areas and return periods were used as in FDMM.

The flood costs corresponding to the return periods are shown in Table 18. It is assumed that these costs are additive. Total flood costs for the without maintenance situation are £4082 (1997/98 prices).

Table 18 Flood costs under the without maintenance situation, Winestead Drain

Flood Return Period (yr)	Area Flooded (%)	Area Flooded (ha)	Annual Flood Cost (£/ha)	(£)
1	5	36.45	32	1166
50	100	729	2	1458
100	100	729	2	1458
			Total	4082

Note: Figures are subject to rounding. 1997/98 prices are used.

Without maintenance benefit area value

The value of the benefit area under the without maintenance situation of bad drainage is calculated by subtracting the flood costs from the net return, as shown in Table 19.

Table 19 Without maintenance, value of benefit area, Winestead Drain

Total Net Return (£) (a)	Total Flood Cost (£) (b)	Benefit Area Value (£) (a-b)
191727	4082	187645

Figures are subject to rounding. 1997/98 prices are used.

1.5.6 Maintenance costs

As identified in Section 1.2, the total annual maintenance expenditure on Winestead Drain, including pumping costs, is £42939 (1997/98 prices).

1.5.7 Benefit of maintenance

The difference in value of the benefit area 'with' and 'without' maintenance is used to determine the benefit of maintenance. From the figures presented in Tables 17 and 19, the benefit of maintenance is calculated to be £49353 (1997/98 economic prices).

1.5.8 Justification

The net benefit of maintenance is greater than the annual maintenance expenditure, therefore the current maintenance regime is justified, given the assumptions made. The benefit:cost ratio is 1.15.

1.6 Sensitivity Analysis

1.6.1 Without maintenance scenarios

In the previous analysis, the benefits of maintenance are derived by comparing the total benefits provided by channel maintenance and pumping with the 'do-nothing' option for the main river only. The IDB watercourse upstream of the main river has been excluded form the analysis. This IDB watercourse, however, benefits from maintenance and pumping on the main river and in order to determine total benefits and costs, this watercourse and associated benefit area should be included within the analysis. Sensitivity analysis to determine the impact of this, and the benefits associated with channel maintenance only, and pumping only, has been carried out. Further details of each scenario are provided in the following sections.

Scenario 1

Scenario 1 compares the total benefits (flooding and drainage) associated with channel maintenance and pumping on the main river and IDB watercourse with the 'do-nothing' option. These total benefits and costs are summarised in Table 20. Further details are presented at the end of this Appendix.

If the benefits and costs associated with the IDB watercourse are included in the analysis, the current maintenance scheme is justified for the assumptions made.

Table 20 **Scenario 1, benefit:cost analysis, channel maintenance and pumping**

	Total Annual Benefits (£) (Agricultural)	Annual Maintenance Costs (£)	Benefit:Cost Ratio (Agricultural only)	Benefit:Cost Ratio (Agricultural + Urban)
Main River	49353			
IDB Watercourse	32916			
Total	82269	46372	1.77	3.68
	Urban Benefits (£)			
Main River	80026			
IDB Watercourse	8320			

Note: Figures are subject to rounding. 1997/98 prices are used.

Scenario 1A

The Booster Pumping Station at head of main river pumps water from the IDB channel up into the main river which is at a higher level. The main river itself derives no benefit from this pumping station. Scenario 1A compares the benefits associated with channel maintenance and pumping on the main river only and the associated costs with the 'do-nothing' option. The costs associated with the Booster Pumping Station at the head of main river on Winestead Drain are therefore omitted from the analysis on the grounds that this delivers benefits to areas beyond the study reach, as shown in Table 21. Exclusion of the Booster Pumping Station costs increases the benefit:cost ratio.

Table 21 **Scenario 1A, benefit:cost analysis, main river only, excluding Booster pumping station**

	Total Annual Benefits (£) (Agricultural)	Annual Maintenance Costs (£)	Benefit:Cost Ratio (Agricultural only)	Benefit:Cost Ratio (Agricultural + Urban
Main River	49353			
Total	49353	26678	1.85	4.85
	Urban Benefits (£)			
Main River	80026			

Note: Figures are subject to rounding. 1997/98 prices are used.

Scenario 1B

Scenario 1B compares the benefits associated with channel maintenance and pumping on the IDB watercourse only, with the 'do-nothing' option, as shown in Table 22. As the IDB watercourse and associated benefit area benefits from operation of the Booster Pumping Station, the cost associated with this should ideally be included in the equation. Table 22 shows that even if the pumping costs are included in the analysis, maintenance on the IDB watercourse is justified given the assumptions made.

Table 22 **Scenario 1B, benefit:cost analysis, IDB watercourse, including Booster pumping station**

	Total Annual Benefits (£) (Agricultural)	Annual Maintenance Costs (£)	Benefit:Cost Ratio (Agricultural only)	Benefit:Cost Ratio (Agricultural + Urban
IDB Watercourse	32916			
Total	32916	19694	1.67	2.09
	Urban Benefits (£)			
IDB Watercourse	8320			

Note: Figures are subject to rounding. 1997/98 prices are used.

Scenario 2

Scenario 2 assumes that Winestead Drain is subject to channel maintenance only and that all pumping is discontinued. It is assumed that flooding will become more frequent and that a larger area will be affected than if pumping were to continue. Using the freeboard:watertable graphs (Figure 2.6 in main text), good drainage status is predicted to prevail if channel maintenance were to continue. This is likely to result in an over-estimation of benefits as if pumping were discontinued, the channel would essentially act as a pond. Channel water levels and the watertable level would rise with a consequent deterioration in drainage status. Further details are presented at the end of this Appendix and in Table 23.

Table 23 Scenario 2, benefits of channel maintenance only, compared with the 'do-nothing' option

	Total Annual Benefits (£) (Agricultural)	Annual Maintenance Costs (£)	Benefit:Cost Ratio (Agricultural only)	Benefit:Cost Ratio (Agricultural + Urban)
Main River	116			
IDB Watercourse	78			
Total	194	9508	0.02	0.10
	Urban Benefits (£)			
Main River	483			
IDB Watercourse	234			

Note: Figures are subject to rounding. 1997/98 prices are used.

Scenario 3

Scenario 3 assumes that Winestead Drain is subject to pumping only and that channel maintenance is discontinued. It is assumed that flooding will become more frequent and that a larger area will be affected that if channel maintenance were to continue. It is assumed that a good drainage status will prevail over the whole flood risk area of the main river and IDB watercourse, due to the continued pumping. Further details are presented at the end of this Appendix and in Table 24.

Table 24 Scenario 3, benefits of pumping only, compared with the 'do-nothing' option

	Total Annual Benefits (£) (Agricultural)	Annual Maintenance Costs (£)	Benefit:Cost Ratio (Agricultural only)	Benefit:Cost Ratio (Agricultural + Urban)
Main River	48609			
IDB Watercourse	32420			
Total	81029	36864	2.20	3.62
	Urban Benefits (£)			
Main River	47628			
IDB Watercourse	4814			

Note: Figures are subject to rounding. 1997/98 prices are used.

WINESTEAD DRAIN

Order of record sheets presented in the following pages:

FDMM

Annual maintenance costs

Land use assessment: reach summary

Flooding

Drainage benefits

Excluding urban benefits: Land use assessment - reach summary

Excluding urban benefits: Flooding

GUIDELINES

General information

Design standard

Maintenance regime

'Do-nothing' - Without maintenance

Maintenance expenditure and benefits of maintenance

WITHOUT MAINTENANCE SCENARIOS

FDMM

- Scenario 1
- Scenario 1A
- Scenario 1B
- Scenario 2
- Scenario 3

GUIDELINES

- Scenario 1
- Scenario 1A
- Scenario 1B
- Scenario 2
- Scenario 3

ANNUAL MAINTENANCE COSTS

Winestead Drain

Element	Annual Maintenance Cost (£)
Main River	
Weedcutting & flail mowing	5353
Dredging	722
Total maintenance costs for channel only	6075
Total operation/maintenance cost: Booster Pumping Station	16261
Total operation/maintenance cost: Outstrays Pumping Station	20603
Combined total	42939
Internal Drainage Board watercourse	
Weedcutting	2250
Dredging	1183
Total costs on IDB watercourse	3433

Source: Environment Agency (North East Region) and Winestead Drain IDB

Note: All maintenance costs relate to annual costs, in 1997/98 prices.
Pumping costs vary according to factors such as time of day in use, number of pumps used, season and frequency of operation.
Actual pumping and pump maintenance costs for the most recent year for which a complete record of costs exists (1996/97) are used in the analysis and inflated to 1997/98 prices.

LAND USE ASSESSMENT : REACH SUMMARY

Watercourse	**Winestead Drain**
Bank	**Left Bank**
OS Map	Pathfinder TA 22/32, TA 21/31
Flood risk area (ha)	460
Effective reach length (km)	7.3

Land Use Factor	Unit	Number or area (a)	House Equivalents HE/unit (b)		Total HE (a) x (b)	
House	Number	*145*	1.00		*145*	
Garden / allotments	Number	*145*	0.04		*5.8*	
NRP - Manufacturing	Area (m^2)		0.030		*0*	
NRP - Distribution	Area (m^2)		0.054		*0*	
NRP - Leisure	Area (m^2)	*25*	0.032		*0.8*	
NRP - Offices	Area (m^2)	*50*	0.033		*1.65*	
NRP - Retail	Area (m^2)		0.035		*0*	
NRP - Agricultural	Area (m^2)	*350*	0.010		*3.5*	
C Roads	Number	*2*	2.7		*5.4*	
B Roads	Number		6.3		*0*	
A Roads (non trunk)	Number		15.9		*0*	
A Roads (trunk)	Number		31.7		*0*	
Motorway	Number		63.5		*0*	
Railway	Number		63.5		*0*	
			Flooding	Drainage	Flooding	Drainage **
Forestry and scrub *	per 100 ha	*0.023*	0.02	0.0	*0.0005*	*0*
Extensive pasture *	per 100 ha		1.3	1.1	*0*	*0*
Intensive pasture *	per 100 ha	*0.023*	3	4.5	*0.07*	*0*
Extensive arable *	per 100 ha	*4.554*	6.3	3.6	*28.69*	*0*
Intensive arable *	per 100 ha		44.1	9.7	*0*	*0*
Formal parks	Number		0.6		*0*	
Golf / race courses	Number		0.7		*0*	
Playing field	Number		0.1		*0*	
Special parks	Number		9.3		*0*	
Total HE (c) *					*190.91*	
HE/km ((c) / effective reach length)					*26.15*	

Note:

* Flooding / drainage values to be summed. ** Apply areal drainage factor if required

HE values are at 1991 base

LAND USE ASSESSMENT : REACH SUMMARY

Watercourse	**Winestead Drain**
Bank	**Right Bank**
OS Map	Pathfinder TA 22/32, TA 21/31
Flood risk area (ha)	269
Effective reach length (km)	7.3

Land Use Factor	Unit	Number or area (a)	House Equivalents HE/unit (b)		Total HE (a) x (b)	
House	Number	*1*	1.00		*1*	
Garden / allotments	Number	*1*	0.04		*0.04*	
NRP - Manufacturing	Area (m^2)		0.030		*0*	
NRP - Distribution	Area (m^2)		0.054		*0*	
NRP - Leisure	Area (m^2)		0.032		*0*	
NRP - Offices	Area (m^2)		0.033		*0*	
NRP - Retail	Area (m^2)		0.035		*0*	
NRP - Agricultural	Area (m^2)		0.010		*0*	
C Roads	Number	*1*	2.7		*2.7*	
B Roads	Number		6.3		*0*	
A Roads (non trunk)	Number		15.9		*0*	
A Roads (trunk)	Number		31.7		*0*	
Motorway	Number		63.5		*0*	
Railway	Number		63.5		*0*	
			Flooding	Drainage	Flooding	Drainage **
Forestry and scrub *	per 100 ha	*0.007*	0.02	0.0	*0.00014*	*0*
Extensive pasture *	per 100 ha		1.3	1.1	*0*	*0*
Intensive pasture *	per 100 ha		3	4.5	*0*	*0*
Extensive arable *	per 100 ha	*2.683*	6.3	3.6	*16.9029*	*0*
Intensive arable *	per 100 ha		44.1	9.7	*0*	*0*
Formal parks	Number		0.6		*0*	
Golf / race courses	Number		0.7		*0*	
Playing field	Number		0.1		*0*	
Special parks	Number		9.3		*0*	
Total HE (c) *					*20.64*	
HE/km ((c) / effective reach length)					*2.83*	

Note:

* Flooding / drainage scores to be summed ** Apply areal drainage factor if required

HE values are at 1991 base

FLOODING

Watercourse	**Winestead Drain**
Bank	**Left Bank**
Flood risk area (ha)	460
Effective reach length (km)	7.3

With maintenance - current situation

Flood Return Period (years)	Probability	Nr. HEs Affected	Probability Interval (a)	Average Nr. HEs Affected (b)	(a) x (b)
1	1	0.00			
no flooding			0.98	33.81	33.13
50	0.02	67.61			
30 % flooded			0.01	146.49	1.46
100	0.01	225.37			
100 % flooded					
Annual Average Number HEs affected with maintenance (AAN $_{with}$)					34.59

Without channel maintenance and pumping

Flood Return Period (years)	Probability	Nr. HEs Affected	Probability Interval (a)	Average Nr. HEs Affected (b)	(a) x (b)
1	1	11.27			
5% flooded			0.98	118.32	115.95
50	0.02	225.37			
100 % flooded			0.01	225.37	2.25
100	0.01	225.37			
100 % flooded					
Annual Average Number HEs affected without maintenance (AAN $_{without}$)					118.21

Severity weightings have been applied to HEs affected by flooding	arable	2.2
	pasture	1.5

FLOODING

Watercourse	**Winestead Drain**
Bank	**Right Bank**
Flood risk area (ha)	269
Effective reach length (km)	7.3

With maintenance - current situation

Flood Return Period (years)	Probability	Nr. HEs Affected	Probability Interval (a)	Average Nr. HEs Affected (b)	(a) x (b)
1	1	0.00			
no flooding			0.98	6.14	6.02
50	0.02	12.28			
30 % flooded			0.01	26.60	0.27
100	0.01	40.93			
100 % flooded					
Annual Average Number HEs affected with maintenance (AAN $_{with}$)					6.28

Without channel maintenance and pumping

Flood Return Period (years)	Probability	Nr. HEs Affected	Probability Interval (a)	Average Nr. HEs Affected (b)	(a) x (b)
1	1	2.05			
5% flooded			0.98	21.49	21.06
50	0.02	40.93			
100 % flooded			0.01	40.93	0.41
100	0.01	40.93			
100 % flooded					
Annual Average Number HEs affected without maintenance (AAN $_{without}$)					21.47

Severity weightings have been applied to HEs affected by floodin	arable	2.2
	pasture	1.5

DRAINAGE BENEFITS

Watercourse	**Winestead Drain**		
Bank	**Left Bank**		
Drainage benefit area (ha)	460		
Land use type	Forestry & scrub	Intensive pasture	Extensive arable
With maintenance drainage status	Good	Good	Good
Without maintenance drainage status	Bad	Bad	Bad
Area affected (ha)	2.3	2.3	455.4
Annual value (£/ha) *	0	75	65
Total value/land use (£) *	0	172.5	29601
Total value (£) *	29773.5		

Watercourse	**Winestead Drain**	
Bank	**Right Bank**	
Drainage benefit area (ha)	269	
Land use type	Forestry & scrub	Extensive arable
With maintenance drainage status	Good	Good
Without maintenance drainage status	Bad	Bad
Area affected (ha)	0.07	268.3
Annual value (£/ha) *	0	65
Total value/land use (£) *	0	17440
Total value (£) *	17439.5	

Note: 1997/98 economic prices are used. Figures are subject to rounding.

LAND USE ASSESSMENT : REACH SUMMARY
AGRICULTURAL BENEFITS ONLY

Watercourse	**Winestead Drain**
Bank	**Left Bank**
OS Map	Pathfinder TA 22/32, TA 21/31
Flood risk area (ha)	460
Effective reach length (km)	7.3

Land Use Factor	Unit	Number or area (a)	House Equivalents HE/unit (b)		Total HE (a) x (b)	
House	Number		1.00		*0*	
Garden / allotments	Number		0.04		*0*	
NRP - Manufacturing	Area (m^2)		0.030		*0*	
NRP - Distribution	Area (m^2)		0.054		*0*	
NRP - Leisure	Area (m^2)		0.032		*0*	
NRP - Offices	Area (m^2)		0.033		*0*	
NRP - Retail	Area (m^2)		0.035		*0*	
NRP - Agricultural	Area (m^2)		0.010		*0*	
C Roads	Number		2.7		*0*	
B Roads	Number		6.3		*0*	
A Roads (non trunk)	Number		15.9		*0*	
A Roads (trunk)	Number		31.7		*0*	
Motorway	Number		63.5		*0*	
Railway	Number		63.5		*0*	
			Flooding	Drainage	Flooding	Drainage **
Forestry and scrub *	per 100 ha	*0.023*	0.02	0.0	*0.0005*	*0*
Extensive pasture *	per 100 ha		1.3	1.1	*0*	*0*
Intensive pasture *	per 100 ha	*0.023*	3	4.5	*0.07*	*0*
Extensive arable *	per 100 ha	*4.554*	6.3	3.6	*28.69*	*0*
Intensive arable *	per 100 ha		44.1	9.7	*0*	*0*
Formal parks	Number		0.6		*0*	
Golf / race courses	Number		0.7		*0*	
Playing field	Number		0.1		*0*	
Special parks	Number		9.3		*0*	
Total HE (c) *					*28.76*	
HE/km ((c) / effective reach length)					*3.94*	

Note:

* Flooding / drainage values to be summed

HE values are at 1991 base

** Apply areal drainage factor if required

LAND USE ASSESSMENT : REACH SUMMARY
AGRICULTURAL BENEFITS ONLY

Watercourse	**Winestead Drain**
Bank	**Right Bank**
OS Map	Pathfinder TA 22/32, TA 21/31
Flood risk area (ha)	269
Effective reach length (km)	7.3

Land Use Factor	Unit	Number or area (a)	House Equivalents HE/unit (b)		Total HE (a) x (b)	
House	Number			1.00		*0*
Garden / allotments	Number			0.04		*0*
NRP - Manufacturing	Area (m^2)			0.030		*0*
NRP - Distribution	Area (m^2)			0.054		*0*
NRP - Leisure	Area (m^2)			0.032		*0*
NRP - Offices	Area (m^2)			0.033		*0*
NRP - Retail	Area (m^2)			0.035		*0*
NRP - Agricultural	Area (m^2)			0.010		*0*
C Roads	Number			2.7		*0*
B Roads	Number			6.3		*0*
A Roads (non trunk)	Number			15.9		*0*
A Roads (trunk)	Number			31.7		*0*
Motorway	Number			63.5		*0*
Railway	Number			63.5		*0*
			Flooding	Drainage	Flooding	Drainage **
Forestry and scrub *	per 100 ha	*0.007*	0.02	0.0	*0.00014*	*0*
Extensive pasture *	per 100 ha		1.3	1.1	*0*	*0*
Intensive pasture *	per 100 ha		3	4.5	*0*	*0*
Extensive arable *	per 100 ha	*2.683*	6.3	3.6	*16.9029*	*0*
Intensive arable *	per 100 ha		44.1	9.7	*0*	*0*
Formal parks	Number			0.6		*0*
Golf / race courses	Number			0.7		*0*
Playing field	Number			0.1		*0*
Special parks	Number			9.3		*0*
				Total HE (c) *		*16.90*
				HE/km ((c) / effective reach length)		*2.32*

Note:
* Flooding / drainage scores to be summed ** Apply areal drainage factor if required
HE values are at 1991 base

FLOODING AGRICULTURAL BENEFITS ONLY

Watercourse	**Winestead Drain**
Bank	**Left Bank**
Flood risk area (ha)	460
Effective reach length (km)	7.3

With maintenance - current situation

Flood Return Period (years)	Probability	Nr. HEs Affected	Probability Interval (a)	Average Nr. HEs Affected (b)	(a) x (b)
1	1	0.00			
no flooding			0.98	9.56	9.37
50	0.02	19.12			
30 % flooded			0.01	41.42	0.41
100	0.01	63.72			
100 % flooded					

Annual Average Number HEs affected with maintenance (AAN_{with}) 9.78

Without channel maintenance and pumping

Flood Return Period (years)	Probability	Nr. HEs Affected	Probability Interval (a)	Average Nr. HEs Affected (b)	(a) x (b)
1	1	3.19			
5% flooded			0.98	33.45	32.78
50	0.02	63.72			
100 % flooded			0.01	63.72	0.64
100	0.01	63.72			
100 % flooded					

Annual Average Number HEs affected without maintenance ($AAN_{without}$) 33.42

Severity weightings have been applied to HEs affected by flooding	arable	2.2
	pasture	1.5

FLOODING AGRICULTURAL BENEFITS ONLY

Watercourse	**Winestead Drain**
Bank	**Right Bank**
Flood risk area (ha)	269
Effective reach length (km)	7.3

With maintenance - current situation

Flood Return Period (years)	Probability	Nr. HEs Affected	Probability Interval (a)	Average Nr. HEs Affected (b)	(a) x (b)
1	1	0.00			
no flooding			0.98	5.58	5.47
50	0.02	11.16			
30 % flooded			0.01	24.17	0.24
100	0.01	37.19			
100 % flooded					

Annual Average Number HEs affected with maintenance (AAN_{with}) 5.71

Without channel maintenance and pumping

Flood Return Period (years)	Probability	Nr. HEs Affected	Probability Interval (a)	Average Nr. HEs Affected (b)	(a) x (b)
1	1	1.86			
5% flooded			0.98	19.52	19.13
50	0.02	37.19			
100 % flooded			0.01	37.19	0.37
100	0.01	37.19			
100 % flooded					

Annual Average Number HEs affected without maintenance ($AAN_{without}$) 19.51

Severity weightings have been applied to HEs affected by floodin	arable	2.2
	pasture	1.5

GUIDELINES: GENERAL INFORMATION

River — 1a **WINESTEAD DRAIN**

Reach Code — 1b **01**

Reach Length (km) — 2 **7.3**

Dominant Substrate Type:-
Gravel, Sand or Silt
(Treat clay as silt) — 3 **CLAY**

Floodplain -
Rising (>1 %) or Flat (< 1 %) — 4 **FLAT/PUMPED**

Catchment Size
Large (> 25 sq. km)
Small (< 25 sq. km) — 5 **LARGE**

Benefit Area (ha)
(Area deriving benefit from maintenance) — 6 **729**

Dominant Land Use Type (LUT)
(Table 1) — 7 **CEREAL/OILS (5)**

Dominant Soil Type — 9 **LOAMY CLAY**

Varied Land Use Types (LUT)
(Table 1)

LUT		7 % Benefit Area as decimal	8a Does the LUT flood ?	8b If yes, % that floods (as decimal)
1	Ext grass			
2	Int grass			
3	Grass/arable			
4	All cereals			
5	Cereal/oil seed			
6	Cereal/root			
7	Horticulture			
8	Other			

Note: All table numbers and references relate to R&D Note 511, Guidelines for the Justification of River Maintenance (Dunderdale and Morris, 1996b)

GUIDELINES: DESIGN STANDARD

Average Bed Width (m) — 10: 6.5

Average Channel Depth (m) — 11: 3.8

% Weed Cover (In channel, submerged & floating weed) — 12: 0 (Emergent vegetation only)

Freeboard (m) — 13: 2.5

Watertable Depth (m) *(Box 4, 9, 13 & Figure 1 or 2)* — 14: 1.25

Drainage Status *(Box 14 & Table 4)* — 15: GOOD

Economic Net Return
(Table 5, using Box 7 & Box 15)

			16
For either :-	Dominant land use	(£/ha)	329
		(£)	239841
or :-	Varied land use	(£/ha)	
		(£)	

LUT	16a Net Return (£/ha)	16b Weighted Net Return
1		
2		
3		
4		
5		
6		
7		

Bankfull Discharge (Qbf) (cumecs) — 17:

* Regional Growth Curve Area *(Figure 3)* — 18:

* Mean Annual Flood (Q bar) (cumecs) — 19:

* Qbf/Q bar (cumecs) *(Box 17 / Box 19)* — 20:

* Flooding Envelopes
* % BA with different flood return periods (years)
(Table 6 or 7, boxes 5, 7, 15)

FRP (yr)	21 % area of each LUT that floods	21a Flooded Area (ha)	22 Flood Cost (£/ha)	22a Total Flood Cost (£) *(Box 21a * box 22)*
0				
1 - 2	0	0	0	0
3 - 5				
6 - 10				
> 10 (50 yr)	30	218.7	3	656
(100 yr)	100	729	3	2187
			Total	2843

* *Not necessary unless detailed information and assessment is required*

Flood Return Period (years) — 23: AS ABOVE

Total Flood Cost (£) — 24: 2843

Design Net Return Less Flood Cost *(Box 16 - box 24)* (£) — 24a: 236998

Note: All table numbers and references relate to R&D Note 511, Guidelines for the Justification of River Maintenance (Dunderdale and Morris, 1996b)

GUIDELINES: "DO NOTHING" (WITHOUT MAINTENANCE)

30
W/o Maintenance Width (m) N/A
(Box 10 - box 25a)

31
W/o Maintenance Depth (m) N/A
(Box 11 - box 26a)

32
W/o Maintenance Freeboard (m) N/A
(Box 13 - box 28a)

33
W/o Maintenance Watertable Depth (m) N/A
(Box 4, 9, 32, Table 3, Figure 1 or 2)

34
W/o Maintenance Drainage Status BAD
(Table 4, box 33)

* Flooding Envelopes
* % BA with different flood return periods (years)
(Table 6 or 7, boxes 5, 7, 34)

FRP (yr.)	38 % area of each LUT that floods	38a Flooded Area (ha)	39 Flood Cost (£/ha)	39a Total Flood Cost (£) *(Box 38a * box 39)*
0				
<1				
1 - 2	5	36.45	32	1166
3 - 5				
6 - 10				
> 10 (50 yr)	100	729	2	1458
> 10 (100 yr)	100	729	2	1458
			Total	4082

* *Not necessary unless detailed information and assessment required*

Economic Net Return (W/o maintenance)
(Table 5, box 8, 34)

35
For either :- Dominant land use (£/ha) 263
£ 191727

or :- Varied land use (£/ha)
£

35b LUT	35a Net Return (£/ha)	Weighted Net Return
1		
2		
3		
4		
5		
6		
7		

40
W/o Maintenance FRP (years) AS ABOVE

41
Total Flood Cost (£) 4082

41a
Do-nothing
Net Return Less Flood Cost (£) 187645
(Box 35 - box 41)

36
W/o Maintenance Bankfull Discharge (Qbf) (cumecs)
(Box 17 - box 29)

37
* W/o Maintenance Qbf/Q bar (cumecs)
(Box 36 / box 19)

Note: All table numbers and references relate to R&D Note 511, Guidelines for the Justification of River Maintenance (Dunderdale and Morris, 1996b)

GUIDELINES: MAINTENANCE EXPENDITURE

	42	43	44	45	46	47
Maintenance Activity	Unit Cost (£)	No. of Units (specify)	Cost/Reach/ Activity (£)	Interval Between Maintenance Activities (years)	Amortisation Value at 6 % Discount Rate *(Box 45, Table 18)*	Annual Cost (£) *(Box 44 * box 46)*
Weedcutting and dredging (Inc. operation/maintenance of pumping stations)						**42939**

Total Annual Cost/Reach (£)	*(Sum box 47)*	48	**42939**
Benefit Area (ha)	*(Box 6)*	49	**729**
Total Annual Maintenance Cost/ha	*(Box 48 / box 49)*	50	**58.9**

GUIDELINES: BENEFITS OF MAINTENANCE

Design Standard (With maintenance)	Net return less flood costs	*(Box 24a)*	(£)	51	**236998**
Do Nothing (Without maintenance)	Net return less flood costs	*(Box 41a)*	(£)	52	**187645**
Change in Net Benefit Due to Maintenance		*(Box 51 - box 52)*	(£)	53	**49353**
Net Benefit of Maintenance	Change in net benefit less total annual maintenance costs	*(Box 53 - box 49 or 50)*	(£)	54	**6414**
	Benefit : cost ratio	*(Box 53/box 48)*			**1.15**

Note: All table numbers and references relate to R&D Note 511, Guidelines for the Justification of River Maintenance (Dunderdale and Morris, 1996b)

WINESTEAD DRAIN

WITHOUT MAINTENANCE SCENARIOS: FDMM

SUMMARY: FDMM

WITH MAINTENANCE (CURRENT SITUATION)

			£
Costs	Main river channel		6075
	IDB channel		0
	Booster Pumping Station		16261
	Outstrays Pumping Station		20603
	Total costs		42939
Main river			
	Drainage	Maintenance gives 100% good drainage	
		Int pasture 2.3 ha x £320/ha	736
		Ext. arable 723.7 ha x £293/ha	212044
			212780
	Flooding	Some flooding with maintenance	53294

DO NOTHING

Stop all pumping and all channel maintenance

			£	Agricultural + Urban	Agricultural Only
Costs	Main river channel		0		
	IDB channel		0		
	Booster Pumping Station		0		
	Outstrays Pumping Station		0		
	Total costs		0		
Main river					
	Drainage	Good to bad over 100 %			
		Int pasture 2.3 ha x £245 /ha *	564		
		Ext. arable 723.7 ha x £228 /ha **	165004		
			165567	47213	47213
	Flooding	More frequent flooding, larger area affected	182143	128849	48823
			Total	176062	96036

	Agricultural + Urban	Agricultural Only
BENEFIT OF CURRENT MAINTENANCE	176062	96036
COST OF MAINTENANCE	42939	42939
BENEFIT COST RATIO	4.10	2.24

Note: * £320/ha less £75/ha which is loss in net return associated with deterioration in drainage from good to bad on int. pasture
** £293/ha less £65/ha which is loss in net return associated with deterioration in drainage from good to bad on ext. arable

Urban **(Flooding)**	£
Main river	80026
IDB	8320

(current maintenance cf to do-nothing)

SUMMARY: FDMM
WITH MAINTENANCE (CURRENT SITUATION)

			£
Costs	*Main river channel*		6075
	IDB channel		3433
	Booster Pumping Station		16261
	Outstrays Pumping Station		20603
	Total costs		46372
Main river			
	Drainage	Maintenance gives 100% good drainage	
		Int pasture 2.3 ha x £320/ha	736
		Ext. arable 723.7 ha x £293/ha	212044
			212780
	Flooding	Some flooding with maintenance	53294
IDB			
	Drainage	Maintenance gives 100% good drainage	
		Ext. arable 486.2 ha x £293/ha	142457
	Flooding	Some flooding with maintenance	16939

Urban (Flooding)	£
Main river	80026
IDB	8320

(current maintenance cf to do-nothing)

SCENARIO 1
DO NOTHING

Stop all pumping and all channel maintenance

			£	Agricultural + Urban	Agricultural Only
Costs	Main river channel		0		
	IDB channel		0		
	Booster Pumping Station		0		
	Outstrays Pumping Station		0		
	Total costs		0		
Main river					
	Drainage	Good to bad over 100 %			
		Int pasture 2.3 ha x £245 /ha *	564		
		Ext. arable 723.7 ha x £228 /ha **	165004		
			165567	47213	47213
	Flooding	More frequent flooding, larger area affected	182143	128849	48823
			Total	176062	96036
IDB					
	Drainage	Good to bad over 100 %			
		Ext. arable 486.2 ha x £228/ha**	110854	31603	31603
	Flooding	More frequent flooding, larger area affected	57858	40920	32600
			Total	72523	64203
				Agricultural + Urban	Agricultural Only
		BENEFIT OF CURRENT MAINTENANCE		248584	160238
		COST OF MAINTENANCE		46372	46372
		BENEFIT COST RATIO		5.36	3.46

Note: * £320/ha less £75/ha which is loss in net return associated with deterioration in drainage from good to bad on int. pasture
** £293/ha less £65/ha which is loss in net return associated with deterioration in drainage from good to bad on ext. arable

SCENARIO 1 DO-NOTHING

Watercourse **Winestead Drain**
Bank **Left Bank**
Flood risk area (ha) 460
Effective reach length (km) 7.3

With maintenance - current situation

Flood Return Period (years)	Probability	Nr. HEs Affected	Probability Interval (a)	Average Nr. HEs Affected (b)	(a) x (b)
1	1	0.00			
no flooding			0.98	33.81	33.13
50	0.02	67.61			
30 % flooded			0.01	146.49	1.46
100	0.01	225.37			
100 % flooded					
Annual Average Number HEs affected with maintenance (AAN $_{with}$)					34.59

NO MAINTENANCE - DO-NOTHING

Flood Return Period (years)	Probability	Nr. HEs Affected	Probability Interval (a)	Average Nr. HEs Affected (b)	(a) x (b)
1	1	11.27			
5% flooded			0.98	118.32	115.95
50	0.02	225.37			
100 % flooded			0.01	225.37	2.25
100	0.01	225.37			
100 % flooded					
Annual Average Number HEs affected without maintenance (AAN $_{without}$)					118.21

Summary: flood cost without maintenance

	AAN $_{without}$ (a)	(b) x £1304*
Left Bank	118.21	154146
Right Bank	21.47	27997
Total	139.68	182143

Note: * value of one He is 31304, 1997/98 prices
Severity weightings have been applied to HEs affected by flooding: arable 2.2, pasture 1.5

SCENARIO 1 DO-NOTHING

Watercourse **Winestead Drain**
Bank **Right Bank**
Flood risk area (ha) 269
Effective reach length (km) 7.3

With maintenance - current situation

Flood Return Period (years)	Probability	Nr. HEs Affected	Probability Interval (a)	Average Nr. HEs Affected (b)	(a) x (b)
1	1	0.00			
no flooding			0.98	6.14	6.02
50	0.02	12.28			
30 % flooded			0.01	26.60	0.27
100	0.01	40.93			
100 % flooded					
Annual Average Number HEs affected with maintenance (AAN $_{with}$)					6.28

NO MAINTENANCE - DO-NOTHING

Flood Return Period (years)	Probability	Nr. HEs Affected	Probability Interval (a)	Average Nr. HEs Affected (b)	(a) x (b)
1	1	2.05			
5% flooded			0.98	21.49	21.06
50	0.02	40.93			
100 % flooded			0.01	40.93	0.41
100	0.01	40.93			
100 % flooded					
Annual Average Number HEs affected without maintenance (AAN $_{without}$)					21.47

SCENARIO 1 **DO-NOTHING**

Watercourse	**Winestead Drain - IDB channel**
Bank	**Left Bank**
Flood risk area (ha)	312
Effective reach length (km)	6.1

With maintenance - current situation

Flood Return Period (years)	Probability	Nr. HEs Affected	Probability Interval (a)	Average Nr. HEs Affected (b)	(a) x (b)
1	1	0.00			
no flooding			0.98	8.65	8.48
50	0.02	17.31			
30 % flooded			0.01	37.50	0.37
100	0.01	57.69			
100 % flooded					

Annual Average Number HEs affected with maintenance (AAN $_{with}$) 8.86

NO MAINTENANCE - DO-NOTHING

Flood Return Period (years)	Probability	Nr. HEs Affected	Probability Interval (a)	Average Nr. HEs Affected (b)	(a) x (b)
1	1	2.88			
5% flooded			0.98	30.29	29.68
50	0.02	57.69			
100 % flooded			0.01	57.69	0.58
100	0.01	57.69			
100 % flooded					

Annual Average Number HEs affected without maintenance (AAN $_{without}$) 30.26

Summary: flood cost without maintenance

	AAN $_{without}$ (a)	(b) x £1304*
Left Bank	30.26	39459
Right Bank	14.11	18399
Total	44.37	57858

Note: * value of one HE is 31304, 1997/98 prices

Severity weightings have been applied to HEs affected by flooding: arable 2.2, pasture 1.5

SCENARIO 1 **DO-NOTHING**

Watercourse	**Winestead Drain - IDB channel**
Bank	**Right Bank**
Flood risk area (ha)	175
Effective reach length (km)	6.1

With maintenance - current situation

Flood Return Period (years)	Probability	Nr. HEs Affected	Probability Interval (a)	Average Nr. HEs Affected (b)	(a) x (b)
1	1	0.00			
no flooding			0.98	4.04	3.95
50	0.02	8.07			
30 % flooded			0.01	17.49	0.17
100	0.01	26.90			
100 % flooded					

Annual Average Number HEs affected with maintenance (AAN $_{with}$) 4.13

NO MAINTENANCE - DO-NOTHING

Flood Return Period (years)	Probability	Nr. HEs Affected	Probability Interval (a)	Average Nr. HEs Affected (b)	(a) x (b)
1	1	1.35			
5% flooded			0.98	14.12	13.84
50	0.02	26.90			
100 % flooded			0.01	26.90	0.27
100	0.01	26.90			
100 % flooded					

Annual Average Number HEs affected without maintenance (AAN $_{without}$) 14.11

SUMMARY: FDMM

WITH MAINTENANCE (CURRENT SITUATION)

			£
Costs	Main river channel		6075
	IDB channel		0
	Booster Pumping Station		0
	Outstrays Pumping Station		20603
	Total costs		26678
Main river			
	Drainage	Maintenance gives 100% good drainage	
		Int pasture 2.3 ha x £320/ha	736
		Ext. arable 723.7 ha x £293/ha	212044
			212780
	Flooding	Some flooding with maintenance	53294

SCENARIO 1A

DO NOTHING

Stop all pumping and all channel maintenance

			£	Agricultural + Urban	Agricultural Only
Costs	Main river channel		0		
	IDB channel		0		
	Booster Pumping Station		0		
	Outstrays Pumping Station		0		
	Total costs		0		
Main river					
	Drainage	Good to bad over 100 %			
		Int pasture 2.3 ha x £245 /ha *	564		
		Ext. arable 723.7 ha x £228 /ha **	165004		
			165567	47213	47213
	Flooding	More frequent flooding, larger area affected	182143	128849	48823
			Total	176062	96036

	Agricultural + Urban	Agricultural Only
BENEFIT OF CURRENT MAINTENANCE	176062	96036
COST OF MAINTENANCE	26678	26678
BENEFIT COST RATIO	6.60	3.60

Urban (Flooding)	£
Main river	80026
IDB	8320

(current maintenance cf to do-nothing)

Note: * £320/ha less £75/ha which is loss in net return associated with deterioration in drainage from good to bad on int. pasture
** £293/ha less £65/ha which is loss in net return associated with deterioration in drainage from good to bad on ext. arable

SUMMARY: FDMM

WITH MAINTENANCE (CURRENT SITUATION)

		£
Costs	Main river channel	0
	IDB channel	3433
	Booster Pumping Station	16261
	Outstrays Pumping Station	0
	Total costs	19694

IDB			
	Drainage	Maintenance gives 100% good drainage	
		Ext. arable 486.2 ha x £293/ha	142457
	Flooding	Some flooding with maintenance	16939

Urban (Flooding)	£
Main river	80026
IDB	8320
(current maintenance cf to do-nothing)	

SCENARIO 1B

DO NOTHING

Stop all pumping and all channel maintenance

		£
Costs	Main river channel	0
	IDB channel	0
	Booster Pumping Station	0
	Outstrays Pumping Station	0
	Total costs	0

				Agricultural + Urban	Agricultural Only
IDB					
	Drainage	Good to bad over 100 %			
		Ext. arable 486.2 ha x £228/ha*	110854	31603	31603
	Flooding	More frequent flooding, larger area affected	57858	40920	32600
			Total	72523	64203

	Agricultural + Urban	Agricultural Only
BENEFIT OF CURRENT MAINTENANCE	72523	64203
COST OF MAINTENANCE	19694	19694
BENEFIT COST RATIO	3.68	3.26

Note: * £293/ha less £65/ha which is loss in net return associated with deterioration in drainage from good to bad on ext. arable

SUMMARY: FDMM

DO NOTHING

Stop all pumping and all channel maintenance

			£
Costs	Main river channel		0
	IDB channel		0
	Booster Pumping Station		0
	Outstrays Pumping Station		0
	Total costs		0
Main river			
	Drainage	Bad over 100 %	
		Int pasture 2.3 ha x £245/ha	564
		Ext. arable 723.7 ha x £228/ha	165004
		Total	165567
	Flooding	Frequent flooding, large area affected	182143
IDB			
	Drainage	Bad over 100 %	
		Ext. arable 486.2 ha x £228/ha	110854
		Total	110854
	Flooding	Frequent flooding, large area affected	57858

Urban		
(Flooding)	£	% flooding benefits apportioned to urban area
Main river	80026	44%
IDB	8320	14%

(current maintenance cf to do-nothing)

SCENARIO 2

CHANNEL MAINTENANCE ONLY

Channel maintenance only

			£			
Costs	Main river channel		6075			
	IDB channel		3433			
	Booster Pumping Station		0			
	Outstrays Pumping Station		0			
	Total costs		9508			
					Agricultural + Urban	Agricultural Only
Main river						
	Drainage	Good over 25%				
		Int pasture 2.3 ha x £320/ha		736		
		Ext. arable 180.93 ha x £293/ha		53012		
		Bad over 75%				
		Ext. arable, 542.77 ha * £228/ha		123752		
			Total	177500	11933	11933
	Flooding	See following page		181282	861	378
				Total	12794	12311
IDB						
	Drainage	Good over 25%				
		Ext. arable 121.55 ha x £293/ha		35614		
		Bad over 75%				
		Ext. arable, 364.65 ha * £228/ha		83140		
			Total	118754	7901	7901
	Flooding	See following page		57585	273	39
				Total	8174	7940

	Agricultural + Urban	Agricultural Only
BENEFIT OF CHANNEL MAINTENANCE ONLY	20968	20251
COST OF MAINTENANCE	9508	9508
BENEFIT COST RATIO	2.21	2.13

FLOODING

SCENARIO 2 CHANNEL MAINTENANCE ONLY

Watercourse	**Winestead Drain**
Bank	**Left Bank**
Flood risk area (ha)	460
Effective reach length (km)	7.3

Do-Nothing

Flood Return Period (years)	Probability	Nr. HEs Affected	Probability Interval (a)	Average Nr. HEs Affected (b)	(a) x (b)
1	1	11.27			
5% flooded			0.98	118.32	115.95
50	0.02	225.37			
100 % flooded			0.01	225.37	2.25
100	0.01	225.37			
100 % flooded					
Annual Average Number HEs affected with maintenance (AAN $_{\text{without}}$)					118.21

With channel maintenance only

Flood Return Period (years)	Probability	Nr. HEs Affected	Probability Interval (a)	Average Nr. HEs Affected (b)	(a) x (b)
1	1	10.14			
4.5% flooded			0.98	117.76	115.40
50	0.02	225.37			
100 % flooded			0.01	225.37	2.25
100	0.01	225.37			
100 % flooded					
Annual Average Number HEs affected without maintenance (AAN $_{\text{with}}$)					117.65

Summary: flood cost with channel maintenance only

	AAN $_{\text{without}}$ (a)	(b) x £1304*
Left Bank	117.65	153416
Right Bank	21.37	27866
Total	139.02	181282

Note: * value of one HE is 31304, 1997/98 prices

Severity weightings have been applied to HEs affected by flooding: arable 2.2, pasture 1.5

SCENARIO 2 CHANNEL MAINTENANCE ONLY

Watercourse	**Winestead Drain**
Bank	**Right Bank**
Flood risk area (ha)	269
Effective reach length (km)	7.3

Do-Nothing

Flood Return Period (years)	Probability	Nr. HEs Affected	Probability Interval (a)	Average Nr. HEs Affected (b)	(a) x (b)
1	1	2.05			
5% flooded			0.98	21.49	21.06
50	0.02	40.93			
100 % flooded			0.01	40.93	0.41
100	0.01	40.93			
100 % flooded					
Annual Average Number HEs affected with maintenance (AAN $_{\text{without}}$)					21.47

With channel maintenance only

Flood Return Period (years)	Probability	Nr. HEs Affected	Probability Interval (a)	Average Nr. HEs Affected (b)	(a) x (b)
1	1	1.84			
4.5% flooded			0.98	21.39	20.96
50	0.02	40.93			
100 % flooded			0.01	40.93	0.41
100	0.01	40.93			
100 % flooded					
Annual Average Number HEs affected without maintenance (AAN $_{\text{with}}$)					21.37

Severity weightings have been applied to HEs affected by flooding: arable 2.2
pasture 1.5

SCENARIO 2 **CHANNEL MAINTENANCE ONLY**

Watercourse	**Winestead Drain - IDB channel**
Bank	**Left Bank**
Flood risk area (ha)	312
Effective reach length (km)	6.1

Do-Nothing

Flood Return Period (years)	Probability	Nr. HEs Affected	Probability Interval (a)	Average Nr. HEs Affected (b)	(a) x (b)
1	1	2.88			
5% flooded			0.98	30.29	29.68
50	0.02	57.69			
100 % flooded			0.01	57.69	0.58
100	0.01	57.69			
100 % flooded					

Annual Average Number HEs affected with maintenance ($\text{AAN}_{\text{without}}$) 30.26

With channel maintenance only

Flood Return Period (years)	Probability	Nr. HEs Affected	Probability Interval (a)	Average Nr. HEs Affected (b)	(a) x (b)
1	1	2.60			
4.5% flooded			0.98	30.14	29.54
50	0.02	57.69			
100 % flooded			0.01	57.69	0.58
100	0.01	57.69			
100 % flooded					

Annual Average Number HEs affected without maintenance (AAN_{with}) 30.12

SCENARIO 2 **CHANNEL MAINTENANCE ONLY**

Watercourse	**Winestead Drain - IDB channel**
Bank	**Right Bank**
Flood risk area (ha)	175
Effective reach length (km)	6.1

Do-Nothing

Flood Return Period (years)	Probability	Nr. HEs Affected	Probability Interval (a)	Average Nr. HEs Affected (b)	(a) x (b)
1	1	1.35			
5% flooded			0.98	14.12	13.84
50	0.02	26.90			
100 % flooded			0.01	26.90	0.27
100	0.01	26.90			
100 % flooded					

Annual Average Number HEs affected with maintenance ($\text{AAN}_{\text{without}}$) 14.11

With channel maintenance only

Flood Return Period (years)	Probability	Nr. HEs Affected	Probability Interval (a)	Average Nr. HEs Affected (b)	(a) x (b)
1	1	1.21			
4.5% flooded			0.98	14.06	13.77
50	0.02	26.90			
100 % flooded			0.01	26.90	0.27
100	0.01	26.90			
100 % flooded					

Annual Average Number HEs affected without maintenance (AAN_{with}) 14.04

Summary: flood cost with channel maintenance only

	$\text{AAN}_{\text{without}}$ (a)	(b) x £1304*
Left Bank	30.12	39276
Right Bank	14.04	18308
Total	44.16	57585

Note: * value of one HE is 31304, 1997/98 prices

Severity weightings have been applied to HEs affected by flooding: arable 2.2, pasture 1.5

SUMMARY: FDMM

DO NOTHING

Stop all pumping and all channel maintenance

		£
Costs	Main river channel	0
	IDB channel	0
	Booster Pumping Station	0
	Outstrays Pumping Station	0
	Total costs	0

Main river			
	Drainage	Bad over 100 %	
		Int pasture 2.3 ha x £245/ha	564
		Ext. arable 723.7 ha x £228/ha	165004
		Total	165567
	Flooding	Frequent flooding, large area affected	182143
IDB			
	Drainage	Bad over 100 %	
		Ext. arable 486.2 ha x £228/ha	110854
		Total	110854
	Flooding	Frequent flooding, large area affected	57858

Urban (Flooding)	£	% flooding benefits apportioned to urban area
Main river	80026	44%
IDB	8320	14%

(current maintenance cf to do-nothing)

SCENARIO 3

PUMPING ONLY

Pumping only, no channel maintenance

		£
Costs	Main river channel	0
	IDB channel	0
	Booster Pumping Station	16261
	Outstrays Pumping Station	20603
	Total costs	36864

				Agricultural + Urban	Agricultural Only
Main river					
	Drainage	Good over 75%			
		Int pasture 2.3 ha x £320/ha	736		
		Ext. arable 542.77 ha x £293/ha	159033		
		Bad over 25%			
		Ext. arable, 180.93 ha * £228/ha	41251		
		Total	201020	35453	35453
	Flooding	See following page	73898	108245	47558
			Total	143698	83011
IDB					
	Drainage	Good over 75%			
		Ext. arable 364.65 ha x £293/ha	106842		
		Bad over 25%			
		Ext. arable, 121.55 ha * £228/ha	27713		
		Total	134556	23702	23702
	Flooding	See following page	23472	34386	4945
			Total	58088	28647

	Agricultural + Urban	Agricultural Only
BENEFIT OF CHANNEL MAINTENANCE ONLY	201786	111658
COST OF MAINTENANCE	36864	36864
BENEFIT COST RATIO	5.47	3.03

SCENARIO 3 PUMPING ONLY

Watercourse	**Winestead Drain**
Bank	**Left Bank**
Flood risk area (ha)	460
Effective reach length (km)	7.3

Do-Nothing

Flood Return Period (years)	Probability	Nr. HEs Affected	Probability Interval (a)	Average Nr. HEs Affected (b)	(a) x (b)
1	1	11.27			
5% flooded			0.98	118.32	115.95
50	0.02	225.37			
100 % flooded			0.01	225.37	2.25
100	0.01	225.37			
100 % flooded					
Annual Average Number HEs affected with maintenance (AAN $_{without}$)					118.21

With pumping only, no channel maintenance

Flood Return Period (years)	Probability	Nr. HEs Affected	Probability Interval (a)	Average Nr. HEs Affected (b)	(a) x (b)
1	1	4.51			
2% flooded			0.98	47.33	46.38
50	0.02	90.15			
40 % flooded			0.01	157.76	1.58
100	0.01	225.37			
100 % flooded					
Annual Average Number HEs affected without maintenance (AAN $_{with}$)					47.96

Summary: flood cost with pumping only

	AAN $_{without}$ (a)	(b) x £1304*
Left Bank	47.96	62540
Right Bank	8.71	11358
Total	56.67	73898

Note: * value of one HE is 31304, 1997/98 prices

Severity weightings have been applied to HEs affected by flooding: arable 2.2, pasture 1.5

SCENARIO 3 PUMPING ONLY

Watercourse	**Winestead Drain**
Bank	**Right Bank**
Flood risk area (ha)	269
Effective reach length (km)	7.3

Do-Nothing

Flood Return Period (years)	Probability	Nr. HEs Affected	Probability Interval (a)	Average Nr. HEs Affected (b)	(a) x (b)
1	1	2.05			
5% flooded			0.98	21.49	21.06
50	0.02	40.93			
100 % flooded			0.01	40.93	0.41
100	0.01	40.93			
100 % flooded					
Annual Average Number HEs affected with maintenance (AAN $_{without}$)					21.47

With pumping only, no channel maintenance

Flood Return Period (years)	Probability	Nr. HEs Affected	Probability Interval (a)	Average Nr. HEs Affected (b)	(a) x (b)
1	1	0.82			
2% flooded			0.98	8.60	8.42
50	0.02	16.37			
40 % flooded			0.01	28.65	0.29
100	0.01	40.93			
100 % flooded					
Annual Average Number HEs affected without maintenance (AAN $_{with}$)					8.71

SCENARIO 3 **PUMPING ONLY**

Watercourse	**Winestead Drain - IDB channel**
Bank	**Left Bank**
Flood risk area (ha)	312
Effective reach length (km)	6.1

Do-Nothing

Flood Return Period (years)	Probability	Nr. HEs Affected	Probability Interval (a)	Average Nr. HEs Affected (b)	(a) x (b)
1	1	2.88			
5% flooded			0.98	30.29	29.68
50	0.02	57.69			
100 % flooded			0.01	57.69	0.58
100	0.01	57.69			
100 % flooded					
Annual Average Number HEs affected with maintenance ($\text{AAN}_{\text{without}}$)					30.26

With pumping only, no channel maintenance

Flood Return Period (years)	Probability	Nr. HEs Affected	Probability Interval (a)	Average Nr. HEs Affected (b)	(a) x (b)
1	1	1.15			
2% flooded			0.98	12.11	11.87
50	0.02	23.08			
40 % flooded			0.01	40.38	0.40
100	0.01	57.69			
100 % flooded					
Annual Average Number HEs affected without maintenance (AAN_{with})					12.28

Summary: flood cost with pumping only

	$\text{AAN}_{\text{without}}$ (a)	(b) x £1304*
Left Bank	12.28	16013
Right Bank	5.72	7459
Total	18.00	23472

Note: * value of one HE is 31304, 1997/98 prices

Severity weightings have been applied to HEs affected by flooding: arable 2.2, pasture 1.5

SCENARIO 3 **PUMPING ONLY**

Watercourse	**Winestead Drain - IDB channel**
Bank	**Right Bank**
Flood risk area (ha)	175
Effective reach length (km)	6.1

Do-Nothing

Flood Return Period (years)	Probability	Nr. HEs Affected	Probability Interval (a)	Average Nr. HEs Affected (b)	(a) x (b)
1	1	1.35			
5% flooded			0.98	14.12	13.84
50	0.02	26.90			
100 % flooded			0.01	26.90	0.27
100	0.01	26.90			
100 % flooded					
Annual Average Number HEs affected with maintenance ($\text{AAN}_{\text{without}}$)					14.11

With pumping only, no channel maintenance

Flood Return Period (years)	Probability	Nr. HEs Affected	Probability Interval (a)	Average Nr. HEs Affected (b)	(a) x (b)
1	1	0.54			
2% flooded			0.98	5.65	5.54
50	0.02	10.76			
40 % flooded			0.01	18.83	0.19
100	0.01	26.90			
100 % flooded					
Annual Average Number HEs affected without maintenance (AAN_{with})					5.72

WINESTEAD DRAIN

WITHOUT MAINTENANCE SCENARIOS: GUIDELINES

SUMMARY: GUIDELINES

WITH MAINTENANCE (CURRENT SITUATION)

			£
Costs	Main river channel		6075
	IDB channel		0
	Booster Pumping Station		16261
	Outstrays Pumping Station		20603
	Total costs		42939
Main river	Drainage	Maintenance gives 100% good drainage	
		Cereal/oil seed £329/ha * 729 ha	239841
	Flooding	Some flooding with maintenance	2843
		See following page	

Urban FDMM
(Flooding) £ flooding benefits apportioned to urban area
Main river 80026
IDB 8320
(current maintenance cf to do-nothing)
These are added to agricultural flooding benefits to determine agricultural + urban benefits.

DO NOTHING

Stop all pumping and all channel maintenance

			£	Agricultural Only	Agricultural + Urban
Costs	Main river channel		0		
	IDB channel		0		
	Booster Pumping Station		0		
	Outstrays Pumping Station		0		
	Total costs		0		
Main river	Drainage	Good to bad over 100 %			
		Cereal / oil seed £263 /ha * 729 ha	191727	48114	48114
	Flooding	More frequent flooding, larger area affected	4082	1239	81265
		See following page			
			Total	49353	129379

	Agricultural Only	Agricultural + Urban
BENEFIT OF CURRENT MAINTENANCE	49353	129379
COST OF MAINTENANCE	42939	42939
BENEFIT COST RATIO	1.15	3.01

SUMMARY: GUIDELINES

WITH MAINTENANCE (CURRENT SITUATION)

			£
Costs	Main river channel		6075
	IDB channel		3433
	Booster Pumping Station		16261
	Outstrays Pumping Station		20603
	Total costs		46372
Main river	Drainage	Maintenance gives 100% good drainage Cereal/oil seed £329/ha * 729 ha	239841
	Flooding	Some flooding with maintenance See following page	2843
IDB	Drainage	Maintenance gives 100% good drainage Cereal/oil seed 486.2 ha * £329/ha	159960
	Flooding	Some flooding with maintenance See following page	1896

Urban **FDMM**
(Flooding) £ flooding benefits apportioned to urban area
Main river 80026
IDB 8320
(current maintenance cf to do-nothing)
These are added to agricultural flooding benefits to determine agricultural + urban benefits.

SCENARIO 1

DO NOTHING

Stop all pumping and all channel maintenance

			£	Agricultural Only	Agricultural + Urban
Costs	Main river channel		0		
	IDB channel		0		
	Booster Pumping Station		0		
	Outstrays Pumping Station		0		
	Total costs		0		
Main river	Drainage	Good to bad over 100 % Cereal / oil seed £263 /ha * 729 ha	191727	48114	48114
	Flooding	More frequent flooding, larger area affected See following page	4082	1239	81265
			Total	49353	129379
IDB	Drainage	Good to bad over 100 % Cereal/oil seed 486.2 ha * £263/ha	127871	32089	32089
	Flooding	More frequent flooding, larger area affected See following page	2723	827	9147
			Total	32916	41236

	Agricultural Only	Agricultural + Urban
BENEFIT OF CURRENT MAINTENANCE	82269	170615
COST OF MAINTENANCE	46372	46372
BENEFIT COST RATIO	1.77	3.68

SUMMARY: GUIDELINES

WITH MAINTENANCE (CURRENT SITUATION)

			£
Costs	Main river channel		6075
	IDB channel		0
	Booster Pumping Station		0
	Outstrays Pumping Station		20603
	Total costs		26678
Main river			
	Drainage	Maintenance gives 100% good drainage	
		Cereal/oil seed £329/ha * 729 ha	239841
	Flooding	Some flooding with maintenance	2843

SCENARIO 1A

DO NOTHING

Stop all pumping and all channel maintenance

			£	Agricultural Only	Agricultural + Urban
Costs	Main river channel		0		
	IDB channel		0		
	Booster Pumping Station		0		
	Outstrays Pumping Station		0		
	Total costs		0		
Main river					
	Drainage	Good to bad over 100 %			
		Cereal / oil seed £263 /ha * 729 ha	191727	48114	48114
	Flooding	More frequent flooding, larger area affected	4082	1239	81265
			Total	49353	129379

Urban	**FDMM**
(Flooding)	£ flooding benefits apportioned to urban area
Main river	80026
IDB	8320

(current maintenance cf to do-nothing)
These are added to agricultural flooding benefits to determine agricultural + urban benefits.

	Agricultural Only	Agricultural + Urban
BENEFIT OF CURRENT MAINTENANCE	49353	129379
COST OF MAINTENANCE	26678	26678
BENEFIT COST RATIO	1.85	4.85

SUMMARY: GUIDELINES

WITH MAINTENANCE (CURRENT SITUATION)

		£
Costs	Main river channel	0
	IDB channel	3433
	Booster Pumping Station	16261
	Outstrays Pumping Station	0
	Total costs	19694

IDB			
	Drainage	maintenance gives 100% good drainage	
		Cereal/oil seed 486.2 ha * £329/ha	159960
	Flooding	Some flooding with maintenance	1896

Urban **FDMM**
(Flooding) £ flooding benefits apportioned to urban area
Main river
IDB 8320
(current maintenance cf to do-nothing)
These are added to agricultural flooding benefits to determine agricultural + urban benefits.

SCENARIO 1B

DO NOTHING

Stop all pumping and all channel maintenance

		£
Costs	Main river channel	0
	IDB channel	0
	Booster Pumping Station	0
	Outstrays Pumping Station	0
	Total costs	0

				Agricultural Only	Agricultural + Urban
IDB					
	Drainage	Good to bad over 100 %			
		Cereal/oil seed 486.2 ha * £263/ha	127871	32089	32089
	Flooding	More frequent flooding, larger area affected	2723	827	9147
			Total	32916	41236

	Agricultural Only	Agricultural + Urban
BENEFIT OF CURRENT MAINTENANCE	32916	41236
COST OF MAINTENANCE	19694	19694
BENEFIT COST RATIO	1.67	2.09

GUIDELINES: GENERAL INFORMATION

River — 1a: **WINESTEAD DRAIN - IDB**

Reach Code — 1b: **01**

Reach Length (km) — 2: **6.1**

Dominant Substrate Type:-
Gravel, Sand or Silt
(Treat clay as silt) — 3: **CLAY**

Floodplain -
Rising (>1 %) or Flat (< 1 %) — 4: **FLAT/PUMPED**

Catchment Size
Large (> 25 sq. km)
Small (< 25 sq. km) — 5: **LARGE**

Benefit Area (ha)
(Area deriving benefit from maintenance) — 6: **487**

Dominant Land Use Type (LUT)
(Table 1) — 7: **CEREAL/OILS (5)**

Dominant Soil Type — 9: **LOAMY CLAY**

Varied Land Use Types (LUT)
(Table 1)

LUT	% Benefit Area as decimal (7)	Does the LUT flood ? (8a)	If yes, % that floods (as decimal) (8b)
1 Ext grass			
2 Int grass			
3 Grass/arable			
4 All cereals			
5 Cereal/oil-seed			
6 Cereal/root			
7 Horticulture			
8 Other			

Note: All table numbers and references relate to R&D Note 511, Guidelines for the Justification of River Maintenance (Dunderdale and Morris, 1996b)

GUIDELINES: DESIGN STANDARD

Average Bed Width (m) — 10: N/A

Average Channel Depth (m) — 11: N/A

% Weed Cover (In channel, submerged & floating weed) — 12: 0 (Emergent vegetation only)

Freeboard (m) — 13: N/A

Watertable Depth (m) *(Box 4, 9, 13 & Figure 1 or 2)* — 14: N/A

Drainage Status *(Box 14 & Table 4)* — 15: GOOD

Economic Net Return *(Table 5, using Box 7 & Box 15)*

For either :- Dominant land use — 16: (£/ha) 329; (£) 159960

or :- Varied land use — (£/ha); (£)

LUT	16a Net Return (£/ha)	16b Weighted Net Return
1		
2		
3		
4		
5		
6		
7		

Bankfull Discharge (Qbf) (cumecs) — 17

* Regional Growth Curve Area *(Figure 3)* — 18

* Mean Annual Flood (Q bar) (cumecs) — 19

* Qbf/Q bar (cumecs) *(Box 17 / Box 19)* — 20

* Flooding Envelopes

* % BA with different flood return periods (years) *(Table 6 or 7, boxes 5, 7, 15)*

FRP (yr)	21 % area of each LUT that floods	21a Flooded Area (ha)	22 Flood Cost (£/ha)	22a Total Flood Cost (£) *(Box 21a * box 22)*
0				
1 - 2	0	0	0	0
3 - 5				
6 - 10				
> 10 (50 yr)	30	146	3	438
(100 yr)	100	486	3	1459
			Total	1896

* *Not necessary unless detailed information and assessment is required*

Flood Return Period (years) — 23: AS ABOVE

Total Flood Cost (£) — 24: 1896

Design Net Return Less Flood Cost (£) *(Box 16 - box 24)* — 24a: 158064

Note: All table numbers and references relate to R&D Note 511, Guidelines for the Justification of River Maintenance (Dunderdale and Morris, 1996b)

GUIDELINES: "DO NOTHING" (WITHOUT MAINTENANCE)

W/o Maintenance Width (m) — 30:
(Box 10 - box 25a)

W/o Maintenance Depth (m) — 31:
(Box 11 - box 26a)

W/o Maintenance Freeboard (m) — 32:
(Box 13 - box 28a)

W/o Maintenance Watertable Depth (m) — 33:
(Box 4, 9, 32, Table 3, Figure 1 or 2)

W/o Maintenance Drainage Status — 34: BAD
(Table 4, box 33)

Economic Net Return (W/o maintenance)
(Table 5, box 8, 34)

			35
For either :-	Dominant land use	(£/ha)	263
		£	127871
or :-	Varied land use	(£/ha)	
		£	

35b LUT	35a Net Return (£/ha)	Weighted Net Return
1		
2		
3		
4		
5		
6		
7		

W/o Maintenance Bankfull Discharge (Qbf) (cumecs) — 36:
(Box 17 - box 29)

* W/o Maintenance Qbf/Q bar (cumecs) — 37:
(Box 36 / box 19)

* Flooding Envelopes
* % BA with different
flood return periods (years)
(Table 6 or 7, boxes 5, 7, 34)

FRP (yr.)	38 % area of each LUT that floods	38a Flooded Area (ha)	39 Flood Cost (£/ha)	39a Total Flood Cost (£) *(Box 38a * box 39)*
0				
<1				
1 - 2	5	24.31	32	778
3 - 5				
6 - 10				
> 10 (50 yr)	100	486	2	972
> 10 (100 yr)	100	486	2	972
			Total	2723

* *Not necessary unless detailed information and assessment required*

W/o Maintenance FRP (years) — 40: AS ABOVE

Total Flood Cost (£) — 41: 2723

Do-nothing
Net Return Less Flood Cost (£) — 41a: 125148
(Box 35 - box 41)

Note: All table numbers and references relate to R&D Note 511, Guidelines for the Justification of River Maintenance (Dunderdale and Morris, 1996b)

SUMMARY: GUIDELINES

DO NOTHING

Stop all pumping and all channel maintenance

		£
Costs	Main river channel	0
	IDB channel	0
	Booster Pumping Station	0
	Outstrays Pumping Station	0
	Total costs	0

Main river			
	Drainage	Bad over 100 %	191727
	Flooding	Frequent flooding, large area affected	4082
IDB			
	Drainage	Bad over 100 %	127871
	Flooding	Frequent flooding, large area affected	2723

Urban **FDMM**
(Flooding) £ flooding benefits apportioned to urban area
Main river 483
IDB 234
(current maintenance cf to do-nothing)
These are added to agricultural flooding benefits to determine agricultural + urban benefits.

SCENARIO 2

CHANNEL MAINTENANCE ONLY

Channel maintenance only

		£
Costs	Main river channel	6075
	IDB channel	3433
	Booster Pumping Station	0
	Outstrays Pumping Statio	0
	Total costs	9508

				Agricultural Only	Agricultural + Urban
Main river					
	Drainage	Bad over 100 %	191727	0	0
	Flooding	See following page	3966	116	599
IDB					
	Drainage	Bad over 100 % 486.2 ha * £329/ha	127871	0	0
	Flooding	See following page	2645	78	312

	Agricultural Only	Agricultural + Urban
BENEFIT OF CHANNEL MAINTENANCE ONLY	194	911
COST OF MAINTENANCE	9508	9508
BENEFIT COST RATIO	0.02	0.10

GUIDELINES: SCENARIO 2 CHANNEL MAINTENANCE ONLY

FLOODING

Flood Return Period (yrs)	% Area of each LUT that Floods	Flooded Area (ha)	Flood Cost (£/ha)	Total Flood Cost (£)
Main River				
0				
1 - 2	4.5	32.8	32	1050
3 - 5				
6 - 10				
> 10 (50 yrs)	100	729	2	1458
> 10 (100 yrs)	100	729	2	1458
			Total	**3966**
IDB Watercourse				
0				
1 - 2	4.5	22	32	700
3 - 5				
6 - 10				
> 10 (50 yrs)	100	486	2	973
> 10 (100 yrs)	100	486	2	973
			Total	**2645**

Note: Figures are subject to rounding. 1997/98 prices are used.

SUMMARY: GUIDELINES

DO NOTHING

Stop all pumping and all channel maintenance

		£
Costs	Main river channel	0
	IDB channel	0
	Booster Pumping Station	0
	Outstrays Pumping Station	0
	Total costs	0

Main river			
	Drainage	Bad over 100 %	191727
	Flooding	Frequent flooding, large area affected	4082
IDB			
	Drainage	Bad over 100 %	127871
	Flooding	See following page	2723

Urban **FDMM**
(Flooding) £ flooding benefits apportioned to urban area
Main river 47628
IDB 4814
(current maintenance cf to do-nothing)
These are added to agricultural flooding benefits to determine agricultural + urban benefits.

SCENARIO 3

PUMPING ONLY

Pumping only, no channel maintenance

		£
Costs	Main river channel	0
	IDB channel	0
	Booster Pumping Station	16261
	Outstrays Pumping Station	20603
	Total costs	36864

				Agricultural Only	Agricultural + Urban
Main river					
	Drainage	Good over 100%	239841	48114	48114
	Flooding	See following page	3587	495	48123
			Total	48609	96237
IDB					
	Drainage	Good over 100%	159960	32089	32089
	Flooding	See following page	2392	331	5145
			Total	32420	37234

	Agricultural Only	Agricultural + Urban
BENEFIT OF PUMPING ONLY	81029	133471
COST OF MAINTENANCE	36864	36864
BENEFIT COST RATIO	2.20	3.62

GUIDELINES: SCENARIO 3 **PUMPING ONLY**

FLOODING

Flood Return Period (yrs)	% Area of each LUT that Floods	Flooded Area (ha)	Flood Cost (£/ha)	Total Flood Cost (£)
Main River				
0				
1 - 2	2	15	36	525
3 - 5				
6 - 10				
> 10 (50 yrs)	40	292	3	875
> 10 (100 yrs)	100	729	3	2187
			Total	**3587**
IDB Watercourse				
0				
1 - 2	2	10	36	350
3 - 5				
6 - 10				
> 10 (50 yrs)	40	194	3	583
> 10 (100 yrs)	100	486	3	1459
			Total	**2392**

Note: Figures are subject to rounding. 1997/98 prices are used.

APPENDIX VI

1. CONWY VALLEY

1.1 Introduction

This Appendix presents the results of the application of FDMM and the Guidelines to the Ffos Fawr, a watercourses in the Conwy Valley, North Wales.

1.2 Conwy Valley

1.2.1 Channel characteristics and drainage network

The Afon Conwy rises from Llyn Conwy in the Migneint Moor, Snowdonia. The catchment area is estimated to be 590 km^2 (59000 ha).

The river is a highland carrier which conveys water from the upland catchment through the flat valley floor to the outfall into Liverpool Bay at Conwy. The Afon Conwy does not provide a land drainage function for the lowland part of the catchment through which it flows.. This lowland area (790 ha) is protected from flooding by the Afon Conwy by flood banks. It is served by an intensive network of channels and is designated as an Internal Drainage District (IDD). This IDD is run and managed by the Environment Agency, who also set the drainage rates and maintain the channels. In affect, these IDD watercourses are 'main' rivers in all but name. Many of the IDD watercourses discharge into the Afon Conwy through the floodbanks via flapped outfalls.

1.2.2 Catchment characteristics

This predominantly upland catchment is rural in character. Land use consists of permanent pasture.. The flat valley floor is grazed by beef and sheep during the winter months. During the summer, the valley floor is cut for hay and silage whilst the livestock graze the upland areas of the catchment.

The solid geology of the area is characterised by hard resistant rocks of Ordovician age on the left bank of the Afon Conwy. These create an alpine landscape of waterfalls, lakes and slate quarries. On the right bank, softer rocks of Silurian age provide a rounder landscape.

The Conway Soil Association is characteristic of the valley floor (Rudeforth et al, 1984). The Association is dominated by the Conway series of fine stoneless silty, typically alluvial gley soils. Excess winter rain is absorbed fairly slowly on level ground, but it reaches the river quickly due to its proximity. Winter floods are common and the soil may be seasonally waterlogged with a risk of poaching (surface damage by livestock). Soils of the Teme series (Teme Association) occur on river alluvium in the wider areas of the floodplain. These are permeable and well drained although they are subject to winter flooding.

1.2.3 River maintenance

The channel of the Afon Conwy is not subject to maintenance. A combination of saline water and seepage from abandoned lead mines provide an environment inconducive to weed growth. The floodbanks, however, are grazed and are flail mown annually. Repairs are carried out as required.

The IDD channels are subject to annual weed removal using a Bradshaw Bucket, during the period late September to January. All the aquatic vegetation is removed. Prior to maintenance, the channels are usually choked by emergent weeds with 100% of the water surface covered by vegetation. *Phragmites* (Common Reed) and *Sparganium* (Branched Bur-Reed) are the dominant types.

1.2.4 Study area

As stated in Section 1.2.1, the IDD watercourses are in affect 'main' rivers in all but name. For this reason, and because no maintenance is performed on the Afon Conwy channel, two discrete areas of the Conwy floodplain were selected for study following discussions with the Environment Agency. These areas are termed Area 1 and 2 respectively.

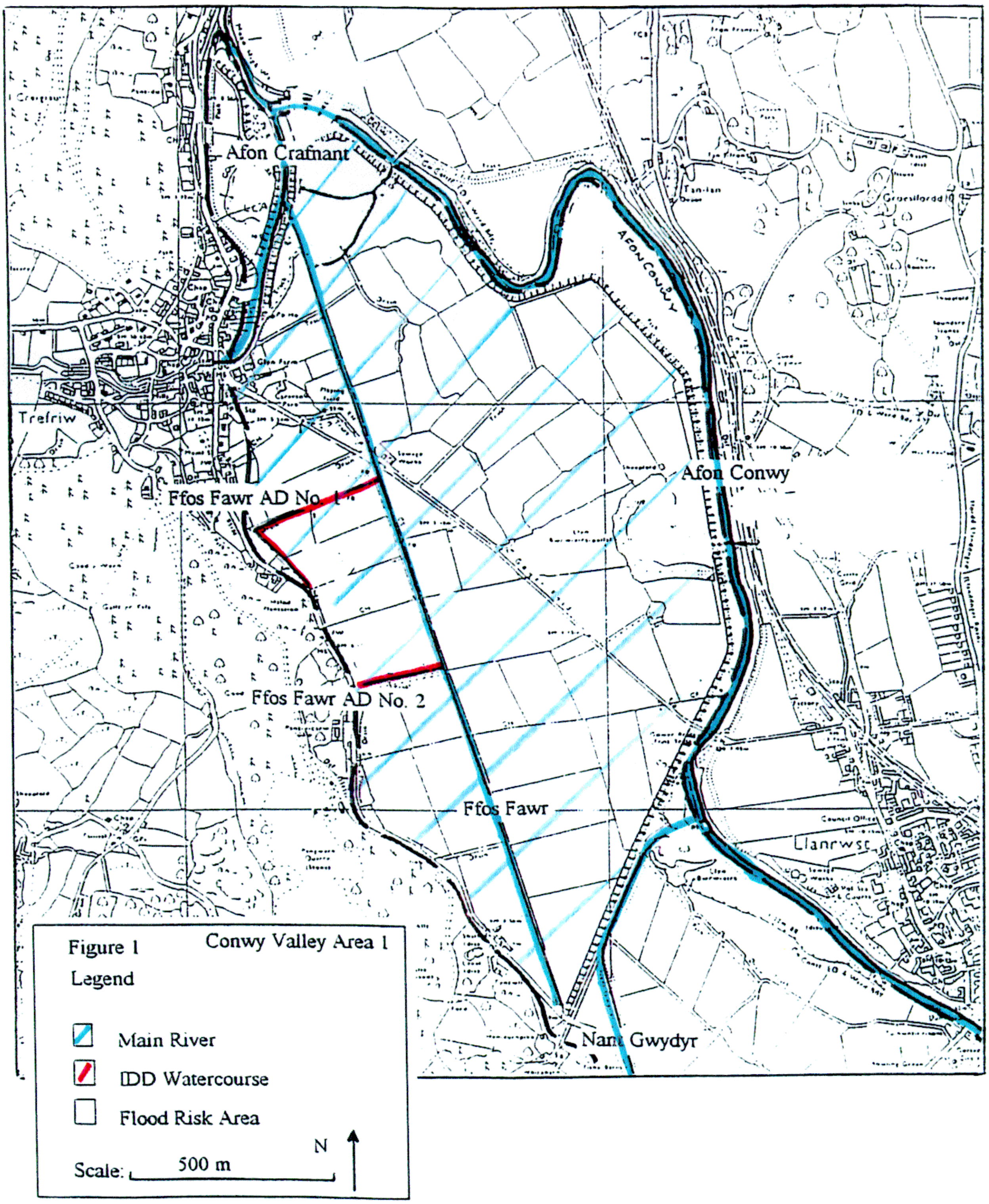


Figure 1 Conwy Valley Area 1

1.3 Application of FDMM to Area 1: Ffos Fawr

1.3.1 General information

Area 1 covers 154 ha on the left bank of the Afon Conwy, to the east of Trefriw. This area is bounded on three sides by the floodbanks of the Afon Conwy, Nant Gwydyr and Afon Crafnant. The western boundary follows the natural limit of the floodplain which is determined by geology and topography.

The Ffos Fawr (main river) drains this area and is fed by two IDD watercourses; the Ffos Fawr AD Number 1 and 2. The Ffos Fawr discharges into the Afon Crafnant through the floodbank and into the Afon Conwy (Figure 1). The whole area is naturally drained by an intensive network of ditches.

The Ffos Fawr and Ffos Fawr AD Number 1 and 2 are all subject to annual weedcutting during the period late September to January. In 1997/98, annual maintenance expenditure on the Ffos Fawr main river is calculated to be £1428. Annual expenditure on AD Number 1 and 2 is calculated to be £294 and £380 respectively (1997/98 prices).

1.3.2 Area of benefit

The area benefiting from maintenance in terms of flood alleviation is estimated to be 154 ha. This is termed the flood risk area and was derived from discussions with the Environment Agency. It is based on the discrete area protected by the floodbanks of the Afon Conwy, Afon Crafnant and Nant Gwydyr (Figure 1).

1.3.3 Land use assessment

Flooding

Land use and features of interest within the flood risk area are shown in the land use assessment reach summary sheet for the left and right bank of the Ffos Fawr. The completed summary sheets may be found at the end of this Appendix.

The area affected by fluvial flooding on the left and right bank is estimated to be 37.93 ha and 116.07 ha respectively. The area is not affected by saline flooding. The effective reach (the length of the main river for which a flood risk area is defined) is estimated to be 2.0 km for the left and right bank.

The flood score is derived by dividing the total HEs/km affected by flooding by the effective reach length (see the summary sheet). The flood scores for the left and right bank are 18.08 and 5.17 respectively.

Drainage

The area of each land use type subject to bad or very bad drainage conditions is determined and weighted by the appropriate factor (e.g.. 3.6 HE/100 ha/yr for extensive arable). This drainage score represents the level of damage caused by waterlogging.

Under the current maintenance regime, the drainage status for the whole catchment is described as good, therefore the drainage score is zero.

1.3.4 Land use band

The flood and drainage HE/km scores are combined to determine the total HE/km for each bank (Table 1). The HE/km falls within the land use band 'C' range for each bank (5.00-24.99 HE/km). High grade agricultural land is at risk of flooding and impeded drainage, with some properties also at risk of flooding.

Table 1 Land use band, Ffos Fawr

	Flood Value (HE/km)	Drainage Value (HE/km)	Total	Land Use Band
Left Bank	18.08	0.0 *	18.08	C
Right Bank	5.17	0.0 *	5.17	C

Note: * the drainage status is described as good under the current maintenance situation
Figures are subject to rounding.

1.3.5 Determining the effect of flooding

No historical records exist for the Ffos Fawr or its tributaries. The effect of flooding is therefore, based purely on use of the predictive technique.

The arithmetic method has been used. The predictive technique takes account of the flood return period at which different areas are inundated and an estimated long-term average annual value for HE affected is derived. The record sheets at the end of this Appendix provide further details.

The area flooded by events with a return period of 1,5,10,15,20,25 and 30 years were identified by the Environment Agency for the left and right bank under the current maintained situation. It must be noted that these areas are estimated as the actual areas flooded by the infrequent events are not documented. It is estimated that with a return period of 5 years, no flooding would occur. Under an event with a return period of 10 years, for example, it is estimated that 20% of the flood risk area would be inundated.

A severity weighting of 1.5 has been applied to the total HEs/km affected by flooding to take account of the impact of timing and duration of flooding on pasture. The number of HEs affected by flooding was derived on a pro-rata basis by multiplying the total number of HEs affected by, for example, 20%, for a return period of 10 years.

The process was repeated using estimates of flooded areas under the various return periods for the without maintenance situation.

The annual benefit of maintenance is shown by the benefit to be gained from the avoidance of flooding. This is derived by subtracting the Annual Average Number HEs affected with maintenance (AAN_{with}) from the Annual Average Number of HEs affected without maintenance ($AAN_{without}$) and multiplying this figure by the value of one HE (£1304 in 1997 prices). The annual benefit (£) is shown in Table 2.

Table 2 Annual benefit, flooding, Ffos Fawr

	$AAN_{without}$ (HE/km) (a)	AAN_{with} (HE/km) (b)	(a) - (b)	Annual Benefit (£)
Left Bank	8.301	1.571	6.370	8775
Right Bank	2.524	0.478	2.046	2668

Note: Figures are subject to rounding. 1997/98 prices are used.

1.3.6 Determining the effect of deterioration in drainage

The area within the flood risk area which is expected to be subject to a deterioration in drainage status in the absence of maintenance was estimated by the Environment Agency. The drainage status of the whole flood risk area is expected to deteriorate from a good to a very bad drainage condition.

The annual benefit of preventing a deterioration in drainage status is calculated from the area affected (ha) multiplied by the annual benefit (£/ha) to be gained from preventing a deterioration in drainage status. This procedure is shown in Table 3 for both banks. The annual benefit of maintaining good drainage on the left bank is £30 /ha or £1138 (1997/98 economic prices).

Table 3 Drainage benefits, Ffos Fawr

Bank	Left Bank	Right Bank
Drainage benefit area (ha)	37.93	116.07
Effective reach length (km)	2.09	2.09
Floodplain topography	Flat	Flat
Predominant soil type	Heavy	Heavy
Drainage system	Natural	Natural
With maintenance drainage status	Good	Good
Without maintenance drainage status	Very bad	Very bad
Annual benefit (£/ha)	30	30
Total benefit (£)	1138	3482

Note: 1997/98 economic prices are used. Figures are subject to rounding.

1.3.7 Actual standard of service

The combined flood score and drainage score (HE/km/yr) for the current, with maintenance situation provides an indication of the adequacy of the existing maintenance regime with respect to set Standards of Service

(SoS). This score for the Ffos Fawr and tributaries for the left and right bank is shown in Table 4. Scores are derived by dividing the annual average HE/km by the effective reach length.

Table 4 ***Actual standard of service provided under the current maintenance regime, Ffos Fawr***

	Flooding (AAN $_{with}$) (HE/km) (a)	Effective Reach Length (km) (b)	Flood Score (HE/km/yr) (a/b) = (c)	Drainage Score (HE/km/yr) (d)	Total (c)+(d)
Left Bank	1.57	2.09	0.75	0.0 *	0.75
Right Bank	0.48	2.09	0.23	0.0 *	0.23
Both Banks				Average Score	0.49

Note: * the drainage status is described as good under the current maintenance situation, therefore the drainage score is zero. Figures are subject to rounding, 1997/98 prices are used.

Comparison of the total score with a target score of 0.5-1.0 HE/km/yr enables the current level of service provided to be determined. This on target standard (OTS) of 0.5-1 HE/km/yr was derived by the Environment Agency, based on analysis of existing SoS (Table 2.3 in main text). The reach status of both banks may be described as marginally above target standard.

1.3.8 Justification

Justification of the maintenance scheme is undertaken using a comparison of the benefits and costs of maintenance in a simple benefit:cost ratio.

The total annual maintenance expenditure of the Environment Agency on the Ffos Fawr main river (1997/98 prices) (see Section 1.3.1) is estimated to be £1428. The total benefits of maintenance taking into account flooding and drainage benefits on both banks are presented in Table 5.

Table 6 shows that the benefit:cost ratio is greater than one, thus the current maintenance regime may be justified.

Table 5 **Total benefits of maintenance, Ffos Fawr**

	Annual Benefit of Flood Alleviation (£)	Annual Benefit of Maintaining Drainage Status (£)	Total Annual Benefit (£)
Left bank	8775	1138	9913
Right bank	2668	3482	6150
Total	11443	4620	16063

Note: Figures are subject to rounding. 1997/98 prices are used.

Table 6 **Benefit:cost ratio, Ffos Fawr**

Total Annual Benefit (£)	Total Annual Maintenance Cost (£)	Benefit:Cost Ratio
16063	1428	11.2

Note: Figures are subject to rounding. 1997/98 prices are used.

1.4 Sensitivity Analysis

1.4.1 Drainage

As the drainage benefit area is estimated to be the same as the flood risk area, but not supported by historical evidence, the areal drainage factor was applied. As the soil type is classed as heavy and there is a developed ditch system, the areal drainage factor is 0.4 (Table 3.8, FDMM). The drainage benefit area is thus 40% of the flood risk area (61.6 ha). The corresponding drainage benefits are shown in the record sheets at the end of this Appendix and the benefit:cost ratio shown in Table 7. The maintenance scheme is still justified as the benefit:cost ratio is greater than 1.0.

Table 7 Benefit:cost ratio, different definitions of drainage benefit area, Ffos Fawr

	Total Annual Benefit (£)	Total Annual Maintenance Cost (£)	Benefit:Cost Ratio
Drainage benefit area estimated to be same as flood risk area			
	16063	1428	11.2
Drainage benefit area defined using areal drainage factor			
	13291	1428	9.3

Note: Figures are subject to rounding. 1997/98 prices are used.

1.4.2 Actual SoS

Estimates of the actual standard of service provided are sensitive to the effective reach length used, as shown in Table 8. This parameter is determined by the user of FDMM and is open to interpretation and subjectivity.

Two IDD watercourses discharge into the Ffos Fawr main river. As these watercourses lie wholly within the flood risk area, and derive benefit from maintenance on the main river, the question arises as to whether they should be included in the calculation of the effective reach length and treated as tributaries. Currently within FDMM non-main river tributaries are ignored and excluded from analysis. Table 8 shows the sensitivity of actual SoS to effective reach length. The HEs associated with the benefit areas of the IDD tributaries are contained within the benefit area of the main river and are therefore included in the analysis.

Table 8 Sensitivity analysis: effective reach length and reach status, Ffos Fawr

Bank	Flooding (AAN $_{with}$) (HE/km) (a)	Effective Reach Length (km) (b)	Flood Score (HE/km/yr) (a/b) = (c)	Drainage Score (HE/km/yr) (d)	Total (c)+(d)	Reach Status
Effective reach comprises: main river only						
LB	1.57	2.09	0.75	0.0 *	0.75	OTS
RB	0.48	2.09	0.23	0.0 *	0.23	ATS
				Average	0.49	c. OTS
Effective reach comprises: main river and IDD tributaries						
LB	1.57	7.59	0.21	0.0 *	0.21	ATS
RB	0.48	2.09	0.23	0.0 *	0.23	ATS
				Average	0.22	ATS

Note: * the drainage status is described as good under the current maintenance situation, therefore the drainage score is zero. Figures are subject to rounding.

1.4.3 Maintenance costs

In accordance with FDMM, the costs of maintenance have been increased by 15% and the benefits reduced by 15% in order to check the sensitivity of assumptions made on the benefit:cost ratio. The results of this are shown in Table 9. Due to the high benefits and low maintenance costs, the maintenance regime would be justified even if costs increased and benefits reduced by 15%.

Table 9 Sensitivity analysis: benefit:cost ratio, Ffos Fawr

Total Annual Benefit (£)	Total Annual Maintenance Cost (£)	Benefit:Cost Ratio
Maintenance costs increased by 15%		
16063	1642	9.8
Benefits reduced by 15%		
13654	1428	9.6
Maintenance costs increased by 15% and benefits reduced by 15%		
13654	1642	8.3

Note: Maintenance costs for main river only. Figures are subject to rounding. 1997/98 prices are used.

If the IDD watercourses were included in the analysis of effective reach length, the maintenance costs associated with these channels should also be included in the benefit:cost equation. Sensitivity of the benefit:cost ratio to these various maintenance costs is shown in Table 10. The results show that the benefit:cost ratio is sensitive to assumptions made regarding maintenance costs.

As the Ffos Fawr discharges into the Afon Crafnant, and derives benefit from maintenance on it, a proportion of the maintenance expenditure on the Afon Crafnant should ideally be included in the costs for the Ffos Fawr. This associated cost may be based on the proportion of flow derived from each watercourse. In the case of the Ffos Fawr, as total maintenance expenditure on the Afon Crafnant is low (£1100), the maintenance scheme on the Ffos Fawr would be justified even if all associated cost were taken into account.

Table 10 Sensitivity of benefit:cost ratio to maintenance costs, Ffos Fawr

Total Annual Benefit (£)	Total Annual Maintenance Cost (£)	Benefit:Cost Ratio
Maintenance costs for Ffos Fawr main river only		
16063	1428	11.2
Maintenance costs for Ffos Fawr and IDD watercourses		
16063	2102	7.6

Note: Maintenance costs for main river only. Figures are subject to rounding. 1997/98 prices are used.

1.4.4 Benefits

If the maintenance costs of the IDD watercourses are taken into account in the benefit:cost equation, the benefits of this maintenance should also be considered. The flood risk area of these IDD watercourses, however, lie within that of the Ffos Fawr and therefore are already included in the analysis. Similarly, if a proportion of expenditure on the Afon Crafnant is included in the analysis, a proportion of benefits associated with this maintenance should be taken into account.

If these benefits are not known and therefore estimated, this will reduce the accuracy of the benefit:cost analysis. It is recommended that the type of these additional benefits is noted and only if the benefits of maintenance appear to be marginal, then an estimate of these benefits is made.

1.5 Application of the Guidelines to Area 1

1.5.1 Introduction

The following sections present the results of the application of the Guidelines to Area 1, the Ffos Fawr. The same data are used as in the application of FDMM in order that results from the two methods may be compared. The completed record sheets and tables/figures required in the use of the Guidelines are presented at the end of this Appendix.

1.5.2 General information

Dominant substrate

Following rapid survey of the watercourse and discussions with the Environment Agency, the dominant substrate is classed as silty clay.

Floodplain topography

The floodplain is classed as flat as it has a slope of < 1%.

Catchment size

The catchment area is described as small (< 2500 ha).

Benefit area

The area benefiting from maintenance in terms of its impact on flooding and land drainage is taken to be the same as the flood risk area identified using FDMM. This area is 154 ha in total. The left and right banks are not treated separately in the Guidelines.

Land use type

Following site survey, the dominant land use type is classed as extensive pasture (LUT 1), which is grazed by beef and sheep.

Dominant soil type

From a rapid assessment of the benefit area and using secondary data sources (SSEW 1980), the dominant soil type is identified as silt.

1.5.3 Design standard (maintained condition)

Average bed width and average channel depth

The average bed width and channel depth are 1.2 m and 1 m respectively. These parameters were estimated by the Environment Agency.

Freeboard

The average freeboard under conditions of mean spring flow is estimated by the Environment Agency to be 0.7 m. This parameter has not been monitored and recorded and so the estimate is based on local knowledge and judgement.

Watertable depth and drainage status

The watertable depth associated with the flat floodplain, silt soil and freeboard of 0.7 m is estimated from Figure 2.6 in the main text, to be 0.3 m. The drainage status is therefore classed as bad.

Economic net return

Using the dominant land use type of extensive pasture and bad drainage status, the economic net return is calculated to be £-81 /ha (1997/98 economic prices). The total economic net return for the benefit area is therefore £-12474 (1997/98 prices).

Bankfull discharge

As the flood return periods are known for the 'with' and 'without' maintenance situation, the bankfull discharge need to be calculated.

Flood costs

Annual flood costs were identified using the Guidelines for extensive pasture under bad drainage, for events with a return period of 10, 15, 20, 25 and 30 years. The same flooded areas and return periods were used as in FDMM.

The flood costs corresponding with these return periods are shown in Table 11. It is assumed that these costs are additive. Total flood costs for the 'with' maintenance situation are £462 (1997/98 prices).

Table 11 Flood costs under the current maintained situation, Ffos Fawr

Flood Return Period (yr)	Area Flooded (%)	Area Flooded (ha)	Annual Flood Cost (£/ha)	(£)
10	20	31	1	31
15	40	62	1	62
20	60	92	1	92
25	80	123	1	123
30	100	154	1	154
			Total	462

Note: Figures are subject to rounding. 1997/98 prices are used.

Design standard benefit area value

The value of the benefit area under the current maintenance regime is calculated by subtracting the flood costs from the net return, as shown in Table 12.

Table 12 Design standard, value of benefit area, Ffos Fawr

Total Net Return (£) (a)	Total Flood Cost (£) (b)	Benefit Area Value (£) (a-b)
-12474	462	-12936

Note: Figures are subject to rounding. 1997/98 prices are used.

1.5.4 Maintenance regime

It is assumed that maintenance increases the channel width by 75% through removal of emergent vegetation.

The impact of widening the channel on freeboard was calculated using the equation $y = a + bx$, which is shown in Box 2.1 in the main text. Assuming an increase in width of 75%, the corresponding increase in freeboard is 16%. This equates to an increase in freeboard of 0.112 m.

1.5.5 Do-nothing (without maintenance)

Drainage status

The change in freeboard as a consequence of maintenance is used to determine the watertable depth and the corresponding drainage status which would prevail in the absence of maintenance. Assuming a freeboard of 0.59 m without maintenance (0.7 m - 0.112 m), using Figure 2.6 in the main text, the without maintenance drainage status is assessed as very bad.

Economic net return

Using the dominant land use type of extensive pasture and very bad drainage, the economic net return is calculated to be £-103 /ha (1997/98 economic prices). The total economic net return for the whole benefit area is therefore £-15862 (1997/98 prices).

Flood costs

Annual flood costs were identified using the Guidelines for extensive pasture under very bad drainage, for various return periods. The same flooded areas and return periods were used as in FDMM.

The flood costs corresponding to the return periods are shown in Table 13. It is assumed that these costs are additive. Total flood costs for the without maintenance situation are £1078 (1997/98 prices).

Without maintenance benefit area value

The value of the benefit area under the 'without' maintenance situation of bad drainage is calculated by subtracting the flood costs from the net return, as shown in Table 14.

1.5.6 Maintenance costs

As identified in Section 1.2, the total annual maintenance expenditure on the Ffos Fawr is £1428 (1997/98 prices).

Table 13 Flood costs under the without maintenance situation, Ffos Fawr

Flood Return Period (yrs)	% Area Flooded	Area Flooded (ha)	Annual Flood Cost (£/ha)	Total Annual Flood Cost (£)
2	20	31	1	31
4	40	62	1	62
6	60	92	1	92
8	80	123	1	123
10	100	154	1	154
			Total	1078

Note: Figures are subject to rounding. 1997/98 prices are used.

Table 14 Without maintenance benefit area value, Ffos Fawr

Total Net Return (£) (a)	Total Flood Cost (£) (b)	Benefit Area Value (£) (a-b)
-15862	1078	-16940

Note: Figures are subject to rounding. 1997/98 prices are used.

1.5.7 Benefit of maintenance

The difference in value of the benefit area 'with' and 'without' maintenance is used to determine the benefit of maintenance. From the figures presented in Tables 12 and 14, the benefit of maintenance is calculated to be £4004.

1.5.8 Justification

The net benefit of maintenance is greater than the annual maintenance expenditure, therefore the maintenance regime is justified. The benefit:cost ratio is 2.8.

FFOS FAWR

Order of record sheets presented in the following pages:

FDMM

Land use assessment: reach summary

Flooding

Drainage benefits

Excluding urban benefits: Land use assessment - reach summary

Excluding urban benefits: Flooding

GUIDELINES

General information

Design standard

Maintenance regime

'Do-nothing' - Without maintenance

Maintenance expenditure and benefits of maintenance

LAND USE ASSESSMENT : REACH SUMMARY

Watercourse	**Ffos Fawr**
Bank	**Left Bank**
OS Map	Landranger 115
Flood risk area (ha)	37.93
Effective reach length (km)	2.09

Land Use Factor	Unit	Number or area (a)	House Equivalents HE/unit (b)		Total HE (a) x (b)	
House	Number	24	1.00		24	
Garden / allotments	Number	4	0.04		0.16	
NRP - Manufacturing	Area (m^2)		0.030		0	
NRP - Distribution	Area (m^2)		0.054		0	
NRP - Leisure	Area (m^2)		0.032		0	
N R P - Offices	Area (m^2)	25	0.033		0.825	
N R P - Retail	Area (m^2)		0.035		0	
N R P - Agricultural	Area (m^2)	950	0.010		9.5	
C Roads	Number	1	2.7		2.7	
B Roads	Number		6.3		0	
A Roads (non trunk)	Number		15.9		0	
A Roads (trunk)	Number		31.7		0	
Motorway	Number		63.5		0	
Railway	Number		63.5		0	
			Flooding	Drainage	Flooding	Drainage **
Forestry and scrub *	per 100 ha		0.02	0.0		
Extensive pasture *	per 100 ha	0.3793	1.3	1.1	0.49309	
Intensive pasture *	per 100 ha		3	4.5		
Extensive arable *	per 100 ha		6.3	3.6		
Intensive arable *	per 100 ha		44.1	9.7		
Formal parks	Number		0.6		0	
Golf / race courses	Number		0.7		0	
Playing field	Number	1	0.1		0.1	
Special parks	Number		9.3		0	
Total HE (c) *					37.78	
HE/km ((c) / effective reach length)					18.08	

Note

* Flooding / drainage scores to be summed ** Apply areal drainage factor if required

HE values are at 1991 base

LAND USE ASSESSMENT : REACH SUMMARY

Watercourse	**Ffos Fawr**
Bank	**Right Bank**
OS Map	Landranger 115
Flood risk area (ha)	116.07
Effective reach length (km)	2.09 (2.09 km Ffos Fawr)

Land Use Factor	Unit	Number or area (a)	House Equivalents HE/unit (b)		Total HE (a) x (b)	
House	Number		1.00		*0*	
Garden / allotments	Number		0.04		*0*	
NRP - Manufacturing	Area (m^2)		0.030		*0*	
NRP - Distribution	Area (m^2)		0.054		*0*	
NRP - Leisure	Area (m^2)		0.032		*0*	
N R P - Offices	Area (m^2)	*200*	0.033		*6.6*	
N R P - Retail	Area (m^2)		0.035		*0*	
N R P - Agricultural	Area (m^2)		0.010		*0*	
C Roads	Number	*1*	2.7		*2.7*	
B Roads	Number		6.3		*0*	
A Roads (non trunk)	Number		15.9		*0*	
A Roads (trunk)	Number		31.7		*0*	
Motorway	Number		63.5		*0*	
Railway	Number		63.5		*0*	
			Flooding	Drainage	Flooding	Drainage **
Forestry and scrub *	per 100 ha		0.02	0.0		
Extensive pasture *	per 100 ha	*1.1607*	1.3	1.1	*1.50891*	
Intensive pasture *	per 100 ha		3	4.5		
Extensive arable *	per 100 ha		6.3	3.6		
Intensive arable *	per 100 ha		44.1	9.7		
Formal parks	Number		0.6		*0*	
Golf / race courses	Number		0.7		*0*	
Playing field	Number		0.1		*0*	
Special parks	Number		9.3		*0*	
Total HE (c) *					*10.81*	
HE/km ((c) / effective reach length)					*5.17*	

Note

* Flooding / drainage scores to be summed

** Apply areal drainage factor if required

HE values are at 1991 base

FLOODING

Watercourse	**Ffos Fawr**
Bank	**Left Bank**
Flood risk area (ha)	37.93
Effective reach length (km)	2.09

With maintenance - current situation

Flood Return Period (years)	Probability	Nr. HEs Affected	Probability Interval (a)	Average Nr. HEs Affected (b)	(a) x (b)
1	1	0.00			
no flooding			0.8	0.00	0.000
5	0.2	0.00			
no flooding			0.1	3.80	0.380
10	0.1	7.60			
20% flooded			0.033	11.41	0.380
15	0.067	15.21			
40% flooded			0.017	19.01	0.317
20	0.050	22.81			
60% flooded			0.010	26.61	0.266
25	0.040	30.42			
80% flooded			0.007	34.22	0.228
30	0.033	38.02			
100% flooded					
Annual Average Number HEs affected with maintenance (AAN $_{\text{with}}$)					1.571

Without maintenance

Flood Return Period (years)	Probability	Nr. HEs Affected	Probability Interval (a)	Average Nr. HEs Affected (b)	(a) x (b)
1	1	0.00			
no flooding			0.5	3.80	1.901
2	0.5	7.60			
20% flooded			0.25	11.41	2.852
4	0.25	15.21			
40% flooded			0.083	19.01	1.584
6	0.167	22.81			
60% flooded			0.042	26.61	1.109
8	0.125	30.42			
80% flooded			0.025	34.22	0.855
10	0.100	38.02			
100% flooded					
Annual Average Number HEs affected without maintenance (AAN $_{\text{without}}$)					8.301

Summary: flooding

Left Bank	AAN $_{\text{without}}$ (a)	AAN $_{\text{with}}$ (b)	(a) - (b)	Annual Benefit (£)
	8.301	1.571	6.730	8775
Value of one HE (£) *	1304			

Note * 1997/98 price

Severity weightings have been applied to HEs affected by flooding: pasture 1.5

FLOODING

Watercourse	**Ffos Fawr**
Bank	**Right Bank**
Flood risk area (ha)	116.07
Effective reach length (km)	2.09

With maintenance - current situation

Flood Return Period (years)	Probability	Nr. HEs Affected	Probability Interval (a)	Average Nr. HEs Affected (b)	(a) x (b)
1	1	0.00			
no flooding			0.8	0.00	0.000
5	0.2	0.00			
no flooding			0.1	1.16	0.116
10	0.1	2.31			
20% flooded			0.033	3.47	0.1156
15	0.067	4.62			
40% flooded			0.017	5.78	0.0963
20	0.050	6.94			
60% flooded			0.010	8.09	0.0809
25	0.040	9.25			
80% flooded			0.007	10.40	0.0694
30	0.033	11.56			
100% flooded					
Annual Average Number HEs affected with maintenance (AAN_{with})					0.478

Without maintenance

Flood Return Period (years)	Probability	Nr. HEs Affected	Probability Interval (a)	Average Nr. HEs Affected (b)	(a) x (b)
1	1	0.00			
no flooding			0.5	1.16	0.578
2	0.5	2.31			
20% flooded			0.25	3.47	0.867
4	0.25	4.62			
40% flooded			0.083	5.78	0.482
6	0.167	6.94			
60% flooded			0.042	8.09	0.337
8	0.125	9.25			
80% flooded			0.025	10.40	0.260
10	0.100	11.56			
100% flooded					
Annual Average Number HEs affected without maintenance ($AAN_{without}$)					2.524

Summary: flooding

Right Bank	$AAN_{without}$ (a)	AAN_{with} (b)	(a) - (b)	Annual Benefit (£)
	2.524	0.478	2.046	2668
Value of one HE (£) *	1304			

Note * 1997/98 price

Severity weightings have been applied to HEs affected by flooding: pasture 1.5

DRAINAGE BENEFITS

Watercourse	**Ffos Fawr**	**Ffos Fawr**
Bank	**Left Bank**	**Right Bank**
Drainage benefit area (ha) *	37.93	116.07
Effective reach length (km)	2.09	2.09
Floodplain topography	Flat	Flat
Predominant soil type	Heavy	Heavy
Drainage system	Natural	Natural
With maintenance, drainage status	Good	Good
Without maintenance, drainage status	Very bad	Very bad
Annual benefit (£/ha) *	30	30
Total benefit (£) *	1138	3482

* 1997/98 economic prices

Note
If the drainage benefit area is not known, multiply the flood risk area by the appropriate areal drainage factor, according to soil type and drainage system

Sensitivity analysis, using areal drainage factor to define drainage benefit area

DRAINAGE BENEFITS

Watercourse	**Ffos Fawr**	**Ffos Fawr**
Bank	**Left Bank**	**Right Bank**
Drainage benefit area (ha) *	37.93	116.07
Effective reach length (km)	2.09	2.09
Floodplain topography	Flat	Flat
Predominant soil type	Heavy	Heavy
Drainage system	Natural	Natural
Areal drainage factor	0.4	0.4
With maintenance, drainage status	Good	Good
Without maintenance, drainage status	Very bad	Very bad
Drainage benefit area (ha)	15.17	46.43
Annual benefit (£/ha) *	30	30
Total benefit (£) *	455	1393

* 1997/98 economic prices

AGRICULTURAL BENEFITS ONLY
LAND USE ASSESSMENT : REACH SUMMARY

Watercourse	**Ffos Fawr**
Bank	**Left Bank**
OS Map	Landranger 115
Flood risk area (ha)	37.93
Effective reach length (km)	2.09

Land Use Factor	Unit	Number or area (a)	House Equivalents HE/unit (b)		Total HE (a) x (b)	
House	Number		1.00		*0*	
Garden / allotments	Number		0.04		*0*	
NRP - Manufacturing	Area (m^2)		0.030		*0*	
NRP - Distribution	Area (m^2)		0.054		*0*	
NRP - Leisure	Area (m^2)		0.032		*0*	
N R P - Offices	Area (m^2)		0.033		*0*	
N R P - Retail	Area (m^2)		0.035		*0*	
N R P - Agricultural	Area (m^2)		0.010		*0*	
C Roads	Number		2.7		*0*	
B Roads	Number		6.3		*0*	
A Roads (non trunk)	Number		15.9		*0*	
A Roads (trunk)	Number		31.7		*0*	
Motorway	Number		63.5		*0*	
Railway	Number		63.5		*0*	
			Flooding	Drainage	Flooding	Drainage **
Forestry and scrub *	per 100 ha		0.02	0.0		
Extensive pasture *	per 100 ha	*0.3793*	1.3	1.1	*0.49309*	
Intensive pasture *	per 100 ha		3	4.5		
Extensive arable *	per 100 ha		6.3	3.6		
Intensive arable *	per 100 ha		44.1	9.7		
Formal parks	Number		0.6		*0*	
Golf / race courses	Number		0.7		*0*	
Playing field	Number		0.1		*0*	
Special parks	Number		9.3		*0*	
Total HE (c) *					*0.49*	
HE/km ((c) / effective reach length)					*0.24*	

Note
* Flooding / drainage scores to be summed
HE values are at 1991 base

** Apply areal drainage factor if required

AGRICULTURAL BENEFITS ONLY
LAND USE ASSESSMENT : REACH SUMMARY

Watercourse	**Ffos Fawr**
Bank	**Right Bank**
OS Map	Landranger 115
Flood risk area (ha)	116.07
Effective reach length (km)	2.09 (2.09 km Ffos Fawr)

Land Use Factor	Unit	Number or area (a)	House Equivalents HE/unit (b)		Total HE (a) x (b)	
House	Number		1.00		*0*	
Garden / allotments	Number		0.04		*0*	
NRP - Manufacturing	Area (m^2)		0.030		*0*	
NRP - Distribution	Area (m^2)		0.054		*0*	
NRP - Leisure	Area (m^2)		0.032		*0*	
N R P - Offices	Area (m^2)		0.033		*0*	
N R P - Retail	Area (m^2)		0.035		*0*	
N R P - Agricultural	Area (m^2)		0.010		*0*	
C Roads	Number		2.7		*0*	
B Roads	Number		6.3		*0*	
A Roads (non trunk)	Number		15.9		*0*	
A Roads (trunk)	Number		31.7		*0*	
Motorway	Number		63.5		*0*	
Railway	Number		63.5		*0*	
			Flooding	Drainage	Flooding	Drainage **
Forestry and scrub *	per 100 ha		0.02	0.0		
Extensive pasture *	per 100 ha	*1.1607*	1.3	1.1	*1.50891*	
Intensive pasture *	per 100 ha		3	4.5		
Extensive arable *	per 100 ha		6.3	3.6		
Intensive arable *	per 100 ha		44.1	9.7		
Formal parks	Number		0.6		*0*	
Golf / race courses	Number		0.7		*0*	
Playing field	Number		0.1		*0*	
Special parks	Number		9.3		*0*	
				Total HE (c) *	*1.51*	
				HE/km ((c) / effective reach length)	*0.72*	

Note
* Flooding / drainage scores to be summed ** Apply areal drainage factor if required
HE values are at 1991 base

AGRICULTURAL BENEFITS ONLY

FLOODING

Watercourse	**Ffos Fawr**
Bank	**Left Bank**
Flood risk area (ha)	37.93
Effective reach length (km)	2.09

With maintenance - current situation

Flood Return Period (years)	Probability	Nr. HEs Affected	Probability Interval (a)	Average Nr. HEs Affected (b)	(a) x (b)
1	1	0.00			
no flooding			0.8	0.00	0.000
5	0.2	0.00			
no flooding			0.1	0.07	0.007
10	0.1	0.15			
20% flooded			0.033	0.22	0.007
15	0.067	0.30			
40% flooded			0.017	0.37	0.006
20	0.050	0.44			
60% flooded			0.010	0.52	0.005
25	0.040	0.59			
80% flooded			0.007	0.67	0.004
30	0.033	0.74			
100% flooded					
		Annual Average Number HEs affected with maintenance (AAN $_{with}$)			0.031

Without maintenance

Flood Return Period (years)	Probability	Nr. HEs Affected	Probability Interval (a)	Average Nr. HEs Affected (b)	(a) x (b)
1	1	0.00			
no flooding			0.5	0.07	0.037
2	0.5	0.15			
20% flooded			0.25	0.22	0.055
4	0.25	0.30			
40% flooded			0.083	0.37	0.031
6	0.167	0.44			
60% flooded			0.042	0.52	0.022
8	0.125	0.59			
80% flooded			0.025	0.67	0.017
10	0.100	0.74			
100% flooded					
		Annual Average Number HEs affected without maintenance (AAN $_{without}$)			0.161

Summary: flooding

Left Bank	AAN $_{without}$ (a)	AAN $_{with}$ (b)	(a) - (b)	Annual Benefit (£)
	0.161	0.031	0.131	171
Value of one HE (£) *	1304			

Note * 1997/98 price

Severity weightings have been applied to HEs affected by flooding: pasture 1.5

AGRICULTURAL BENEFITS ONLY

FLOODING

Watercourse	**Ffos Fawr**
Bank	**Right Bank**
Flood risk area (ha)	116.07
Effective reach length (km)	2.09

With maintenance - current situation

Flood Return Period (years)	Probability	Nr. HEs Affected	Probability Interval (a)	Average Nr. HEs Affected (b)	(a) x (b)
1	1	0.00			
no flooding			0.8	0.00	0.000
5	0.2	0.00			
no flooding			0.1	0.23	0.023
10	0.1	0.45			
20% flooded			0.033	0.68	0.0226
15	0.067	0.91			
40% flooded			0.017	1.13	0.0189
20	0.050	1.36			
60% flooded			0.010	1.58	0.0158
25	0.040	1.81			
80% flooded			0.007	2.04	0.0136
30	0.033	2.26			
100% flooded					
	Annual Average Number HEs affected with maintenance (AAN $_{with}$)				0.094

Without maintenance

Flood Return Period (years)	Probability	Nr. HEs Affected	Probability Interval (a)	Average Nr. HEs Affected (b)	(a) x (b)
1	1	0.00			
no flooding			0.5	0.23	0.113
2	0.5	0.45			
20% flooded			0.25	0.68	0.170
4	0.25	0.91			
40% flooded			0.083	1.13	0.094
6	0.167	1.36			
60% flooded			0.042	1.58	0.066
8	0.125	1.81			
80% flooded			0.025	2.04	0.051
10	0.100	2.26			
100% flooded					
	Annual Average Number HEs affected without maintenance (AAN $_{without}$)				0.494

Summary: flooding

Right Bank	AAN $_{without}$ (a)	AAN $_{with}$ (b)	(a) - (b)	Annual Benefit (£)
	0.494	0.094	0.401	522
Value of one HE (£) *	1304			

Note * 1997/98 price

Severity weightings have been applied to HEs affected by flooding: pasture 1.5

GENERAL INFORMATION

River — 1a **FFOS FAWR**

Reach Code — 1b **01**

Reach Length (km) — 2 **2.09**

Dominant Substrate Type:-
Gravel, Sand or Silt
(Treat clay as silt) — 3 **SILTY/CLAY**

Floodplain -
Rising (>1 %) or Flat (< 1 %) — 4 **FLAT**

Catchment Size
Large (> 25 sq. km)
Small (< 25 sq. km) — 5 **SMALL**

Benefit Area (ha)
(Area deriving benefit from maintenance) — 6 **154**

Dominant Land Use Type (LUT)
(Table 1) — 7 **EXT. GRASS (1)**

Dominant Soil Type — 9 **SILT**

Varied Land Use Types (LUT)
(Table 1)

LUT		7 % Benefit Are as decimal	8a Does the LUT flood ?	8b If yes, % that floods (as decimal)
1	Ext grass			
2	Int grass			
3	Grass/arable			
4	All cereals			
5	Cereal/oil seed			
6	Cereal/root			
7	Horticulture			
8	Other			

Note: All table numbers and references relate to R&D Note 511, Guidelines for the Justification of River Maintenance

DESIGN STANDARD

Average Bed Width (m)	10	1.2
Average Channel Depth (m)	11	1
% Weed Cover (In channel, submerged & floating weed)	12	0 (Emergent vegetation only)
Freeboard (m)	13	0.7
Watertable Depth (m) *(Box 4, 9, 13 & Figure 1 or 2)*	14	0.3
Drainage Status *(Box 14 & Table 4)*	15	BAD

Economic Net Return
(Table 5, using Box 7 & Box 15)

			16
For either :-	Dominant land use	(£/ha)	-81
		(£)	-12474
or :-	Varied land use	(£/ha)	
		(£)	

LUT	16a Net Return (£/ha)	16b Weighted Net Return
1		
2		
3		
4		
5		
6		
7		

Bankfull Discharge (Qbf) (cumecs)	17	
* Regional Growth Curve Area *(Figure 3)*	18	
* Mean Annual Flood (Q bar) (cumecs)	19	
* Qbf/Q bar (cumecs) *(Box 17 / Box 19)*	20	

* Flooding Envelopes
* % BA with different flood return periods (years)
(Table 6 or 7, boxes 5, 7, 15)

FRP (yr)	21 % area of each LUT that floods	21a Flooded Area (ha)	22 Flood Cost (£/ha)	22a Total Flood Cost (£) *(Box 21a * box 22)*
0	0	0	0	0
1 - 2				
3 - 5	0	0	0	0
6 - 10				
> 10 (10 yr)	20	31	1	31
(15 yr)	40	62	1	62
(20 yr)	60	92	1	92
(25 yr)	80	123	1	123
(30 yr)	100	154	1	154
			Total	462

* *Not necessary unless detailed information and assessment is required*

Flood Return Period (years)		23	AS ABOVE
Total Flood Cost	(£)	24	462
Design Net Return Less Flood Cost *(Box 16 - box 24)*	(£)	24a	-12936

Note: All table numbers and references relate to R&D Note 511, Guidelines for the Justification of River Maintenance

MAINTENANCE REGIME

Widening, change in width, expressed in metres and as a %, (including cutting of banks and emergent vegetation)	25a (m) 0.9	25b (%) 75
Deepening, change in depth, expressed in metres and as a %	26a (m)	26b (%)
Weed cutting, % cover removed (Submerged & floating weed)		27
Change in freeboard, expressed in metres and as a % (Table 8 - 15, & boxes 25, 26, 27)	28a (m) 0.112	28b (%) 16
Change in Qbf, expressed in metres and as a % (Table 8 - 15, & boxes 25, 26, 27)	29a (m)	29b (%)

Note: All table numbers and references relate to R&D Note 511, Guidelines for the Justification of River Maintenance

"DO NOTHING" (WITHOUT MAINTENANCE)

30 W/o Maintenance Width (m) **0.3**
(Box 10 - box 25a)

31 W/o Maintenance Depth (m) **1**
(Box 11 - box 26a)

32 W/o Maintenance Freeboard (m) **0.59**
(Box 13 - box 28a)

33 W/o Maintenance Watertable Depth (m) **0.25**
(Box 4, 9, 32, Table 3, Figure 1 or 2)

34 W/o Maintenance Drainage Status **VERY BAD**
(Table 4, box 33)

Economic Net Return (W/o maintenance)
(Table 5, box 8, 34)

			35
For either :-	Dominant land use	(£/ha)	**-103**
		£	**-15862**
or :-	Varied land use	(£/ha)	
		£	

LUT	35b Net Return (£/ha)	35a Weighted Net Return
1		
2		
3		
4		
5		
6		
7		

36 W/o Maintenance Bankfull Discharge (Qbf) (cumecs)
(Box 17 - box 29)

37 * W/o Maintenance Qbf/Q bar (cumecs)
(Box 36 / box 19)

	FRP (yr.)	38 % area of each LUT that floods	38a Flooded Area (ha)	39 Flood Cost (£/ha)	39a Total Flood Cost (£) *(Box 38a * box 39)*
* Flooding Envelopes * % BA with different	0	**0**	**0**	**0**	**0**
flood return periods (years)	<1				
(Table 6 or 7, boxes 5, 7, 34)	1 - 2	**20**	**31**	**10**	**308**
	3 - 5	**40**	**62**	**3**	**185**
	6 - 10 (6 yr)	**60**	**92**	**2**	**185**
	7 - 10 (8 yr)	**80**	**123**	**2**	**246**
	> 10 (10 yr)	**100**	**154**	**1**	**154**
				Total	**1078**

* *Not necessary unless detailed information and assessment required*

40 W/o Maintenance FRP (years) **AS ABOVE**

41 Total Flood Cost (£) **1078**

41a Do-nothing
Net Return Less Flood Cost (£) **-16940**
(Box 35 - box 41)

Note: All table numbers and references relate to R&D Note 511, Guidelines for the Justification of River Maintenance

MAINTENANCE EXPENDITURE

Maintenance Activity	42 Unit Cost (£)	43 No. of Units (specify)	44 Cost/Reach/ Activity (£)	45 Interval Between Maintenance Activities (years)	46 Amortisation Value at 6 % Discount Rate *(Box 45, Table 18)*	47 Annual Cost (£) *(Box 44 * box 46)*
Weedcutting						**1428**

Total annual cost/reach (£) *(Sum box 47)* 48 **1428**

Benefit Area (ha) *(Box 6)* 49 **154**

Total annual maintenance cost/ha *(Box 48 / box 49)* 50 **9.3**

BENEFITS OF MAINTENANCE

Design Standard (With maintenance) Net return less flood costs *(Box 24a)* (£) 51 **-12936**

Do Nothing (Without maintenance) Net return less flood costs *(Box 41a)* (£) 52 **-16940**

Change in Net Benefit Due to Maintenance *(Box 51 - box 52)* (£) 53 **4004**

Net Benefit of Maintenance Change in net benefit less total annual maintenance costs *(Box 53 - box 49 or 50)* (£) 54 **2576**

Benefit : cost ratio *(Box 53/box 48)* **2.80**

Note: All table numbers and references relate to R&D Note 511, *Guidelines for the Justification of River Maintenance*

APPENDIX VII

1. ABBEY VIEW AD

1.1 Introduction

This Appendix presents the results of the application of FDMM and the Guidelines to Abbey View AD, a lowland watercourse in the Catchment of the Afon Conwy, North Wales.

1.2 Application of FDMM to Area 2: Abbey View AD

1.2.1 General information

Area 2 covers 90.26 ha on the left bank of the Afon Conwy, to the south of Dolgarrog. The floodbanks of the Afon Conwy and Afon Ddu form the boundaries of the area to the north, east and south. The B5106 road forms the western boundary.

The Abbey View AD flows through the study area and discharges through the floodbank into the Afon Ddu via a flapped outfall. Dolgarrog AD Number 5 drains the northern area and also discharges into the Afon Ddu. Two adopted ditches (Cae Coch AD Number 1 and 2) flow over the southern end of the study area and discharge into the Afon Conwy via flapped outfalls in the floodbank (Figure 1). An intensive network of field ditches drain the area.

Abbey View AD and Dolgarrog AD Number 5 are subject to annual weedcutting during late September to January. In 1997/98, annual maintenance expenditure is estimated to be £763.

As a main river does not flow through this area, FDMM has been applied to the Abbey View adopted ditch, which is in affect, a main river in all but name.

1.2.2 Area of benefit

The area benefiting from maintenance in terms of flood alleviation is estimated to be 90.26 ha. This is termed the flood risk area and was derived from discussions with the Environment Agency (Figure 1). It is based on the discrete area protected from flooding by the floodbanks of the Afon Conwy and Afon Ddu.

1.2.3 Land use assessment

Flooding

Land use and features of interest within the flood risk area are shown in the land use assessment reach summary sheet for the left and right bank of the Abbey View AD. The completed summary sheets may be found at the end of this Appendix.

The area affected by fluvial flooding on the left and right bank is estimated to be 41.95 ha and 48.31 ha respectively. The area is not affected by saline flooding. The effective reach is estimated to be 1.09 km for the left and right bank. There are no tributaries.

The flood score is derived by dividing the total HEs/km affected by flooding by the effective reach length (Appendix VII). The flood scores for the left and right bank are 6.23 and 0.58 respectively.

Drainage

The area of each land use type subject to bad or very bad drainage conditions is determined and weighted by the appropriate factor (e.g.. 3.6 HE/100 ha/yr for extensive arable. This drainage score represents the level of damage caused by waterlogging.

Under the current maintenance regime, the drainage status for the whole catchment is described as good, therefore the drainage score is zero.

1.2.4 Land use band

The flood and drainage HE/km scores are combined to determine the total HE/km for each bank (Table 1). The HE/km falls within the land use band 'C' range for the left bank (5-24.99 HE/km; see Table 2.3 in main text). Agricultural land is at risk of flooding and waterlogging, with some properties also at risk of flooding. Land on the right bank falls within the 'E'. category. This low grade agricultural land is at risk of flooding and inadequate drainage.

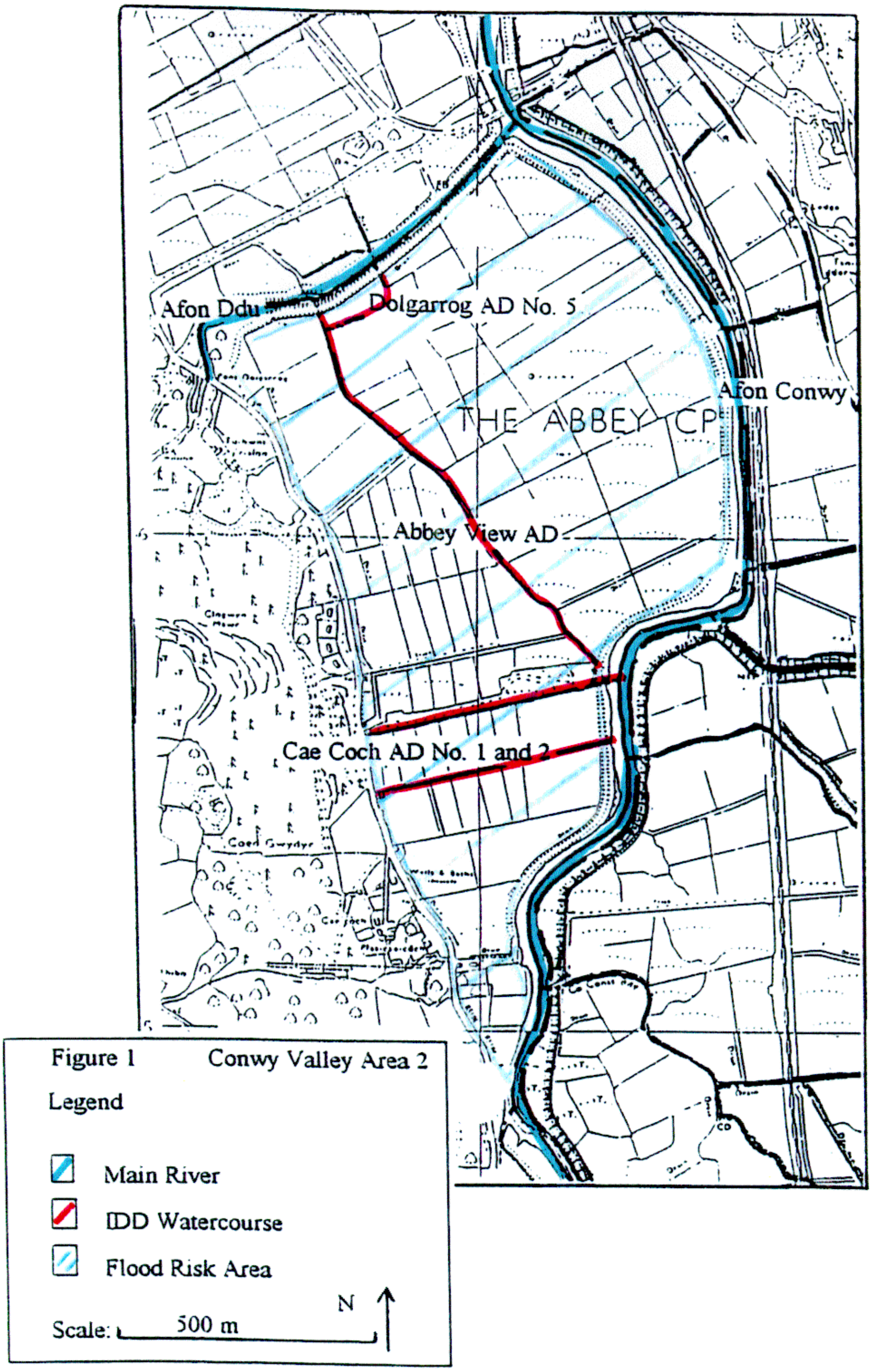


Figure 1 Conwy Valley Area 2

Table 1 Land use band, Abbey View AD

	Flood Value (HE/km)	Drainage Value (HE/km)	Total	Land Use Band
Left Bank	6.23	0.0 *	6.23	C
Right Bank	0.58	0.0 *	0.58	E

Note: * the drainage status is described as good under the current maintenance situation. Figures are subject to rounding.

1.2.5 Determining the effect of flooding

No historical records exist for the Abbey View AD or Dolgarrog AD Number 5. The effect of flooding is therefore, based purely on use of the predictive technique and the arithmetic method.

The predictive technique takes account of the flood return period at which different areas are inundated and an estimated long-term average annual value for HE affected is derived. Full details are contained within the record sheets at the end of this Appendix.

The area flooded by events with a return period of 1,5,10,15,20,25 and 30 years were identified by the Environment Agency for the left and right bank under the current maintained situation. It must be noted that these areas are estimated as the actual areas flooded by the infrequent events are not documented. It is estimated that with a return period of 5 years, no flooding would occur. Under an event with a return period of 10 years, for example, it is estimated that 20% of the flood risk area would be inundated.

A severity weighting of 1.5 has been applied to the total HEs/km affected by flooding to take account of the impact of timing and duration of flooding on pasture. The number of HEs affected by flooding was derived on a pro-rata basis by multiplying the total number of HEs affected by, for example, 20%, for a return period of 10 years. The process was repeated using estimates of flooded areas under various return periods for the without maintenance situation.

The annual benefit of maintenance is shown by the benefit to be gained from the avoidance of flooding. This is derived by subtracting the Annual Average Number HEs affected with maintenance (AAN $_{with}$) from the Annual Average Number of HEs affected without maintenance (AAN $_{without}$) and multiplying this figure by the value of one HE (£1304 in 1997 prices). The annual benefit (£) is shown in Table 2.

Table 2 Annual benefit, flooding, Abbey View AD

	AAN $_{without}$ (HE/km) (a)	AAN $_{with}$ (HE/km) (b)	(a) - (b)	Annual Benefit (£)
Left Bank	1.541	0.292	1.249	1629
Right Bank	0.206	0.039	0.167	217

Note: Figures are subject to rounding. 1997/98 prices are used.

1.2.6 Determining the effect of deterioration in drainage

The area within the flood risk area which is expected to be subject to a deterioration in drainage status in the absence of maintenance was estimated by the Environment Agency. The drainage status of the whole flood risk area is expected to deteriorate from a good to a very bad drainage condition.

The annual benefit of preventing a deterioration in drainage status is calculated from the area affected (ha) multiplied by the annual benefit (£/ha) to be gained from preventing a deterioration in drainage status. This procedure is shown in Table 3 for both banks. The annual benefit of maintaining good drainage on the left bank is £30 /ha or £1259 (1997/98 economic prices).

Table 3 Drainage benefits, Abbey View AD

	Left Bank	Right Bank
Area affected by deterioration in drainage status without maintenance (ha)	41.95	48.31
Drainage status with maintenance	Good	Good
Drainage status without maintenance	Very Bad	Very Bad
Annual benefit (£/ha)	30	30
Total Annual benefit (£)	1259	1449

Note: Figures are subject to rounding. 1997/98 prices are used.

1.2.7 Actual standard of service

The combined flood score and drainage score (HE/km/yr) for the current, with maintenance situation provides an indication of the adequacy of the existing maintenance regime with respect to set Standards of Service (SoS). This score for the Abbey View AD and Dolgarrog Ad Number 5 for the left and right bank is shown in Table 4. Scores are derived by dividing the HE/km by the effective reach length.

Table 4 Actual standard of service provided under the current maintenance regime, Abbey View AD

	Flooding (AAN $_{with}$) (HE/km) (a)	Effective Reach Length (km) (b)	Flood Score (HE/km/yr) (a/b) = (c)	Drainage Score (HE/km/yr) (d)	Total (c)+(d)
Left Bank	0.292	1.09	0.27	0.0	0.27
Right Bank	0.039	1.09	0.04	0.0	0.04
Both Banks				Average Score	0.155

Note: * the drainage status is described as good under the current maintenance situation, therefore the drainage score is zero. Figures are subject to rounding.

Comparison of the total score with a target score of 0.5-1.0 HE/km/yr enables the current level of service provided to be determined. This on target standard (OTS) of 0.5-1 HE/km/yr was derived by the Environment Agency, based on analysis of existing SoS. The reach status of both banks is above target.

1.2.8 Justification

Justification of the maintenance scheme is undertaken using a comparison of the benefits and costs of maintenance in a simple benefit:cost ratio.

The total annual maintenance expenditure of the Environment Agency on the Abbey View AD and Dolgarrog AD Number 5 (1997/98 prices) (see Section 1.2.1) is estimated to be £763. The total benefits of maintenance taking into account flooding and drainage benefits on both banks are presented in Table 5.

Table 6 shows that the benefit:cost ratio is greater than one, thus the current maintenance regime may be justified.

Table 5 Total benefits of maintenance, Abbey View AD

	Annual Benefit of Flood Alleviation (£)	Annual Benefit of Maintaining Drainage Status (£)	Total Annual Benefit (£)
Left bank	1629	1259	2888
Right bank	217	1449	1666
Total	1846	2708	4554

Note: Figures are subject to rounding. 1997/98 prices are used.

Table 6 Benefit:cost ratio, Abbey View AD

Total Annual Benefit (£)	Total Annual Maintenance Cost (£)	Benefit:Cost Ratio
4554	763	5.9

Note: Figures are subject to rounding. 1997/98 prices are used.

1.3 Sensitivity Analysis

1.3.1 Drainage

As the drainage benefit area is estimated to be the same as the flood risk area, but not supported by historical evidence, the areal drainage factor was applied. As the soil type is classed as heavy and there is a developed ditch system, the areal drainage factor is 0.4 (Table 3.8, FDMM). The drainage benefit area is thus 40% of the flood risk area (36.1 ha). The corresponding drainage benefits record sheets are presented at the end of this Appendix and the benefit:cost ratio shown in Table 7. The maintenance scheme is still justified as the benefit:cost ratio is greater than 1.0.

1.3.2 Maintenance costs

In accordance with FDMM, the costs of maintenance have been increased by 15% and the benefits reduced by 15% in order to check the sensitivity of assumptions made on the benefit:cost ratio. The results of this are shown in Table 8. Due to the high benefits and low maintenance costs, the maintenance regime would be justified even if costs increased and benefits reduced by 15%.

The Abbey View AD and Dolgarrog Ad Number 5 discharge into the Afon Ddu. The Afon Ddu is not subject to maintenance. If it were, however, a proportion of the maintenance expenditure on the Afon Ddu should ideally be included in the costs for the Abbey View AD and Dolgarrog AD No. 5 as these watercourses would derive benefit from this maintenance. This associated cost may be based on the proportion of flow derived from each watercourse.

Table 7 Benefit:cost ratio, different definitions of drainage benefit area, Abbey View AD

Total Annual Benefit (£)	Total Annual Maintenance Cost (£)	Benefit:Cost Ratio
Drainage benefit area estimated to be same as flood risk area		
4554	763	5.9
Drainage benefit area defined using areal drainage factor		
2132	763	2.8

Note: Figures are subject to rounding. 1997/98 prices are used.

Table 8 Sensitivity analysis: benefit:cost ratio, Abbey View AD

Total Annual Benefit (£)	Total Annual Maintenance Cost (£)	Benefit:Cost Ratio
Maintenance costs increased by 15%		
4554	877	5.2
Benefits reduced by 15%		
3871	763	5.1
Maintenance costs increased by 15% and benefits reduced by 15%		
3871	877	4.4

Note: Figures are subject to rounding. 1997/98 prices are used.

1.3.3 Benefits

If the maintenance costs of the Afon Ddu were taken into account in the benefit:cost equation, the benefits of this maintenance should also be considered.

If these benefits are not known and therefore estimated, the accuracy of the benefit:cost analysis will be reduced. It is recommended that the type of these additional benefits is noted and only if the benefits of maintenance on the Abbey View AD and Dolgarrog AD Number 5 appear to be marginal, then an estimate of these benefits is made.

1.4 Application of the Guidelines to Area 2

1.4.1 Introduction

The following sections present the results of the application of the Guidelines to Area 2, Abbey View. The same data are used as in the application of FDMM in order that results from the two methods may be compared. The completed record sheets and tables/figures required in the use of the Guidelines are presented at the end of this Appendix.

1.4.2 General information

Table 9 General information, Abbey View

Parameter		Comment
Dominant substrate	Silt/clay	
Floodplain topography	Flat (<1%)	
Catchment size	Small	
Benefit area (ha)	90.26	Same as total flood risk area. Left and right banks are combined.
Land use type	Extensive pasture (LUT 1)	
Dominant soil type	Silt	

1.4.3 Design standard (maintained condition)

Table 10 With maintenance channel parameters, drainage status and net return

Parameter		Comment
Average bed width (m)	1.2	
Average channel depth (m)	1	
Freeboard under mean spring flow (m)	0.7	
Watertable depth (m)	0.3	Using Figure 2.6 in main text
Drainage status	Bad	Using Figure 2.6 in main text
Economic net return (£/ha)	-81	1997/98 prices
Economic net return (£)	-7311	1997/98 prices

Note: Figures are subject to rounding. 1997/98 prices are used.

Annual flood costs were identified using the Guidelines for extensive pasture under bad drainage, for events with a return period of 10, 15, 20, 25 and 30 years. The same flooded areas and return periods were used as in FDMM. The flood costs corresponding with these return periods are shown in Table 11. It is assumed that these costs are additive. Total flood costs for the 'with' maintenance situation are £271 (1997/98 prices).

Table 11 With maintenance flood costs, Abbey View

Flood Return Period (yr)	Area Flooded (%)	Area Flooded (ha)	Annual Flood Cost * (£/ha)	(£)
10	20	18	1	18
15	40	36	1	36
20	60	54	1	54
25	80	72	1	72
30	100	90	1	90
			Total	271

Note: Figures are subject to rounding. 1997/98 prices are used.

The value of the benefit area under the current maintenance regime is calculated by subtracting the flood costs from the net return, as shown in Table 12.

Table 12 Design standard, value of benefit area, Abbey View

Total Net Return (£) (a)	Total Flood Cost (£) (b)	Benefit Area Value (£) (a-b)
-7311	271	-7582

Note: Figures are subject to rounding. 1997/98 prices are used.

1.4.4 Maintenance regime

Table 13 Impact of maintenance on freeboard, Abbey View

Parameter		Comment
Increase in bed width	75%, 0.9 m	
Impact of widening on freeboard	13%	Using equation $y=a+bx$, Box 2.1 in main text

1.4.5 Do-nothing (without maintenance)

Table 14 Without maintenance channel parameters, drainage status and net return

Parameters without maintenance		Comment
Freeboard under mean spring flow (m)	0.59	Freeboard reduced by 13%
Watertable depth (m)	0.25	Using Figure 2.6 in main text
Drainage status	Very bad	Using Figure 2.6 in main text
Economic net return (£/ha)	-103	1997/98 prices
Economic net return (£)	-9297	1997/98 prices

Note: Figures are subject to rounding. 1997/98 prices are used.

Annual flood costs were identified using the Guidelines for extensive pasture under very bad, for events with various return periods. The same flooded areas and return periods were used as in FDMM.

The flood costs corresponding to the return periods are shown in Table 15, for each flooding scenario. It is assumed that these costs are additive. Using an average of the three flooding scenarios, total flood costs for the without maintenance situation are £9251 (1997/98 prices).

Table 15 Flood costs under the without maintenance situation, Abbey View

Flood Return Period (yrs)	% Area Flooded	Area Flooded (ha)	Annual Flood Cost (£/ha) *	Total Annual Flood Cost (£) *
2	20	18	10	181
4	40	36	3	108
6	60	54	2	108
8	80	72	2	144
10	100	90	1	90
			Total	632

Note: Figures are subject to rounding. 1997/98 prices are used.

The value of the benefit area under the without maintenance situation of bad drainage is calculated by subtracting the flood costs from the net return, as shown in Table 16.

Table 16 Design standard, value of benefit area, Abbey View

Total Net Return (£) (a)	Total Flood Cost (£) (b)	Benefit Area Value (£) (a-b)
-9297	632	-9929

Note: Figures are subject to rounding.. 1997/98 prices are used.

1.4.6 Maintenance costs

As identified in Section 1.2, the total annual maintenance expenditure on Abbey View, is £763 (1997/98 prices).

1.4.7 Benefit of maintenance

The difference in value of the benefit area 'with' and 'without' maintenance is used to determine the benefit of maintenance. From the figures presented in Tables 12 and 16, the benefit of maintenance is calculated to be £2347.

1.4.8 Justification

The net benefit of maintenance is greater than the annual maintenance expenditure, therefore the current maintenance regime is justified. The benefit:cost ratio is 3.08.

ABBEY VIEW AD

Order of record sheets presented in the following pages:

FDMM

Land use assessment: reach summary

Flooding

Drainage benefits

Excluding urban benefits: Land use assessment - reach summary

Excluding urban benefits: Flooding

GUIDELINES

General information

Design standard

Maintenance regime

'Do-nothing' - Without maintenance

Maintenance expenditure and benefits of maintenance

LAND USE ASSESSMENT : REACH SUMMARY

Watercourse	**Abbey View**
Bank	**Left Bank**
OS Map	Landranger 115
Flood risk area (ha)	41.95
Effective reach length (km)	1.09 (D24, 880 m + D29, 210 m)

Land Use Factor	Unit	Number or area (a)	House Equivalents HE/unit (b)		Total HE (a) x (b)	
House	Number	*6*	1.00		*6*	
Garden / allotments	Number	*6*	0.04		*0.24*	
NRP - Manufacturing	Area (m^2)		0.030		*0*	
NRP - Distribution	Area (m^2)		0.054		*0*	
NRP - Leisure	Area (m^2)		0.032		*0*	
N R P - Offices	Area (m^2)		0.033		*0*	
N R P - Retail	Area (m^2)		0.035		*0*	
N R P - Agricultural	Area (m^2)		0.010		*0*	
C Roads	Number		2.7		*0*	
B Roads	Number		6.3		*0*	
A Roads (non trunk)	Number		15.9		*0*	
A Roads (trunk)	Number		31.7		*0*	
Motorway	Number		63.5		*0*	
Railway	Number		63.5		*0*	
			Flooding	Drainage	Flooding	Drainage **
Forestry and scrub *	per 100 ha		0.02	0.0		
Extensive pasture *	per 100 ha	*0.4195*	1.3	1.1	*0.54535*	
Intensive pasture *	per 100 ha		3	4.5		
Extensive arable *	per 100 ha		6.3	3.6		
Intensive arable *	per 100 ha		44.1	9.7		
Formal parks	Number		0.6		*0*	
Golf / race courses	Number		0.7		*0*	
Playing field	Number		0.1		*0*	
Special parks	Number		9.3		*0*	
Total HE (c) *					*6.79*	
HE/km ((c) / effective reach length)					*6.23*	

Note

* Flooding / drainage scores to be summed

** Apply areal drainage factor if required

HE values are at 1991 base

LAND USE ASSESSMENT : REACH SUMMARY

Watercourse	**Abbey View**	
Bank	**Right Bank**	
OS Map	Landranger 115	
Flood risk area (ha)	48.31	
Effective reach length (km)	1.09	(D24, 880m + D29, 210 m)

Land Use Factor	Unit	Number or area (a)	House Equivalents HE/unit (b)		Total HE (a) x (b)	
House	Number			1.00		*0*
Garden / allotments	Number			0.04		*0*
NRP - Manufacturing	Area (m^2)			0.030		*0*
NRP - Distribution	Area (m^2)			0.054		*0*
NRP - Leisure	Area (m^2)			0.032		*0*
N R P - Offices	Area (m^2)			0.033		*0*
N R P - Retail	Area (m^2)			0.035		*0*
N R P - Agricultural	Area (m^2)			0.010		*0*
C Roads	Number			2.7		*0*
B Roads	Number			6.3		*0*
A Roads (non trunk)	Number			15.9		*0*
A Roads (trunk)	Number			31.7		*0*
Motorway	Number			63.5		*0*
Railway	Number			63.5		*0*
			Flooding	Drainage	Flooding	Drainage **
Forestry and scrub *	per 100 ha		0.02	0.0		
Extensive pasture *	per 100 ha	*0.4831*	1.3	1.1	*0.62803*	
Intensive pasture *	per 100 ha		3	4.5		
Extensive arable *	per 100 ha		6.3	3.6		
Intensive arable *	per 100 ha		44.1	9.7		
Formal parks	Number			0.6		*0*
Golf / race courses	Number			0.7		*0*
Playing field	Number			0.1		*0*
Special parks	Number			9.3		*0*
				Total HE (c) *		*0.63*
				HE/km ((c) / effective reach length)		*0.58*

Note

* Flooding / drainage scores to be summed ** Apply areal drainage factor if required

HE values are at 1991 base

FLOODING

Watercourse	**Abbey View**
Bank	**Left Bank**
Flood risk area (ha)	41.95
Effective reach length (km)	1.09

With maintenance - current situation

Flood Return Period (years)	Probability	Nr. HEs Affected	Probability Interval (a)	Average Nr. HEs Affected (b)	(a) x (b)
1	1	0.00			
no flooding			0.8	0.00	0.000
5	0.2	0.00			
no flooding			0.1	0.71	0.071
10	0.1	1.41			
20% flooded			0.033	2.12	0.071
15	0.067	2.82			
40% flooded			0.017	3.53	0.059
20	0.050	4.23			
60% flooded			0.010	4.94	0.049
25	0.040	5.65			
80% flooded			0.007	6.35	0.042
30	0.033	7.06			
100% flooded					
	Annual Average Number HEs affected with maintenance (AAN $_{\text{with}}$)				0.292

Without maintenance

Flood Return Period (years)	Probability	Nr. HEs Affected	Probability Interval (a)	Average Nr. HEs Affected (b)	(a) x (b)
1	1	0.00			
no flooding			0.5	0.71	0.353
2	0.5	1.41			
20% flooded			0.25	2.12	0.529
4	0.25	2.82			
40% flooded			0.083	3.53	0.294
6	0.167	4.23			
60% flooded			0.042	4.94	0.206
8	0.125	5.65			
80% flooded			0.025	6.35	0.159
10	0.100	7.06			
100% flooded					
	Annual Average Number HEs affected without maintenance (AAN $_{\text{without}}$)				1.541

Summary: flooding

Left Bank	AAN $_{\text{without}}$ (a)	AAN $_{\text{with}}$ (b)	(a) - (b)	Annual Benefit (£)
	1.541	0.292	1.249	1629
Value of one HE (£) *	1304			

Note * 1997/98 price

Severity weightings have been applied to HEs affected by flooding: pasture 1.5

FLOODING

Watercourse	**Abbey View**
Bank	**Right Bank**
Flood risk area (ha)	48.31
Effective reach length (km)	1.09

With maintenance - current situation

Flood Return Period (years)	Probability	Nr. HEs Affected	Probability Interval (a)	Average Nr. HEs Affected (b)	(a) x (b)
1	1	0.00			
no flooding			0.8	0.00	0.000
5	0.2	0.00			
no flooding			0.1	0.09	0.009
10	0.1	0.19			
20% flooded			0.033	0.28	0.0094
15	0.067	0.38			
40% flooded			0.017	0.47	0.0079
20	0.050	0.57			
60% flooded			0.010	0.66	0.0066
25	0.040	0.75			
80% flooded			0.007	0.85	0.0057
30	0.033	0.94			
100% flooded					
Annual Average Number HEs affected with maintenance (AAN$_{with}$)					0.039

Without maintenance

Flood Return Period (years)	Probability	Nr. HEs Affected	Probability Interval (a)	Average Nr. HEs Affected (b)	(a) x (b)
1	1	0.00			
no flooding			0.5	0.09	0.047
2	0.5	0.19			
20% flooded			0.25	0.28	0.071
4	0.25	0.38			
40% flooded			0.083	0.47	0.039
6	0.167	0.57			
60% flooded			0.042	0.66	0.027
8	0.125	0.75			
80% flooded			0.025	0.85	0.021
10	0.100	0.94			
100% flooded					
Annual Average Number HEs affected without maintenance (AAN$_{without}$)					0.206

Summary: flooding

Right Bank	AAN$_{without}$ (a)	AAN$_{with}$ (b)	(a) - (b)	Annual Benefit (£)
	0.206	0.039	0.167	217
Value of one HE (£) *	1304			

Note * 1997/98 price

Severity weightings have been applied to HEs affected by flooding: pasture 1.5

DRAINAGE BENEFITS

Watercourse	**Abbey View**	**Abbey View**
Bank	**Left Bank**	**Right Bank**
Drainage benefit area (ha)	41.95	48.31
Effective reach length (km)	1.09	1.09
Floodplain topography	Flat	Flat
Predominant soil type	Heavy	Heavy
Drainage system	Natural	Natural
With maintenance, drainage status	Good	Good
Without maintenance, drainage status	Very bad	Very bad
Annual benefit (£/ha) *	30	30
Total benefit (£) *	1259	1449

* 1997/98 economic prices

Note

If the drainage benefit area is not known, multiply the flood risk area by the appropriate areal drainage factor, according to soil type and drainage system

Sensitivity analysis.

Areal drainage factor used to determine drainage benefit area

DRAINAGE BENEFITS

Watercourse	**Abbey View**	**Abbey View**
Bank	**Left Bank**	**Right Bank**
Flood risk area (ha)	41.95	48.31
Effective reach length (km)	1.09	1.09
Floodplain topography	Flat	Flat
Predominant soil type	Heavy	Heavy
Drainage system	Natural	Natural
Areal drainage factor	0.4	0.4
Drainage benefit area (ha)	16.78	19.32
With maintenance, drainage status	Good	Good
Without maintenance, drainage status	Very bad	Very bad
Annual benefit (£/ha) *	30	30
Total benefit (£) *	503	580

* 1997/98 economic prices

AGRICULTURAL BENEFITS ONLY

LAND USE ASSESSMENT : REACH SUMMARY

Watercourse	**Abbey View**	
Bank	**Left Bank**	
OS Map	Landranger 115	
Flood risk area (ha)	41.95	
Effective reach length (km)	1.09	(D24, 880 m + D29, 210 m)

Land Use Factor	Unit	Number or area (a)	House Equivalents HE/unit (b)		Total HE (a) x (b)	
House	Number		1.00		*0*	
Garden / allotments	Number		0.04		*0*	
NRP - Manufacturing	Area (m^2)		0.030		*0*	
NRP - Distribution	Area (m^2)		0.054		*0*	
NRP - Leisure	Area (m^2)		0.032		*0*	
N R P - Offices	Area (m^2)		0.033		*0*	
N R P - Retail	Area (m^2)		0.035		*0*	
N R P - Agricultural	Area (m^2)		0.010		*0*	
C Roads	Number		2.7		*0*	
B Roads	Number		6.3		*0*	
A Roads (non trunk)	Number		15.9		*0*	
A Roads (trunk)	Number		31.7		*0*	
Motorway	Number		63.5		*0*	
Railway	Number		63.5		*0*	
			Flooding	Drainage	Flooding	Drainage **
Forestry and scrub *	per 100 ha		0.02	0.0		
Extensive pasture *	per 100 ha	*0.4195*	1.3	1.1	*0.54535*	
Intensive pasture *	per 100 ha		3	4.5		
Extensive arable *	per 100 ha		6.3	3.6		
Intensive arable *	per 100 ha		44.1	9.7		
Formal parks	Number		0.6		*0*	
Golf / race courses	Number		0.7		*0*	
Playing field	Number		0.1		*0*	
Special parks	Number		9.3		*0*	
				Total HE (c) *	*0.55*	
				HE/km ((c) / effective reach length)	*0.50*	

Note
* Flooding / drainage scores to be summed ** Apply areal drainage factor if required
HE values are at 1991 base

AGRICULTURAL BENEFITS ONLY

FLOODING

Watercourse	**Abbey View**
Bank	**Left Bank**
Flood risk area (ha)	41.95
Effective reach length (km)	1.09

With maintenance - current situation

Flood Return Period (years)	Probability	Nr. HEs Affected	Probability Interval (a)	Average Nr. HEs Affected (b)	(a) x (b)
1	1	0.00			
no flooding			0.8	0.00	0.000
5	0.2	0.00			
no flooding			0.1	0.08	0.008
10	0.1	0.16			
20% flooded			0.033	0.25	0.008
15	0.067	0.33			
40% flooded			0.017	0.41	0.007
20	0.050	0.49			
60% flooded			0.010	0.57	0.006
25	0.040	0.65			
80% flooded			0.007	0.74	0.005
30	0.033	0.82			
100% flooded					
Annual Average Number HEs affected with maintenance (AAN$_{with}$)					0.034

Without maintenance

Flood Return Period (years)	Probability	Nr. HEs Affected	Probability Interval (a)	Average Nr. HEs Affected (b)	(a) x (b)
1	1	0.00			
no flooding			0.5	0.08	0.041
2	0.5	0.16			
20% flooded			0.25	0.25	0.061
4	0.25	0.33			
40% flooded			0.083	0.41	0.034
6	0.167	0.49			
60% flooded			0.042	0.57	0.024
8	0.125	0.65			
80% flooded			0.025	0.74	0.018
10	0.100	0.82			
100% flooded					
Annual Average Number HEs affected without maintenance (AAN$_{withou}$)					0.179

Summary: flooding

Left Bank	AAN$_{withou}$ (a)	AAN$_{with}$ (b)	(a) - (b)	Annual Benefit (£)
	0.179	0.034	0.145	189
Value of one HE (£) *	1304			

Note * 1997/98 price

Severity weightings have been applied to HEs affected by flooding: pasture 1.5

GENERAL INFORMATION

River 1a **ABBEY VIEW**

Reach Code 1b **01**

Reach Length (km) 2 **1.09**

Dominant Substrate Type:-
Gravel, Sand or Silt
(Treat clay as silt)
3 **SILT/CLAY**

Floodplain -
Rising (>1 %) or Flat (< 1 %)
4 **FLAT**

Catchment Size
Large (> 25 sq. km)
Small (< 25 sq. km)
5 **SMALL**

Benefit Area (ha)
(Area deriving benefit from maintenance)
6 **90.26**

Dominant Land Use Type (LUT)
(Table 1)
7 **EXT. GRASS (1)**

Dominant Soil Type 9 **SILT**

Varied Land Use Types (LUT)
(Table 1)

LUT		7 % Benefit Are as decimal	8a Does the LUT flood ?	8b If yes, % that floods (as decimal)
1	Ext grass			
2	Int grass			
3	Grass/arable			
4	All cereals			
5	Cereal/oil seed			
6	Cereal/root			
7	Horticulture			
8	Other			

Note: All table numbers and references relate to R&D Note 511, Guidelines for the Justification of River Maintenance

DESIGN STANDARD

Average Bed Width (m) 10 **1.2**

Average Channel Depth (m) 11 **1**

% Weed Cover (In channel, submerged & floating weed) 12 **0** (Emergent vegetation only)

Freeboard (m) 13 **0.7**

Watertable Depth (m) 14 **0.3**
(Box 4, 9, 13 & Figure 1 or 2)

Drainage Status 15 **BAD**
(Box 14 & Table 4)

Economic Net Return
(Table 5, using Box 7 & Box 15)

For either :- Dominant land use 16 (£/ha) **-81** (£) **-7311**

or :- Varied land use (£/ha) (£)

LUT	16a Net Return (£/ha)	16b Weighted Net Return
1		
2		
3		
4		
5		
6		
7		

Bankfull Discharge (Qbf) (cumecs) 17

* Regional Growth Curve Area *(Figure 3)* 18

* Mean Annual Flood (Q bar) (cumecs) 19

* Qbf/Q bar (cumecs) *(Box 17 / Box 19)* 20

* Flooding Envelopes
* % BA with different flood return periods (years)
(Table 6 or 7, boxes 5, 7, 15)

FRP (yr)	21 % area of each LUT that floods	21a Flooded Area (ha)	22 Flood Cost (£/ha)	22a Total Flood Cost (£) *(Box 21a * box 22)*
0	**0**	**0**	**0**	**0**
1 - 2				
3 - 5	**0**	**0**	**0**	**0**
6 - 10				
> 10 (10 yr)	**20**	**18**	**1**	**18**
(15 yr)	**40**	**36**	**1**	**36**
(20 yr)	**60**	**54**	**1**	**54**
(25 yr)	**80**	**72**	**1**	**72**
(30 yr)	**100**	**90**	**1**	**90**
			Total	**271**

* *Not necessary unless detailed information and assessment is required*

Flood Return Period (years) 23 **AS ABOVE**

Total Flood Cost (£) 24 **271**

Design
Net Return Less Flood Cost (£) 24a **-7582**
(Box 16 - box 24)

Note: All table numbers and references relate to R&D Note 511, Guidelines for the Justification of River Maintenance

MAINTENANCE REGIME

Widening, change in width, expressed in metres and as a %, (including cutting of banks and emergent vegetation)	25a (m) 0.9	25b (%) 75
Deepening, change in depth, expressed in metres and as a %	26a (m)	26b (%)
Weed cutting, % cover removed (Submerged & floating weed)		27
Change in freeboard, expressed in metres and as a % (Table 8 - 15, & boxes 25, 26, 27)	28a (m) 0.112	28b (%) 13
Change in Qbf, expressed in metres and as a % (Table 8 - 15, & boxes 25, 26, 27)	29a (m)	29b (%)

Note: All table numbers and references relate to R&D Note 511, Guidelines for the Justification of River Maintenance

"DO NOTHING" (WITHOUT MAINTENANCE)

W/o Maintenance Width (m) *(Box 10 - box 25a)* — 30: **0.3**

W/o Maintenance Depth (m) *(Box 11 - box 26a)* — 31: **1**

W/o Maintenance Freeboard (m) *(Box 13 - box 28a)* — 32: **0.59**

W/o Maintenance Watertable Depth (m) *(Box 4, 9, 32, Table 3, Figure 1 or 2)* — 33: **0.25**

W/o Maintenance Drainage Status *(Table 4, box 33)* — 34: **VERY BAD**

Economic Net Return (W/o maintenance) *(Table 5, box 8, 34)*

For either :- Dominant land use (£/ha) — 35: **-103**
£ **-9297**

or :- Varied land use (£/ha)
£

LUT	35b Net Return (£/ha)	35a Weighted Net Return
1		
2		
3		
4		
5		
6		
7		

W/o Maintenance bankfull discharge (Qbf) (cumecs) *(Box 17 - box 29)* — 36

* W/o Maintenance Qbf/Q bar (cumecs) *(Box 36 / box 19)* — 37

* Flooding Envelopes * % BA with different flood return periods (years) *(Table 6 or 7, boxes 5, 7, 34)*	FRP (yr.)	38 % area of each LUT that floods	38a Flooded Area (ha)	39 Flood Cost (£/ha)	39a Total Flood Cost (£) *(Box 38a * box 39)*
	0	**0**	**0**	**0**	**0**
	<l				
	1 - 2	**20**	**18**	**10**	**181**
	3 - 5	**40**	**36**	**3**	**108**
	6 - 10 (6 yr)	**60**	**54**	**2**	**108**
	7 - 10 (8 yr)	**80**	**72**	**2**	**144**
	> 10 (10 yr)	**100**	**90**	**1**	**90**
				Total	**632**

* *Not necessary unless detailed information and assessment required*

W/o Maintenance FRP (years) — 40: **AS ABOVE**

Total Flood Cost (£) — 41: **632**

Do-nothing
Net Return Less Flood Cost (£) *(Box 35 - box 41)* — 41a: **-9929**

Note: All table numbers and references relate to R&D Note 511, Guidelines for the Justification of River Maintenance

MAINTENANCE EXPENDITURE

Maintenance Activity	42 Unit Cost (£)	43 No. of Units (specify)	44 Cost/Reach/ Activity (£)	45 Interval Between Maintenance Activities (years)	46 Amortisation Value at 6 % Discount Rate *(Box 45, Table 18)*	47 Annual Cost (£) *(Box 44 * box 46)*
Weedcutting						763

	Total annual cost/reach (£)	*(Sum box 47)*		48	763
	Benefit Area (ha)	*(Box 6)*		49	90.26
	Total annual maintenance cost/ha	*(Box 48 / box 49)*		50	8.5

BENEFITS OF MAINTENANCE

Design Standard (With maintenance)	Net return less flood costs	*(Box 24a)*	(£)	51	-7582
Do Nothing (Without maintenance)	Net return less flood costs	*(Box 41a)*	(£)	52	-9929
Change in Net Benefit Due to Maintenance		*(Box 51 - box 52)*	(£)	53	2347
Net Benefit of Maintenance	Change in net benefit less total annual maintenance costs	*(Box 53 - box 49 or 50)*	(£)	54	1584
	Benefit : cost ratio	*(Box 53/box 48)*			3.08

Note: All table numbers and references relate to R&D Note 511, Guidelines for the Justification of River Maintenance

APPENDIX VIII

1. FFYNNON-Y-DDOL

1.1 Introduction

This Appendix presents the results of the application of FDMM and the Guidelines to the Ffynnon-y-ddol and its tributaries, in the Vale of Clwyd, North Wales.

1.2 Vale of Clwyd

1.2.1 Channel characteristics and drainage network

The Afon Clwyd rises in the peaty uplands of the Clocaenog forest to the south west of Ruthin. It flows northwards through the Vale of Clwyd and discharges into Liverpool Bay at Rhyl. The Vale of Clwyd is drained by numerous tributaries of the Afon Clwyd and a comprehensive network of drainage ditches.

1.2.2 Catchment characteristics

This predominantly upland catchment is rural in character. Land use consists of predominantly permanent pasture which is quite productive. However, rushes reduce the herbage value on the wetter land. The flat valley floor is grazed by beef (store cattle) and sheep and is cut for hay and silage. Small areas of extensive arable are found to the west of Towyn and near Rhuddlan. Silage crops such as sweetcorn are commonly grown. Winter wheat is occasionally used as a break crop before reseeding grassland.

The Afon Clwyd is situated within a rift valley of Triassic age. It is bounded to the east and west by older and harder rocks of Silurian age. Soils of the Wallasea association are found at the mouth of the Vale of Clwyd (Rudeforth et al, 1984). High groundwater levels may cause severe waterlogging, although this has been alleviated somewhat by the intensive drainage network. The Salop association dominates the Vale of Clwyd away from the mouth. These stagnogley soils are slowly permeable and seasonally waterlogged. They are at risk from poaching (surface damage by livestock) and compaction which may reduce grass growth.

1.2.3 River maintenance

The channel of the Afon Clwyd is not subject to regular maintenance. Tree and bush work and debris and rubbish removal is carried out as required and is not scheduled on a regular basis.

Some tributaries are subject to annual weed removal during the autumn and winter. A Bradshaw Bucket is used to cut the bed and bank vegetation in one operation. All the aquatic vegetation is removed. Prior to maintenance, the channels are usually choked by emergent weeds with 100% of the water surface covered by vegetation. *Phragmites* (Common Reed), *Apium* (Fool's Water-cress) and Blanket weed (Cott) are the dominant types. The culverts and reaches which are inaccessible by machinery are cut by hand.

1.2.4 Study area

The study area is the catchment of the Ffynnon-y-ddol and its tributaries (Figure 1). The Ffynnon-y-ddol is 5.69 km in length, a tributary of the Afon Clwyd and runs broadly parallel to the coast of North Wales. It discharges into the Afon Clwyd via the Clwyd pumping station. The tributaries all discharge under gravity into the Ffynnon-y-ddol with the exception of the Pensarn Drain which is pumped into the Ffynnon-y-ddol via the Belgrano pumping station.

The catchment of the Ffynnon-y-ddol is bounded to the east and north by the Afon Clywd and the North Wales coast respectively. The embankment on the left bank of the Afon Gele forms the southern and western boundary to the Ffynnon-y-ddol catchment.

The Ffynnon-y-ddol is culverted through the southern area of Towyn. The main river branches into three: Ffynnon-y-ddol Dyke Farm, Ffynnon-y-ddol Gors Branch and Ffynnon-y-ddol Kinmel Way. These provide alternative routes for the Ffynnon-y-ddol should one culvert become blocked. In an emergency, if levels in the Ffynnon-y-ddol are dangerously high and providing there is sufficient capacity in the Afon Gele, the flap valves may be opened in the bank of the Afon Gele to allow the Gors Branch leg of the Ffynnon-y-ddol to discharge into it.

Three watercourses: Towyn Splashover Drain, Splashover Towyn East and Splashover Towyn West, serve the north of Towyn. Their purpose is to remove runoff and to provide a route for sea water should a breach of the sea defences occur.

1.3 Application of FDMM to the Ffynnon-y-ddol and tributaries

1.3.1 Area of benefit

The catchment of the Ffynnon-y-ddol is not subject to flooding. The channel has been designed to contain flood flows with a return period of 100 years. No historical records of fluvial flooding are documented. The benefits of maintenance are therefore based purely on the benefits to land drainage.

1.3.2 Land use assessment: drainage

Approximately 482 ha of the Ffynnon-y-ddol catchment is under agricultural land use. Of this area, following a visual survey of the catchment and through discussions with the Environment Agency, it is estimated that 85 ha experiences good drainage under the current maintenance regime. The remaining area (397 ha) experiences bad drainage. The drainage benefit area for each watercourse within the Ffynnon-y-ddol catchment is shown in Table 1.

According to the procedure defined in FDMM (p3/21), the area of each land use type subject to bad and very bad drainage has been weighted by the appropriate factor (e.g. 1.1 for extensive pasture, FDMM p3/22) to determine the drainage score. This drainage score represents the level of damage caused by waterlogging.

The drainage score for each watercourse is shown in Table 1. Full details are shown at the end of this Appendix. The Ffynnon-y-ddol Kinmel Way is excluded from the drainage score analysis because this watercourse is culverted for its entire length and hence is not assigned a drainage benefit area. Similarly the left bank of the Green Avenue Drain is excluded from the analysis as this borders the Afon Clwyd and also has no drainage benefit area.

Table 1 Drainage score for the Ffynnon-y-ddol and tributaries

Watercourse	Bank	Drainage Benefit Area (ha)	Effective Reach Length (km)	Drainage Score (HE/km/yr)
Ffynnon-y-ddol	LB	101.90	5.69	0.25
	RB	249.10	5.69	0.56
Ffynnon-y-ddol - Dyke Farm	LB	0.48	0.148	0.08
	RB	0.92	0.148	0.55
Ffynnon-y-ddol - Gors Branch	LB	1.52	0.479	0.04
	RB	4.27	0.479	0.12
Ffynnon-y-ddol - Holland Drive	LB	21.27	0.27	1.10
	RB	3.90	0.27	0.20
Pensarn Drain	LB	16.81	0.687	0.34
	RB	17.57	0.687	0.36
Towyn Splashover Drain	LB	7.80	1.05	0.10
	RB	13.60	1.05	0.18
Towyn Splashover East	LB	1.89	0.517	0.05
	RB	11.48	0.517	0.31
Towyn Splashover West	LB	9.87	1.073	0.13
	RB	1.98	1.073	0.03
Green Avenue Drain	RB	17.44	1.15	0.21

Note: Figures are subject to rounding

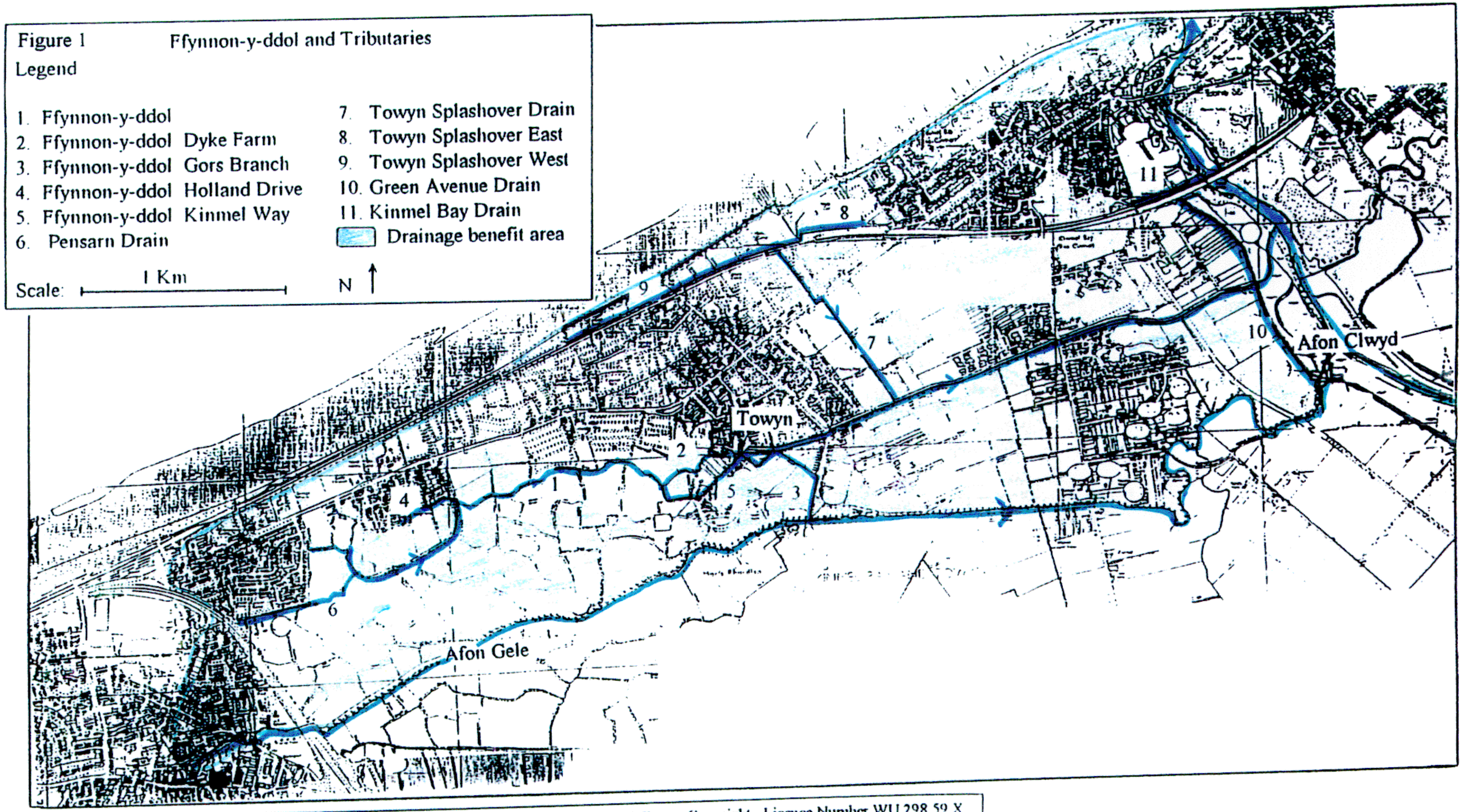


Figure 1 Ffynnon-y-ddol and Tributaries

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1.3.3 Actual standard of service

An indication of the adequacy of the existing maintenance regime with respect to set Standards of Service (SoS) is provided by combining the flood score and drainage score. As the area is not subject to flooding and as no flood risk area is defined, the actual SoS is based purely on the drainage score (HE/km/yr) for the current, with maintenance situation.

Comparison of the total score with a target score of 0.5-1.0 HE/km/yr (FDMM p3/24) enables the current level of service provided to be determined. This on target standard (OTS) of 0.5-1 HE/km/yr was derived by the Environment Agency, based on analysis of existing SoS.

The right banks of the Ffynnon-y-ddol and Ffynnon-y-ddol Dyke Farm are on target (Table 1). Only one watercourse, the Ffynnon-y-ddol Holland Drive is described as being below target in the SoS provided. The standard of service provided by most of the watercourses shown in Table 1 may be described as above target. This is largely due to the very short effective reach lengths.

1.3.4 Determining the effect of deterioration in drainage

To determine the effect of inadequate drainage on land use, the predictive technique was used (see record sheets at end of this Appendix). No historical records exist therefore this technique could not be applied. In the absence of maintenance, the drainage status is predicted to deteriorate by one class.

The annual benefit of preventing a deterioration in drainage status is calculated from the area affected (ha) multiplied by the annual benefit (£/ha) to be gained from preventing the deterioration. Drainage benefits are summarised in Table 2. Full details are presented at the end of this Appendix.

Table 2 Drainage benefits, Ffynnon-y-ddol and tributaries

Watercourse	Annual Drainage Benefit (£)
Ffynnon-y-ddol	15160
Ffynnon-y-ddol - Dyke Farm	56
Ffynnon-y-ddol - Gors Branch	233
Ffynnon-y-ddol - Holland Drive	1012
Ffynnon-y-ddol - Kinmel Way	0
Pensarn Drain	1379
Towyn Splashover Drain	859
Towyn Splashover East	536
Towyn Splashover West	476
Green Avenue Drain	700

Note: Figures are subject to rounding. 1997/98 prices are used.

1.3.5 Justification

Justification of the maintenance scheme is undertaken using a comparison of the benefits and costs of maintenance in a simple benefit:cost ratio.

The total maintenance expenditure (1997/98 prices) of the Environment Agency on the Ffynnon-y-ddol and tributaries is shown in Table 3. Further details are presented in at the end of this Appendix. The total benefits of maintenance and the benefit:cost ratio are also shown in Table 3.

The current maintenance regime is justified on six of the nine watercourses (66 %) and marginal on the Towyn Splashover West. The Ffynnon-y-ddol Kinmel Way which is culverted and Kinmel Bay Drain which is partly culverted and partly a lagoon have been included in the analysis as a system approach has been adopted whereby the Ffynnon-y-ddol and all its tributaries are considered. If maintenance were not carried out on these culverts, blockages may occur, causing water to back-up upstream with a concomitant impact on drainage status and the connected watercourses.

If the total annual benefits of maintenance on the Ffynnon-y-ddol and its tributaries (£20411, 1997/98 economic prices) are compared with the total annual maintenance expenditure (£9476, 1997/98 prices), the current maintenance regime may be justified with a benefit:cost ratio of 2.2.

Table 3 Benefit:cost ratio, Ffynnon-y-ddol and tributaries

Watercourse	Annual Benefit (£)	Annual Maintenance Cost (£)	Benefit:Cost Ratio
Ffynnon-y-ddol	15160	4769	3.2
Ffynnon-y-ddol - Dyke Farm	56	733	0.1
Ffynnon-y-ddol - Gors Branch	233	1095	0.2
Ffynnon-y-ddol - Holland Drive	1012	95	10.7
Ffynnon-y-ddol - Kinmel Way	0	366	0.0
Pensarn Drain	1379	412	3.3
Towyn Splashover Drain	859	457	1.9
Towyn Splashover East	536	366	1.5
Towyn Splashover West	476	525	0.9
Green Avenue Drain	700	582	1.2
Kinmel Bay Drain	0	76	0.0
Total	20411	9476	2.2

Note: Figures are subject to rounding. 1997/98 prices are used.

1.4 Sensitivity Analysis

1.4.1 Maintenance costs

In accordance with FDMM, maintenance expenditure has been increased by 15% and the benefits reduced by 15% in order to check the sensitivity of assumptions made on the benefit:cost ratio. The results of this are shown in Table 4. If these results are compared with the actual benefits and costs shown in Table 3, the same six maintenance schemes remain justified. The benefit:cost ratios therefore of this watercourse system are therefore relatively insensitive to assumptions made.

Table 4 Sensitivity analysis: benefit:cost ratio, Ffynnon-y-ddol and tributaries

Watercourse	Benefit (£)	Cost (£) Increased 15%	B:C Ratio	Benefit (£) Reduced 15%	B:C Ratio	Benefits Reduced 15% Costs Increased 15% B:C Ratio
Ffynnon-y-ddol	15160	5484	2.8	12886	2.7	2.3
Ffynnon-y-ddol - Dyke Farm	56	843	0.1	48	0.1	0.1
Ffynnon-y-ddol - Gors Branch	233	1259	0.2	198	0.2	0.2
Ffynnon-y-ddol - Holland Drive	1012	109	9.3	860	9.1	7.9
Ffynnon-y-ddol - Kinmel Way	0	421	0	0	0	0
Pensarn Drain	1379	474	2.9	1172	2.8	2.5
Towyn Splashover Drain	859	526	1.6	730	1.6	1.4
Towyn Splashover East	536	421	1.3	456	1.2	1.1
Towyn Splashover West	476	604	0.8	405	0.8	0.7
Green Avenue Drain	700	669	1.0	595	1.0	0.9
Kinmel Bay Drain	0	87	0	0	0	0

Note: Figures are subject to rounding. 1997/98 prices are used.

1.5 Application of the Guidelines to the Ffynnon-y-ddol and tributaries

1.5.1 Introduction

The following sections present the results of the application of the Guidelines to the Ffynnon-y-ddol and its tributaries. The same data are used as in the application of FDMM in order that results from the two methods may be compared. The completed record sheets and tables/figures required in the use of the Guidelines are presented at the end of this Appendix.

1.5.2 General information

Dominant substrate

Following rapid survey of the watercourse and discussions with the Environment Agency, the dominant substrate of the Ffynnon-y-ddol and tributaries is classed as clay.

Floodplain topography

The floodplain of the Ffynnon-y-ddol catchment is classed as flat with a slope of < 1%.

Catchment size

The catchment area of the Ffynnon-y-ddol and its tributaries is described as small (< 2500 ha).

Benefit area

The area benefiting from maintenance in terms of its impact on land drainage is taken to be the same as that identified using FDMM. This benefit area for each watercourse is listed in Table 5. The left and right banks are not treated separately in the Guidelines.

Table 5 Benefit areas

Watercourse	Benefit Area (ha)
Ffynnon-y-ddol	351
Ffynnon-y-ddol - Dyke Farm	1.4
Ffynnon-y-ddol - Gors Branch	5.8
Ffynnon-y-ddol - Holland Drive	25.2
Pensarn Drain	34.4
Towyn Splashover Drain	21.4
Towyn Splashover East	13.4
Towyn Splashover West	11.9
Green Avenue Drain	17.4

Note: Figures are subject to rounding.

Land use type

Following site survey, the land use type is split between extensive pasture (LUT 1), which is grazed by beef and sheep and intensive pasture (LUT 2). A small area of land under a grass/arable rotation (LUT 3) lies within the benefit area of the Ffynnon-y-ddol. Full details are presented in the Guideline record sheets at the end of this Appendix.

Dominant soil type

From a rapid assessment of the benefit area and using secondary data sources (SSEW 1980), the dominant soil type is identified as clay loam for all benefit areas except those relating to the Towyn Splashover Drain, East and West. These soils are predominantly clay.

1.5.3 Design standard (maintained condition)

Average bed width and average channel depth

The average bed widths and channel depths range from 0.8-2.2 m and 1.5-2.5 m respectively. These parameters were measured by the NRA and predecessors. Further details may be found at the end of this Appendix in the Guidelines record sheets.

Freeboard

The average freeboard under conditions of mean spring flow ranges from 1.2-2.1 m according to the watercourse concerned. This parameter was measured by the NRA and predecessors.

Watertable depth and drainage status

The watertable depths associated with the flat floodplain, clay loam and clay soils and freeboard of each watercourse are estimated from Figure 2.6 in the main text. The drainage status associated with these watertable depth is shown in Table 6.

Economic net return

Using the varied land use type of extensive pasture, intensive pasture and grass/arable rotation and the drainage status previously identified, the total annual economic net return associated with the benefit area of each watercourse is shown in Table 7.

Table 6 Drainage status with maintenance

Watercourse	Drainage Status With Maintenance
Ffynnon-y-ddol	Bad
Ffynnon-y-ddol - Dyke Farm	Bad
Ffynnon-y-ddol - Gors Branch	Good
Ffynnon-y-ddol - Holland Drive	Bad
Pensarn Drain	Bad
Towyn Splashover Drain	Bad
Towyn Splashover East	Bad
Towyn Splashover West	Very bad
Green Avenue Drain	Bad

Table 7 Economic net return according to drainage status

Watercourse	Annual Economic Net Return (£) With Maintenance
Ffynnon-y-ddol	7554
Ffynnon-y-ddol - Dyke Farm	1
Ffynnon-y-ddol - Gors Branch	147
Ffynnon-y-ddol - Holland Drive	10
Pensarn Drain	15
Towyn Splashover Drain	11
Towyn Splashover East	6
Towyn Splashover West	-527
Green Avenue Drain	7
Total, for all watercourses	7214

Note: Figures are subject to rounding. 1997/98 prices are used.

Bankfull discharge

As the benefit area is not prone to flooding, the bankfull discharge need to be calculated.

Flood costs

The benefit area is not prone to flooding, therefore flood costs are not identified.

Design standard benefit area value

The value of the benefit area under the current maintenance regime is shown by the total of the drainage benefits. These are shown in Table 7 for each watercourse and for the system as a whole.

1.5.4 Maintenance regime

It is assumed that maintenance increases the channel width by 50% through removal of emergent vegetation.

The impact of widening the channel on freeboard was calculated using Table 2.8 in the main text. Assuming an increase in width of 50%, the corresponding increase in freeboard is 9%. The impact of maintenance on freeboard is shown for each watercourse in the Guideline record sheets at the end of this Appendix.

1.5.5 Do-nothing (without maintenance)

Drainage status

The change in freeboard as a consequence of maintenance is used to determine the watertable depth and the corresponding drainage status which would prevail in the absence of maintenance. Using Figure 2.6 in the main text, the without maintenance drainage status for each watercourse has been assessed, as shown in Table 8.

Economic net return

Using the varied land use types and drainage status identified in Table 8, the annual economic net return for the benefit area of each watercourse is shown in Table 9. This provides an indication of the value of the benefit area under a 'without' maintenance situation.

Table 8 Drainage status without maintenance

Watercourse	Drainage Status With Maintenance
Ffynnon-y-ddol	Very bad
Ffynnon-y-ddol - Dyke Farm	Very bad
Ffynnon-y-ddol - Gors Branch	Bad
Ffynnon-y-ddol - Holland Drive	Very bad
Pensarn Drain	Very bad
Towyn Splashover Drain	Very bad
Towyn Splashover East	Very bad
Towyn Splashover West	Very bad
Green Avenue Drain	Very bad

Table 9 Economic net return according to drainage status

Watercourse	Annual Economic Net Return (£) Without Maintenance
Ffynnon-y-ddol	-10190
Ffynnon-y-ddol - Dyke Farm	-62
Ffynnon-y-ddol - Gors Branch	4
Ffynnon-y-ddol - Holland Drive	-1124
Pensarn Drain	-1532
Towyn Splashover Drain	-952
Towyn Splashover East	-596
Towyn Splashover West	-527
Green Avenue Drain	-778
Total, for all watercourses	-15757

Note: Figures are subject to rounding. 1997/98 prices are used.

1.5.6 Maintenance costs

As identified in Section 1.3.5, the total annual maintenance expenditure on the Ffynnon-y-ddol and tributaries is £9476 (1997/98 prices).

1.5.7 Benefit of maintenance

The difference in value of the benefit area 'with' and 'without' maintenance is used to determine the benefit of maintenance. From the figures presented in Tables 7 and 9, the benefit of maintenance is calculated to be £22981 for the catchment as a whole. Further details are presented in the Guideline record sheets at the end of this Appendix.

1.5.8 Justification

If the catchment is taken as a whole, with the benefits of maintenance in each drainage benefit area summed, the net benefit of maintenance (£22981) is greater than the annual maintenance expenditure (£9476), therefore the maintenance regime may be justified. The benefit:cost ratio is 2.4.

If the watercourses are looked at individually, the current maintenance regime may be justified on six of the 11; the same six watercourses which were justified using FDMM.

FFYNNON-Y-DDOL

Order of record sheets presented in the following pages:

FDMM

Annual maintenance costs

Drainage score

Drainage benefits

GUIDELINES

General information

Design standard

Maintenance regime

'Do-nothing' - Without maintenance

Maintenance expenditure and benefits of maintenance

ANNUAL MAINTENANCE COSTS

Ffynnon-y-ddol and tributaries
1997/98 prices

Watercourse	Annual Maintenance Cost (£)	
Ffynnon-y-ddol	4769	
Ffynnon-y-ddol - Dyke Farm	733	
Ffynnon-y-ddol - Gors Branch	1095	
Ffynnon-y-ddol - Holland Drive	95	
Ffynnon-y-ddol - Kinmel Way	366	
Pensarn Drain	412	
Towyn Splashover Drain	457	
Towyn Splashover East	366	
Towyn Splashover West	525	
Green Avenue Drain	582	
Kinmel Bay Drain	76	
Clwyd pumping station		
annual maintenance	3232	
electricity (approximate cost)		2000
Belgrano pumping station		
annual maintenance	3232	
electricity (approximate cost)		2000
Maintenance of assets		
flap valves	1008	
grids (weed screens)	860	
Total annual maintenance costs (excluding pumping station running costs)	17808	
Total annual maintenance costs (excluding pumping station running costs and maintenance of assets)	15940	
Total		21808

Source: Environment Agency (Welsh Region)

DRAINAGE

Watercourse	**Ffynnon-y-ddol**
Bank	**LB**
Drainage benefit area (ha)	101.9
Effective reach length (km)	5.69
Floodplain topography	Flat
Predominant soil type	Heavy
Drainage system	Developed ditch

a Land use type	Forestry scrub	Extensive pasture	Intensive pasture	Extensive arable	Intensive arable
b Drainage benefit area (100 ha)	0	0.76	0.26	0	0
c Area subject to 'poor' drainage status, under the current maintenance regime (100 ha)	0	0.76	0.13	0	0
d Losses due to poor drainage status	0	1.1	4.5	3.6	9.7
e Losses per land use type (c * d)	0	0.84	0.57	0.00	0
f Total losses for reach (HE/yr)	1.41				
g Drainage score (HE/km/yr) (f / effective reach length)	0.25				

Watercourse	**Ffynnon-y-ddol**
Bank	**RB**
Drainage benefit area (ha)	249.1
Effective reach length (km)	5.69
Floodplain topography	Flat
Predominant soil type	Heavy
Drainage system	Developed ditch

a Land use type	Forestry scrub	Extensive pasture	Intensive pasture	Extensive arable	Intensive arable
b Drainage benefit area (100 ha)	0	1.62	0.62	0.25	0
c Area subject to 'poor' drainage status, under the current maintenance regime (100 ha)	0	1.62	0.31	0	0
d Losses due to poor drainage status	0	1.1	4.5	3.6	9.7
e Losses per land use type (c * d)	0	1.78	1.40	0	0
f Total losses for reach (HE/yr)	3.18				
g Drainage score (HE/km/yr) (f / effective reach length)	0.56				

Note: Based on data collected by WS Atkins, for the Environment Agency Welsh Region, 1996/97.
Losses due to poor drainage status are the waterlogging damage factors presented in FDMM, p3/22 Table 3.9.
Figures are subject to rounding.

DRAINAGE

Watercourse	**Ffynnon-y-ddol Dyke Farm**
Bank	**LB**
Drainage benefit area (ha)	0.48
Effective reach length (km)	0.148
Floodplain topography	Flat
Predominant soil type	Heavy
Drainage system	Developed ditch

a	Land use type	Forestry scrub	Extensive pasture	Intensive pasture	Extensive arable	Intensive arable
b	Drainage benefit area (100 ha)	0	0.004	0.004	0	0
c	Area subject to 'poor' drainage status, under the current maintenance regime (100 ha)	0	0.004	0.002	0	0
d	Losses due to poor drainage status	0	1.1	4.5	3.6	9.7
e	Losses per land use type (c * d)	0	0.00	0.01	0	0
f	Total losses for reach (HE/yr)	0.01				
g	Drainage score (HE/km/yr) (f / effective reach length)	0.08				

Watercourse	**Ffynnon-y-ddol Dyke Farm**
Bank	**RB**
Drainage benefit area (ha)	0.92
Effective reach length (km)	0.148
Floodplain topography	Flat
Predominant soil type	Heavy
Drainage system	Developed ditch

a	Land use type	Forestry scrub	Extensive pasture	Intensive pasture	Extensive arable	Intensive arable
b	Drainage benefit area (100 ha)	0	0.007	0.002	0	0
c	Area subject to 'poor' drainage status, under the current maintenance regime (100 ha)	0	0.069	0.001	0	0
d	Losses due to poor drainage status	0	1.1	4.5	3.6	9.7
e	Losses per land use type (c * d)	0	0.08	0.01	0	0
f	Total losses for reach (HE/yr)	0.08				
g	Drainage score (HE/km/yr) (f / effective reach length)	0.55				

Note: Based on data collected by WS Atkins, for the Environment Agency Welsh Region, 1996/97.
Losses due to poor drainage status are the waterlogging damage factors presented in FDMM, p3/22 Table 3.9.
Figures are subject to rounding.

DRAINAGE

Watercourse	**Ffynnon-y-ddol Gors Branch**
Bank	**LB**
Drainage benefit area (ha)	1.52
Effective reach length (km)	0.479
Floodplain topography	Flat
Predominant soil type	Heavy
Drainage system	Developed ditch

	Forestry scrub	Extensive pasture	Intensive pasture	Extensive arable	Intensive arable
a Land use type					
b Drainage benefit area (100 ha)	0	0.011	0.004	0	0
c Area subject to 'poor' drainage status, under the current maintenance regime (100 ha)	0	0.011	0.002	0	0
d Losses due to poor drainage status	0	1.1	4.5	3.6	9.7
e Losses per land use type (c * d)	0	0.01	0.01	0	0
f Total losses for reach (HE/yr)	0.02				
g Drainage score (HE/km/yr) (f / effective reach length)	0.04				

Watercourse	**Ffynnon-y-ddol Gors Branch**
Bank	**RB**
Drainage benefit area (ha)	4.271
Effective reach length (km)	0.479
Floodplain topography	Flat
Predominant soil type	Heavy
Drainage system	Developed ditch

	Forestry scrub	Extensive pasture	Intensive pasture	Extensive arable	Intensive arable
a Land use type					
b Drainage benefit area (100 ha)	0	0.032	0.011	0	0
c Area subject to 'poor' drainage status, under the current maintenance regime (100 ha)	0	0.032	0.005	0	0
d Losses due to poor drainage status	0	1.1	4.5	3.6	9.7
e Losses per land use type (c * d)	0	0.04	0.02	0	0
f Total losses for reach (HE/yr)	0.06				
g Drainage score (HE/km/yr) (f / effective reach length)	0.12				

Note: Based on data collected by WS Atkins, for the Environment Agency Welsh Region, 1996/97.
Losses due to poor drainage status are the waterlogging damage factors presented in FDMM, p3/22 Table 3.9.
Figures are subject to rounding.

DRAINAGE

Watercourse	**Ffynnon-y-ddol Holland Drive**
Bank	**LB**
Drainage benefit area (ha)	21.27
Effective reach length (km)	0.27
Floodplain topography	Flat
Predominant soil type	Heavy
Drainage system	Developed ditch

a Land use type	Forestry scrub	Extensive pasture	Intensive pasture	Extensive arable	Intensive arable
b Drainage benefit area (100 ha)	0	0.16	0.05	0	0
c Area subject to 'poor' drainage status, under the current maintenance regime (100 ha)	0	0.16	0.03	0	0
d Losses due to poor drainage status	0	1.1	4.5	3.6	9.7
e Losses per land use type (c * d)	0	0.18	0.12	0	0
f Total losses for reach (HE/yr)	0.30				
g Drainage score (HE/km/yr) (f / effective reach length)	1.10				

Watercourse	**Ffynnon-y-ddol Holland Drive**
Bank	**RB**
Drainage benefit area (ha)	3.9
Effective reach length (km)	0.27
Floodplain topography	Flat
Predominant soil type	Heavy
Drainage system	Developed ditch

a Land use type	Forestry scrub	Extensive pasture	Intensive pasture	Extensive arable	Intensive arable
b Drainage benefit area (100 ha)	0	0.029	0.010	0	0
c Area subject to 'poor' drainage status, under the current maintenance regime (100 ha)		0.029	0.005	0	0
d Losses due to poor drainage status	0	1.1	4.5	3.6	9.7
e Losses per land use type (c * d)	0	0.03	0.02	0	0
f Total losses for reach (HE/yr)	0.05				
g Drainage score (HE/km/yr) (f / effective reach length)	0.20				

Note: Based on data collected by WS Atkins, for the Environment Agency Welsh Region, 1996/97.
Losses due to poor drainage status are the waterlogging damage factors presented in FDMM, p3/22 Table 3.9.
Figures are subject to rounding.

DRAINAGE

Watercourse	**Ffynnon-y-ddol Kinmel Way**
Bank	**LB**
Drainage benefit area (ha)	0 (Culvert)
Effective reach length (km)	0
Floodplain topography	Flat
Predominant soil type	Heavy
Drainage system	Developed ditch

a Land use type	Forestry scrub	Extensive pasture	Intensive pasture	Extensive arable	Intensive arable
b Drainage benefit area (100 ha)	0	0	0	0	0
c Area subject to 'poor' drainage status, under the current maintenance regime (100 ha)	0	0	0	0	0
d Losses due to poor drainage status	0	1.1	4.5	3.6	9.7
e Losses per land use type (c * d)	0	0	0	0	0
f Total losses for reach (HE/yr)	0				
g Drainage score (HE/km/yr) (f / effective reach length)	0				

Watercourse	**Ffynnon-y-ddol Kinmel Way**
Bank	**LB**
Drainage benefit area (ha)	0 (Culvert)
Effective reach length (km)	0
Floodplain topography	Flat
Predominant soil type	Heavy
Drainage system	Developed ditch

a Land use type	Forestry scrub	Extensive pasture	Intensive pasture	Extensive arable	Intensive arable
b Drainage benefit area (100 ha)	0	0	0	0	0
c Area subject to 'poor' drainage status, under the current maintenance regime (100 ha)	0	0	0	0	0
d Losses due to poor drainage status	0	1.1	4.5	3.6	9.7
e Losses per land use type (c * d)	0	0	0	0	0
f Total losses for reach (HE/yr)	0				
g Drainage score (HE/km/yr) (f / effective reach length)	0				

Note: Based on data collected by WS Atkins, for the Environment Agency Welsh Region, 1996/97.
Losses due to poor drainage status are the waterlogging damage factors presented in FDMM, p3/22 Table 3.9.
Figures are subject to rounding.

DRAINAGE

Watercourse	**Pensarn Drain**
Bank	**LB**
Drainage benefit area (ha)	16.81
Effective reach length (km)	0.687
Floodplain topography	Flat
Predominant soil type	Heavy
Drainage system	Developed ditch

a	Land use type	Forestry scrub	Extensive pasture	Intensive pasture	Extensive arable	Intensive arable
b	Drainage benefit area (100 ha)	0	0.13	0.04	0	0
c	Area subject to 'poor' drainage status, under the current maintenance regime (100 ha)	0	0.13	0.02	0	0
d	Losses due to poor drainage status	0	1.1	4.5	3.6	9.7
e	Losses per land use type (c * d)	0	0.14	0.09	0	0
f	Total losses for reach (HE/yr)	0.23				
g	Drainage score (HE/km/yr) (f / effective reach length)	0.34				

Watercourse	**Pensarn Drain**
Bank	**RB**
Drainage benefit area (ha)	17.57
Effective reach length (km)	0.687
Floodplain topography	Flat
Predominant soil type	Heavy
Drainage system	Developed ditch

a	Land use type	Forestry scrub	Extensive pasture	Intensive pasture	Extensive arable	Intensive arable
b	Drainage benefit area (100 ha)	0	0.13	0.04	0	0
c	Area subject to 'poor' drainage status, under the current maintenance regime (100 ha)	0	0.13	0.02	0	0
d	Losses due to poor drainage status	0	1.1	4.5	3.6	9.7
e	Losses per land use type (c * d)	0	0.15	0.10	0	0
f	Total losses for reach (HE/yr)	0.24				
g	Drainage score (HE/km/yr) (f / effective reach length)	0.36				

Note: Based on data collected by WS Atkins, for the Environment Agency Welsh Region, 1996/97.
Losses due to poor drainage status are the waterlogging damage factors presented in FDMM, p3/22 Table 3.9.
Figures are subject to rounding.

DRAINAGE

Watercourse	**Towyn Splashover Drain**
Bank	**LB**
Drainage benefit area (ha)	7.8
Effective reach length (km)	1.05
Floodplain topography	Flat
Predominant soil type	Heavy
Drainage system	Developed ditch

		Forestry scrub	Extensive pasture	Intensive pasture	Extensive arable	Intensive arable
a	Land use type	Forestry scrub	Extensive pasture	Intensive pasture	Extensive arable	Intensive arable
b	Drainage benefit area (100 ha)	0	0.06	0.02	0	0
c	Area subject to 'poor' drainage status, under the current maintenance regime (100 ha)	0	0.06	0.01	0	0
d	Losses due to poor drainage status	0	1.1	4.5	3.6	9.7
e	Losses per land use type (c * d)	0	0.06	0.04	0	0
f	Total losses for reach (HE/yr)	0.11				
g	Drainage score (HE/km/yr) (f / effective reach length)	0.10				

Watercourse	**Towyn Splashover Drain**
Bank	**RB**
Drainage benefit area (ha)	13.6
Effective reach length (km)	1.05
Floodplain topography	Flat
Predominant soil type	Heavy
Drainage system	Developed ditch

		Forestry scrub	Extensive pasture	Intensive pasture	Extensive arable	Intensive arable
a	Land use type	Forestry scrub	Extensive pasture	Intensive pasture	Extensive arable	Intensive arable
b	Drainage benefit area (100 ha)	0	0.10	0.03	0	0
c	Area subject to 'poor' drainage status, under the current maintenance regime (100 ha)	0	0.10	0.02	0	0
d	Losses due to poor drainage status	0	1.1	4.5	3.6	9.7
e	Losses per land use type (c * d)	0	0.11	0.08	0	0
f	Total losses for reach (HE/yr)	0.19				
g	Drainage score (HE/km/yr) (f / effective reach length)	0.18				

Note: Based on data collected by WS Atkins, for the Environment Agency Welsh Region, 1996/97.
Losses due to poor drainage status are the waterlogging damage factors presented in FDMM, p3/22 Table 3.9.
Figures are subject to rounding.

DRAINAGE

Watercourse	**Towyn Splashover East**
Bank	**LB**
Drainage benefit area (ha)	1.887
Effective reach length (km)	0.517
Floodplain topography	Flat
Predominant soil type	Heavy
Drainage system	Developed ditch

	Forestry scrub	Extensive pasture	Intensive pasture	Extensive arable	Intensive arable
a Land use type					
b Drainage benefit area (100 ha)	0	0.014	0.005	0	0
c Area subject to 'poor' drainage status, under the current maintenance regime (100 ha)	0	0.014	0.002	0	0
d Losses due to poor drainage status	0	1.1	4.5	3.6	9.7
e Losses per land use type (c * d)	0	0.02	0.01	0	0
f Total losses for reach (HE/yr)	0.03				
g Drainage score (HE/km/yr) (f / effective reach length)	0.05				

Watercourse	**Towyn Splashover East**
Bank	**RB**
Drainage benefit area (ha)	11.48
Effective reach length (km)	0.517
Floodplain topography	Flat
Predominant soil type	Heavy
Drainage system	Developed ditch

	Forestry scrub	Extensive pasture	Intensive pasture	Extensive arable	Intensive arable
a Land use type					
b Drainage benefit area (100 ha)	0	0.09	0.03	0	0
c Area subject to 'poor' drainage status, under the current maintenance regime (100 ha)	0	0.09	0.01	0	0
d Losses due to poor drainage status	0	1.1	4.5	3.6	9.7
e Losses per land use type (c * d)	0	0.09	0.06	0	0
f Total losses for reach (HE/yr)	0.16				
g Drainage score (HE/km/yr) (f / effective reach length)	0.31				

Note: Based on data collected by WS Atkins, for the Environment Agency Welsh Region, 1996/97.
Losses due to poor drainage status are the waterlogging damage factors presented in FDMM, p3/22 Table 3.9.
Figures are subject to rounding.

DRAINAGE

Watercourse	**Towyn Splashover West**
Bank	**LB**
Drainage benefit area (ha)	9.871
Effective reach length (km)	1.073
Floodplain topography	Flat
Predominant soil type	Heavy
Drainage system	Developed ditch

	Forestry scrub	Extensive pasture	Intensive pasture	Extensive arable	Intensive arable
a Land use type					
b Drainage benefit area (100 ha)	0	0.07	0.02	0	0
c Area subject to 'poor' drainage status, under the current maintenance regime (100 ha)	0	0.07	0.01	0	0
d Losses due to poor drainage status	0	1.1	4.5	3.6	9.7
e Losses per land use type (c * d)	0	0.08	0.06	0	0
f Total losses for reach (HE/yr)	0.14				
g Drainage score (HE/km/yr) (f / effective reach length)	0.13				

Watercourse	**Towyn Splashover West**
Bank	**RB**
Drainage benefit area (ha)	1.98
Effective reach length (km)	1.073
Floodplain topography	Flat
Predominant soil type	Heavy
Drainage system	Developed ditch

	Forestry scrub	Extensive pasture	Intensive pasture	Extensive arable	Intensive arable
a Land use type					
b Drainage benefit area (100 ha)	0	0.015	0.005	0	0
c Area subject to 'poor' drainage status, under the current maintenance regime (100 ha)	0	0.015	0.002	0	0
d Losses due to poor drainage status	0	1.1	4.5	3.6	9.7
e Losses per land use type (c * d)	0	0.02	0.01	0	0
f Total losses for reach (HE/yr)	0.03				
g Drainage score (HE/km/yr) (f / effective reach length)	0.03				

Note: Based on data collected by WS Atkins, for the Environment Agency Welsh Region, 1996/97.
Losses due to poor drainage status are the waterlogging damage factors presented in FDMM, p3/22 Table 3.9.
Figures are subject to rounding.

DRAINAGE

Watercourse	**Green Avenue Drain**
Bank	**LB**
Drainage benefit area (ha)	0 (Zero as against Afon Clwyd)
Effective reach length (km)	0
Floodplain topography	Flat
Predominant soil type	Heavy
Drainage system	Developed ditch

a Land use type	Forestry scrub	Extensive pasture	Intensive pasture	Extensive arable	Intensive arable
b Drainage benefit area (100 ha)	0	0	0	0	0
c Area subject to 'poor' drainage status, under the current maintenance regime (100 ha)	0	0	0	0	0
d Losses due to poor drainage status	0	1.1	4.5	3.6	9.7
e Losses per land use type (c * d)	0	0	0	0	0
f Total losses for reach (HE/yr)	0				
g Drainage score (HE/km/yr) (f / effective reach length)	0				

Watercourse	**Green Avenue Drain**
Bank	**RB**
Drainage benefit area (ha)	17.44
Effective reach length (km)	1.15
Floodplain topography	Flat
Predominant soil type	Heavy
Drainage system	Developed ditch

a Land use type	Forestry scrub	Extensive pasture	Intensive pasture	Extensive arable	Intensive arable
b Drainage benefit area (100 ha)	0	0.13	0.04	0	0
c Area subject to 'poor' drainage status, under the current maintenance regime (100 ha)	0	0.13	0.02	0	0
d Losses due to poor drainage status	0	1.1	4.5	3.6	9.7
e Losses per land use type (c * d)	0	0.14	0.10	0	0
f Total losses for reach (HE/yr)	0.24				
g Drainage score (HE/km/yr) (f / effective reach length)	0.21				

Note: Based on data collected by WS Atkins, for the Environment Agency Welsh Region, 1996/97.
Losses due to poor drainage status are the waterlogging damage factors presented in FDMM, p3/22 Table 3.9.
Figures are subject to rounding.

DRAINAGE BENEFITS

Watercourse	**Ffynnon-y-ddol**						
Bank	**Left Bank**			**Right Bank**			
Drainage benefit area (ha)	101.9			249.1			
Land use	Ext. pasture	Int. pasture	Int. pasture	Ext. pasture	Int. pasture	Int. pasture	Ext. arable
With maintenance, drainage status	Bad	Good	Bad	Bad	Good	Bad	Good
Without maintenance, drainage status	Very bad	Bad	Very bad	Very bad	Bad	Very bad	Bad
Area affected by deterioration (ha)	76	13	13	162	31	31	25
Annual benefit (£/ha) *	22	75	114	22	75	114	65
Annual benefit per land use type (£) *	1681	956	1454	3564	2336	3551	1619
Total benefit (£) *	15160						

* 1997/98 economic prices Figures are subject to rounding

Watercourse	**Ffynnon-y-ddol Dyke Farm**					
Bank	**Left Bank**			**Right Bank**		
Drainage benefit area (ha)	0.48			0.92		
Land use	Ext. pasture	Int. pasture	Int. pasture	Ext. pasture	Int. pasture	Int. pasture
With maintenance, drainage status	Bad	Good	Bad	Bad	Good	Bad
Without maintenance, drainage status	Very bad	Bad	Very bad	Very bad	Bad	Very bad
Area affected by deterioration (ha)	0.36	0.06	0.06	0.69	0.12	0.12
Annual benefit (£/ha) *	22	75	114	22	75	114
Annual benefit per land use type (£) *	8	5	7	15	9	13
Total benefit (£) *	56					

* 1997/98 economic prices Figures are subject to rounding

Watercourse	**Ffynnon-y-ddol Gors Branch**					
Bank	**Left Bank**			**Right Bank**		
Drainage benefit area (ha)	1.52			4.271		
Land use	Ext. pasture	Int. pasture	Int. pasture	Ext. pasture	Int. pasture	Int. pasture
With maintenance, drainage status	Bad	Good	Bad	Bad	Good	Bad
Without maintenance, drainage status	Very bad	Bad	Very bad	Very bad	Bad	Very bad
Area affected by deterioration (ha)	1.14	0.19	0.19	3.20	0.54	0.54
Annual benefit (£/ha) *	22	75	114	22	75	114
Annual benefit per land use type (£) *	25	14	22	70	40	61
Total benefit (£) *	233					

* 1997/98 economic prices Figures are subject to rounding

Watercourse	**Ffynnon-y-ddol Holland Drive**					
Bank	**Left Bank**			**Right Bank**		
Drainage benefit area (ha)	21.27			3.9		
Land use	Ext. pasture	Int. pasture	Int. pasture	Ext. pasture	Int. pasture	Int. pasture
With maintenance, drainage status	Bad	Good	Bad	Bad	Good	Bad
Without maintenance, drainage status	Very bad	Bad	Very bad	Very bad	Bad	Very bad
Area affected by deterioration (ha)	16.00	2.66	2.66	2.93	0.49	0.49
Annual benefit (£/ha) *	22	75	114	22	75	114
Annual benefit per land use type (£) *	352	200	303	64	37	56
Total benefit (£) *	1012					

* 1997/98 economic prices   Figures are subject to rounding

Watercourse	**Pensarn Drain**					
Bank	**Left Bank**			**Right Bank**		
Drainage benefit area (ha)	16.81			17.57		
Land use	Ext. pasture	Int. pasture	Int. pasture	Ext. pasture	Int. pasture	Int. pasture
With maintenance, drainage status	Bad	Good	Bad	Bad	Good	Bad
Without maintenance, drainage status	Very bad	Bad	Very bad	Very bad	Bad	Very bad
Area affected by deterioration (ha)	12.6	2.1	2.1	13.2	2.2	2.2
Annual benefit (£/ha) *	22	75	114	22	75	114
Annual benefit per land use type (£) *	277	158	239	290	165	250
Total benefit (£) *	1379					

* 1997/98 economic prices   Figures are subject to rounding

Watercourse	**Towyn Splashover Drain**					
Bank	**Left Bank**			**Right Bank**		
Drainage benefit area (ha)	7.8			13.6		
Land use	Ext. pasture	Int. pasture	Int. pasture	Ext. pasture	Int. pasture	Int. pasture
With maintenance, drainage status	Bad	Good	Bad	Bad	Good	Bad
Without maintenance, drainage status	Very bad	Bad	Very bad	Very bad	Bad	Very bad
Area affected by deterioration (ha)	5.85	0.98	0.98	10.20	1.70	1.70
Annual benefit (£/ha) *	22	75	114	22	75	114
Annual benefit per land use type (£) *	129	73	111	224	128	194
Total benefit (£) *	859					

* 1997/98 economic prices   Figures are subject to rounding

Watercourse	**Towyn Splashover East**					
Bank	**Left Bank**			**Right Bank**		
Drainage benefit area (ha)	1.887			11.48		
Land use	Ext. pasture	Int. pasture	Int. pasture	Ext. pasture	Int. pasture	Int. pasture
With maintenance, drainage status	Bad	Good	Bad	Bad	Good	Bad
Without maintenance, drainage status	Very bad	Bad	Very bad	Very bad	Bad	Very bad
Area affected by deterioration (ha)	1.42	0.24	0.24	8.61	1.44	1.44
Annual benefit (£/ha) *	22	75	114	22	75	114
Annual benefit per land use type (£) *	31	18	27	189	108	164
Total benefit (£) *	536					

* 1997/98 economic prices Figures are subject to rounding

Watercourse	**Towyn Splashover West**					
Bank	**Left Bank**			**Right Bank**		
Drainage benefit area (ha)	9.871			1.98		
Land use	Ext. pasture	Int. pasture	Int. pasture	Ext. pasture	Int. pasture	Int. pasture
With maintenance, drainage status	Bad	Good	Bad	Bad	Good	Bad
Without maintenance, drainage status	Very bad	Bad	Very bad	Very bad	Bad	Very bad
Area affected by deterioration (ha)	7.40	1.24	1.24	1.49	0.25	0.25
Annual benefit (£/ha) *	22	75	114	22	75	114
Annual benefit per land use type (£) *	163	93	141	33	19	29
Total benefit (£) *	476					

* 1997/98 economic prices Figures are subject to rounding

Watercourse	**Green Avenue Drain**					
Bank	**Left Bank**			**Right Bank**		
Drainage benefit area (ha)	0			17.44		
Land use	-	-	-	Ext. pasture	Int. pasture	Int. pasture
With maintenance, drainage status	-	-	-	Bad	Good	Bad
Without maintenance, drainage status	-	-	-	Very bad	Bad	Very bad
Area affected by deterioration (ha)	-	-	-	13.1	2.2	2.2
Annual benefit (£/ha) *	-	-	-	22	75	114
Annual benefit per land use type (£) *	-	-	-	288	164	249
Total benefit (£) *	700					

* 1997/98 economic prices Figures are subject to rounding

GENERAL INFORMATION

River 1a **FFYNNON-Y-DDOL**

Reach Code 1b **01**

Reach Length (km) 2 **5.69**

Dominant Substrate Type:-
Gravel, Sand or Silt
(Treat clay as silt) 3 **SILT (CLAY)**

Floodplain -
Rising (>1 %) or Flat (< 1 %) 4 **FLAT**

Catchment Size
Large (> 25 sq. km)
Small (< 25 sq. km) 5 **SMALL**

Benefit Area (ha)
(Area deriving benefit from maintenance) 6 **351**

Dominant Land Use Type (LUT)
(Table 1) 7 -

Dominant Soil Type 9 **CLAY**

Varied Land Use Types (LUT)
(Table 1)

LUT		7 % Benefit Area as decimal	8a Does the LUT flood ?	8b If yes, % that floods (as decimal)
1	Ext grass	**238.4**	**NO**	-
2	Int grass	**87.8**	**NO**	-
3	Grass/arable	**24.9**	**NO**	-
4	All cereals			
5	Cereal/oil seed			
6	Cereal/root			
7	Horticulture			
8	Other			

Note: All table numbers and references relate to R&D Note 511, Guidelines for the Justification of River Maintenance

DESIGN STANDARD

Average Bed Width (m) 10: 2.2

Average Channel Depth (m) 11: 2.5

% Weed Cover (In channel, submerged & floating weed) 12: 0 (Emergent vegetation only)

Freeboard (m) 13: 2

Watertable Depth (m) 14: 0.4
(Box 4, 9, 13 & Figure 1 or 2)

Drainage Status 15: BAD
(Box 14 & Table 4)

Economic Net Return
(Table 5, using Box 7 & Box 15)

For either :- Dominant land use (£/ha) (£) 16:

or :- Varied land use (£/ha) 22
(£) 7554

LUT	16a Net Return (£/ha)	16b Weighted Net Return
1	-81	-19310
2	245	21511
3	215	5354
4		
5		
6		
7		

Bankfull Discharge (Qbf) (cumecs) 17:

* Regional Growth Curve Area 18:
(Figure 3)

* Mean Annual Flood (Q bar) (cumecs) 19:

* Qbf/Q bar (cumecs) 20:
(Box 17 / Box 19)

* Flooding Envelopes
* % BA with different flood return periods (years)
(Table 6 or 7, boxes 5, 7, 15)

FRP (yr)	21 % area of each LUT that floods	21a Flooded Area (ha)	22 Flood Cost (£/ha)	22a Total Flood Cost (£) *(Box 21a * box 22)*
0				
1 - 2				
3 - 5				
6 - 10				
> 10 (10 yr)				
(15 yr)				
(20 yr)				
(25 yr)				
(30 yr)				
			Total	

* *Not necessary unless detailed information and assessment is required*

Flood Return Period (years) 23: N/A

Total Flood Cost (£) 24: 0

Design
Net Return Less Flood Cost (£) 24a: 7554
(Box 16 - box 24)

Note: All table numbers and references relate to R&D Note 511, Guidelines for the Justification of River Maintenance

MAINTENANCE REGIME

	25a (m)	25b (%)
Widening, change in width, expressed in metres and as a %, (including cutting of banks and emergent vegetation)	1.1	50
	26a (m)	26b (%)
Deepening, change in depth, expressed in metres and as a %		
		27
Weedcutting, % cover removed (Submerged & floating weed)		
	28a (m)	28b (%)
Change in freeboard, expressed in metres and as a % (Table 8 - 15, & boxes 25, 26, 27)	0.18	9 (Table 9)
	29a (m)	29b (%)
Change in Qbf, expressed in metres and as a % (Table 8 - 15, & boxes 25, 26, 27)		

Note: All table numbers and references relate to R&D Note 511, Guidelines for the Justification of River Maintenance

"DO NOTHING" (WITHOUT MAINTENANCE)

W/o Maintenance Width (m) 30 **1.1**
(Box 10 - box 25a)

W/o Maintenance Depth (m) 31
(Box 11 - box 26a)

W/o Maintenance Freeboard (m) 32 **1.82**
(Box 13 - box 28a)

W/o Maintenance Watertable Depth (m) 33 **0.25**
(Box 4, 9, 32, Table 3, Figure 1 or 2)

W/o Maintenance Drainage Status 34 **VERY BAD**
(Table 4, box 33)

Economic Net Return (W/o maintenance)
(Table 5, box 8, 34)

			35
For either :-	Dominant land use	(£/ha)	
		£	
or :-	Varied land use	(£/ha)	**-29**
		£	**-10190**

LUT	35b Net Return (£/ha)	35a Weighted Net Return
1	**-103**	**-24555**
2	**131**	**11502**
3	**115**	**2864**
4		
5		
6		
7		

W/o Maintenance bankfull discharge (Qbf) (cumecs) 36
(Box 17 - box 29)

* W/o Maintenance Qbf/Q bar (cumecs) 37
(Box 36 / box 19)

* Flooding Envelopes
* % BA with different flood return periods (years)
(Table 6 or 7, boxes 5, 7, 34)

FRP (yr.)	38 % area of each LUT that floods	38a Flooded Area (ha)	39 Flood Cost (£/ha)	39a Total Flood Cost (£) *(Box 38a * box 39)*
0				
<1				
1 - 2				
3 - 5				
6 - 10 (6 yr)				
7 - 10 (8 yr)				
> 10 (10 yr)				
			Total	

* *Not necessary unless detailed information and assessment required*

W/o Maintenance FRP (years) 40 **N/A**

Total Flood Cost (£) 41 **0**

Do-nothing
Net Return Less Flood Cost (£) 41a **-10190**
(Box 35 - box 41)

Note: All table numbers and references relate to R&D Note 511, Guidelines for the Justification of River Maintenance

MAINTENANCE EXPENDITURE

	42	43	44	45	46	47
Maintenance Activity	Unit Cost (£)	No. of Units (specify)	Cost/Reach/ Activity (£)	Interval Between Maintenance Activities (years)	Amortisation Value at 6 % Discount Rate *(Box 45, Table 18)*	Annual Cost (£) *(Box 44 * box 46)*
						4769

Total annual cost/reach (£)	*(Sum box 47)*		48	**4769**
Benefit Area (ha)	*(Box 6)*		49	**351**
Total annual maintenance cost/ha	*(Box 48 / box 49)*		50	**14**

BENEFITS OF MAINTENANCE

Design Standard (With maintenance)	Net return less flood costs	*(Box 24a)*	(£)	51	**7554**
Do Nothing (Without maintenance)	Net return less flood costs	*(Box 41a)*	(£)	52	**-10190**
Change in Net Benefit Due to Maintenance		*(Box 51 - box 52)*	(£)	53	**17744**
Net Benefit of Maintenance	Change in net benefit less total annual maintenance costs	*(Box 53 - box 49 or 50)*	(£)	54	**12975**
	Benefit : cost ratio	*(Box 53/box 48)*			**3.7**

Note: All table numbers and references relate to R&D Note 511, Guidelines for the Justification of River Maintenance

GENERAL INFORMATION

River (1a) **FFYNNON-Y-DDOL DYKE FARM**

Reach Code (1b) **01**

Reach Length (km) (2) **0.148**

Dominant Substrate Type:-
Gravel, Sand or Silt
(Treat clay as silt) (3) **SILT (CLAY)**

Floodplain -
Rising (>1 %) or Flat (< 1 %) (4) **FLAT**

Catchment Size
Large (> 25 sq. km)
Small (< 25 sq. km) (5) **SMALL**

Benefit Area (ha) (6) **1.4**
(Area deriving benefit from maintenance)

Dominant Land Use Type (LUT)
(Table 1) (7) **-**

Dominant Soil Type (9) **CLAY/LOAM**

Varied Land Use Types (LUT)
(Table 1)

LUT		7 % Benefit Area as decimal	8a Does the LUT flood ?	8b If yes, % that floods (as decimal)
1	Ext grass	**1.05**	**NO**	-
2	Int grass	**0.35**	**NO**	-
3	Grass/arable			
4	All cereals			
5	Cereal/oil seed			
6	Cereal/root			
7	Horticulture			
8	Other			

Note: All table numbers and references relate to R&D Note 511, Guidelines for the Justification of River Maintenance

DESIGN STANDARD

Average Bed Width (m) — 10: **1.9**

Average Channel Depth (m) — 11: **1.5**

% Weed Cover (In channel, submerged & floating weed) — 12: **0** (Emergent vegetation only)

Freeboard (m) — 13: **1.2**

Watertable Depth (m) *(Box 4, 9, 13 & Figure 1 or 2)* — 14: **0.4**

Drainage Status *(Box 14 & Table 4)* — 15: **BAD**

Economic Net Return *(Table 5, using Box 7 & Box 15)*

For either :- Dominant land use — 16: (£/ha) ; (£)

or :- Varied land use — (£/ha) **0.50** ; (£) **0.70**

LUT	16a Net Return (£/ha)	16b Weighted Net Return
1	-81	-85.05
2	245	85.75
3		
4		
5		
6		
7		

Bankfull Discharge (Qbf) (cumecs) — 17:

* Regional Growth Curve Area *(Figure 3)* — 18:

* Mean Annual Flood (Q bar) (cumecs) — 19:

* Qbf/Q bar (cumecs) *(Box 17 / Box 19)* — 20:

* Flooding Envelopes
* % BA with different flood return periods (years)
(Table 6 or 7, boxes 5, 7, 15)

FRP (yr)	21 % area of each LUT that floods	21a Flooded Area (ha)	22 Flood Cost (£/ha)	22a Total Flood Cost (£) *(Box 21a * box 22)*
0				
1 - 2				
3 - 5				
6 - 10				
> 10 (10 yr)				
(15 yr)				
(20 yr)				
(25 yr)				
(30 yr)				
			Total	

* *Not necessary unless detailed information and assessment is required*

Flood Return Period (years) — 23: **N/A**

Total Flood Cost (£) — 24: **0**

Design Net Return Less Flood Cost *(Box 16 - box 24)* (£) — 24a: **1**

Note: All table numbers and references relate to R&D Note 511, Guidelines for the Justification of River Maintenance

MAINTENANCE REGIME

Widening, change in width, expressed in metres and as a %, (including cutting of banks and emergent vegetation)	25a (m) **0.95**	25b (%) **50**	
Deepening, change in depth, expressed in metres and as a %	26a (m)	26b (%)	
Weedcutting, % cover removed (Submerged & floating weed)		27	
Change in freeboard, expressed in metres and as a % (Table 8 - 15, & boxes 25, 26, 27)	28a (m) **0.108**	28b (%) **9**	(Table 9)
Change in Qbf, expressed in metres and as a % (Table 8 - 15, & boxes 25, 26, 27)	29a (m)	29b (%)	

Note: All table numbers and references relate to R&D Note 511, Guidelines for the Justification of River Maintenance

"DO NOTHING" (WITHOUT MAINTENANCE)

30
W/o Maintenance Width (m) **0.95**
(Box 10 - box 25a)

31
W/o Maintenance Depth (m)
(Box 11 - box 26a)

32
W/o Maintenance Freeboard (m) **1.092**
(Box 13 - box 28a)

33
W/o Maintenance Watertable Depth (m) **0.25**
(Box 4, 9, 32, Table 3, Figure 1 or 2)

34
W/o Maintenance Drainage Status **VERY BAD**
(Table 4, box 33)

Economic Net Return (W/o maintenance)
(Table 5, box 8, 34)

35

For either :-	Dominant land use	(£/ha)	
		£	
or :-	Varied land use	(£/ha)	**-45**
		£	**-62**

35b LUT	35a Net Return (£/ha)	Weighted Net Return
1	**-103**	**-108**
2	**131**	**46**
3		
4		
5		
6		
7		

36
W/o Maintenance Bankfull Discharge (Qbf) (cumecs)
(Box 17 - box 29)

37
* W/o Maintenance Qbf/Q bar (cumecs)
(Box 36 / box 19)

* Flooding Envelopes
* % BA with different
flood return periods (years)
(Table 6 or 7, boxes 5, 7, 34)

FRP (yr.)	38 % area of each LUT that floods	38a Flooded Area (ha)	39 Flood Cost (£/ha)	39a Total Flood Cost (£) *(Box 38a * box 39)*
0				
<1				
1 - 2				
3 - 5				
6 - 10 (6 yr)				
7 - 10 (8 yr)				
> 10 (10 yr)				
			Total	

* *Not necessary unless detailed information and assessment required*

40
W/o Maintenance FRP (years) **N/A**

41
Total Flood Cost (£) **0**

41a
Do-nothing
Net Return Less Flood Cost (£) **-62**
(Box 35 - box 41)

Note: All table numbers and references relate to R&D Note 511, Guidelines for the Justification of River Maintenance

MAINTENANCE EXPENDITURE

	42	43	44	45	46	47
Maintenance Activity	Unit Cost (£)	No. of Units (specify)	Cost/Reach/ Activity (£)	Interval Between Maintenance Activities (years)	Amortisation Value at 6 % Discount Rate *(Box 45, Table 18)*	Annual Cost (£) *(Box 44 * box 46)*
						733

	Total annual cost/reach (£)	*(Sum box 47)*		48	**733**
	Benefit Area (ha)	*(Box 6)*		49	**1.4**
	Total annual maintenance cost/ha	*(Box 48 / box 49)*		50	**524**

BENEFITS OF MAINTENANCE

Design Standard (With maintenance)	Net return less flood costs	*(Box 24a)*	(£)	51	**1**
Do Nothing (Without maintenance)	Net return less flood costs	*(Box 41a)*	(£)	52	**-62**
Change in Net Benefit Due to Maintenance		*(Box 51 - box 52)*	(£)	53	**63**
Net Benefit of Maintenance	Change in net benefit less total annual maintenance costs	*(Box 53 - box 49 or 50)*	(£)	54	**-670**
	Benefit : cost ratio	*(Box 53/box 48)*			**0.1**

Note: All table numbers and references relate to R&D Note 511, Guidelines for the Justification of River Maintenance

GENERAL INFORMATION

River (1a): **FFYNNON-Y-DDOL GORS BRANCH**

Reach Code (1b): **01**

Reach Length (km) (2): **0.479**

Dominant Substrate Type:- Gravel, Sand or Silt (Treat clay as silt) (3): **SILT (CLAY)**

Floodplain - Rising (>1 %) or Flat (< 1 %) (4): **FLAT**

Catchment Size Large (> 25 sq. km) Small (< 25 sq. km) (5.0): **SMALL**

Benefit Area (ha) *(Area deriving benefit from maintenance)* (6.0): **5.8**

Dominant Land Use Type (LUT) *(Table 1)* (7): -

Dominant Soil Type (9): **CLAY/LOAM**

Varied Land Use Types (LUT) *(Table 1)*

LUT		7 % Benefit Area as decimal	8a Does the LUT flood ?	8b If yes, % that floods (as decimal)
1	Ext grass	**4.34**	**NO**	-
2	Int grass	**1.45**	**NO**	-
3	Grass/arable			
4	All cereals			
5	Cereal/oil seed			
6	Cereal/root			
7	Horticulture			
8	Other			

Note: All table numbers and references relate to R&D Note 511, Guidelines for the Justification of River Maintenance

DESIGN STANDARD

Average Bed Width (m) — 10: **2.1**

Average Channel Depth (m) — 11: **1.5**

% Weed Cover (In channel, submerged & floating weed) — 12: **0** (Emergent vegetation only)

Freeboard (m) — 13: **1.4**

Watertable Depth (m) — 14: **1.55**
(Box 4, 9, 13 & Figure 1 or 2)

Drainage Status — 15: **GOOD**
(Box 14 & Table 4)

Economic Net Return
(Table 5, using Box 7 & Box 15)

			16
For either :-	Dominant land use	(£/ha)	
		(£)	
or :-	Varied land use	(£/ha)	**25**
		(£)	**147**

LUT	16a Net Return (£/ha)	16b Weighted Net Return
1	**-73**	**-317**
2	**320**	**464**
3		
4		
5		
6		
7		

Bankfull Discharge (Qbf) (cumecs) — 17:

* Regional Growth Curve Area — 18:
(Figure 3)

* Mean Annual Flood (Q bar) (cumecs) — 19:

* Qbf/Q bar (cumecs) — 20:
(Box 17 / Box 19)

* Flooding Envelopes
* % BA with different flood return periods (years)
(Table 6 or 7, boxes 5, 7, 15)

FRP (yr)	21 % area of each LUT that floods	21a Flooded Area (ha)	22 Flood Cost (£/ha)	22a Total Flood Cost (£) *(Box 21a * box 22)*
0				
1 - 2				
3 - 5				
6 - 10				
> 10 (10 yr)				
(15 yr)				
(20 yr)				
(25 yr)				
(30 yr)				
			Total	

* *Not necessary unless detailed information and assessment is required*

Flood Return Period (years) — 23: **N/A**

Total Flood Cost (£) — 24: **0**

Design
Net Return Less Flood Cost (£) — 24a: **147**
(Box 16 - box 24)

Note: All table numbers and references relate to R&D Note 511, Guidelines for the Justification of River Maintenance

MAINTENANCE REGIME

	25a (m)	25b (%)	
Widening, change in width, expressed in metres and as a %, (including cutting of banks and emergent vegetation)	1.05	50	
	26a (m)	26b (%)	
Deepening, change in depth, expressed in metres and as a %			
		27	
Weedcutting, % cover removed (Submerged & floating weed)			
	28a (m)	28b (%)	
Change in freeboard, expressed in metres and as a % (Table 8 - 15, & boxes 25, 26, 27)	0.126	9	(Table 9)
	29a (m)	29b (%)	
Change in Qbf, expressed in metres and as a % (Table 8 - 15, & boxes 25, 26, 27)			

Note: All table numbers and references relate to R&D Note 511, Guidelines for the Justification of River Maintenance

"DO NOTHING" (WITHOUT MAINTENANCE)

30
W/o Maintenance Width (m) **1.05**
(Box 10 - box 25a)

31
W/o Maintenance Depth (m)
(Box 11 - box 26a)

32
W/o Maintenance Freeboard (m) **1.27**
(Box 13 - box 28a)

33
W/o Maintenance Watertable Depth (m) **0.4**
(Box 4, 9, 32, Table 3, Figure 1 or 2)

34
W/o Maintenance Drainage Status **BAD**
(Table 4, box 33)

Economic Net Return (W/o maintenance)
(Table 5, box 8, 34)

35
For either :- Dominant land use (£/ha)
£

or :- Varied land use (£/ha) **1**
£ **4**

35b LUT	35a Net Return (£/ha)	Weighted Net Return
1	**-81**	**-352**
2	**245**	**355**
3		
4		
5		
6		
7		

36
W/o Maintenance bankfull discharge (Qbf) (cumecs)
(Box 17 - box 29)

37
* W/o Maintenance Qbf/Q bar (cumecs)
(Box 36 / box 19)

* Flooding Envelopes
* % BA with different flood return periods (years)
(Table 6 or 7, boxes 5, 7, 34)

FRP (yr.)	38 % area of each LUT that floods	38a Flooded Area (ha)	39 Flood Cost (£/ha)	39a Total Flood Cost (£) *(Box 38a * box 39)*
0				
<1				
1 - 2				
3 - 5				
6 - 10 (6 yr)				
7 - 10 (8 yr)				
> 10 (10 yr)				
			Total	

* *Not necessary unless detailed information and assessment required*

40
W/o Maintenance FRP (years) **N/A**

41
Total Flood Cost (£) **0**

41a
Do-nothing
Net Return Less Flood Cost (£) **4**
(Box 35 - box 41)

Note: All table numbers and references relate to R&D Note 511, Guidelines for the Justification of River Maintenance

MAINTENANCE EXPENDITURE

	42	43	44	45	46	47
Maintenance Activity	Unit Cost (£)	No. of Units (specify)	Cost/Reach/ Activity (£)	Interval Between Maintenance Activities (years)	Amortisation Value at 6 % Discount Rate *(Box 45, Table 18)*	Annual Cost (£) *(Box 44 * box 46)*
						1095

Total annual cost/reach (£)	*(Sum box 47)*	48	1095
Benefit Area (ha)	*(Box 6)*	49	5.8
Total annual maintenance cost/ha	*(Box 48 / box 49)*	50	189

BENEFITS OF MAINTENANCE

Design Standard (With maintenance)	Net return less flood costs	*(Box 24a)*	(£)	51	147
Do Nothing (Without maintenance)	Net return less flood costs	*(Box 41a)*	(£)	52	4
Change in Net Benefit Due to Maintenance		*(Box 51 - box 52)*	(£)	53	143
Net Benefit of Maintenance	Change in net benefit less total annual maintenance costs	*(Box 53 - box 49 or 50)*	(£)	54	-952
	Benefit : cost ratio	*(Box 53/box 48)*			0.1

Note: All table numbers and references relate to R&D Note 511, Guidelines for the Justification of River Maintenance

GENERAL INFORMATION

River 1a **FFYNNON-Y-DDOL HOLLAND DRIVE**

Reach Code 1b **01**

Reach Length (km) 2 **0.27**

Dominant Substrate Type:-
Gravel, Sand or Silt
(Treat clay as silt)
3 **SILT (CLAY)**

Floodplain -
Rising (>1 %) or Flat (< 1 %)
4 **FLAT**

Catchment Size
Large (> 25 sq. km)
Small (< 25 sq. km)
5 **SMALL**

Benefit Area (ha)
(Area deriving benefit from maintenance)
6 **25.2**

Dominant Land Use Type (LUT)
(Table 1)
7 **-**

Dominant Soil Type 9 **CLAY/LOAM**

Varied Land Use Types (LUT)
(Table 1)

LUT		7 % Benefit Area as decimal	8a Does the LUT flood ?	8b If yes, % that floods (as decimal)
1	Ext grass	**18.93**	**NO**	-
2	Int grass	**6.3**	**NO**	-
3	Grass/arable			
4	All cereals			
5	Cereal/oil seed			
6	Cereal/root			
7	Horticulture			
8	Other			

Note: All table numbers and references relate to R&D Note 511, Guidelines for the Justification of River Maintenance

DESIGN STANDARD

Average Bed Width (m) — 10: **1.9**

Average Channel Depth (m) — 11: **1.5**

% Weed Cover (In channel, submerged & floating weed) — 12: **0** (Emergent vegetation only)

Freeboard (m) — 13: **1.2**

Watertable Depth (m) — 14: **0.4**
(Box 4, 9, 13 & Figure 1 or 2)

Drainage Status — 15: **BAD**
(Box 14 & Table 4)

Economic Net Return
(Table 5, using Box 7 & Box 15)

For either :- Dominant land use (£/ha) (£) — 16:

or :- Varied land use (£/ha) **0.4** (£) **10**

LUT	16a Net Return (£/ha)	16b Weighted Net Return
1	-81	-1533
2	245	1544
3		
4		
5		
6		
7		

Bankfull Discharge (Qbf) (cumecs) — 17:

* Regional Growth Curve Area — 18:
(Figure 3)

* Mean Annual Flood (Q bar) (cumecs) — 19:

* Qbf/Q bar (cumecs) — 20:
(Box 17 / Box 19)

* Flooding Envelopes
* % BA with different flood return periods (years)
(Table 6 or 7, boxes 5, 7, 15)

FRP (yr)	21 % area of each LUT that floods	21a Flooded Area (ha)	22 Flood Cost (£/ha)	22a Total Flood Cost (£) *(Box 21a * box 22)*
0				
1 - 2				
3 - 5				
6 - 10				
> 10 (10 yr)				
(15 yr)				
(20 yr)				
(25 yr)				
(30 yr)				
			Total	

* *Not necessary unless detailed information and assessment is required*

Flood Return Period (years) — 23: **N/A**

Total Flood Cost (£) — 24: **0**

Design
Net Return Less Flood Cost (£) — 24a: **10**
(Box 16 - box 24)

Note: All table numbers and references relate to R&D Note 511, Guidelines for the Justification of River Maintenance

MAINTENANCE REGIME

	25a (m)	25b (%)
Widening, change in width, expressed in metres and as a % , (including cutting of banks and emergent vegetation)	**0.95**	**50**
	26a (m)	26b (%)
Deepening, change in depth, expressed in metres and as a %		
		27
Weedcutting, % cover removed (Submerged & floating weed)		
	28a (m)	28b (%)
Change in freeboard, expressed in metres and as a % (Table 8 - 15, & boxes 25, 26, 27)	**0.108**	**9** (Table 9)
	29a (m)	29b (%)
Change in Qbf , expressed in metres and as a % (Table 8 - 15, & boxes 25, 26, 27)		

Note: All table numbers and references relate to R&D Note 511, Guidelines for the Justification of River Maintenance

"DO NOTHING" (WITHOUT MAINTENANCE)

W/o Maintenance Width (m) 30 **0.95**
(Box 10 - box 25a)

W/o Maintenance Depth (m) 31
(Box 11 - box 26a)

W/o Maintenance Freeboard (m) 32 **1.09**
(Box 13 - box 28a)

W/o Maintenance Watertable Depth (m) 33 **0.25**
(Box 4, 9, 32, Table 3, Figure 1 or 2)

W/o Maintenance Drainage Status 34 **VERY BAD**
(Table 4, box 33)

Economic Net Return (W/o maintenance)
(Table 5, box 8, 34)

			35
For either :-	Dominant land use	(£/ha)	
		£	
or :-	Varied land use	(£/ha)	**-45**
		£	**-1124**

LUT	35b Net Return (£/ha)	35a Weighted Net Return
1	**-103**	**-1950**
2	**131**	**825**
3		
4		
5		
6		
7		

W/o Maintenance Bankfull Discharge (Qbf) (cumecs) —
(Box 17 - box 29)

* W/o Maintenance Qbf/Q bar (cumecs) —
(Box 36 / box 19)

* Flooding Envelopes
* % BA with different
flood return periods (years)
(Table 6 or 7, boxes 5, 7, 34)

FRP (yr.)	38 % area of each LUT that floods
0	
<1	
1 - 2	
3 - 5	
6 - 10 (6 yr)	
7 - 10 (8 yr)	
> 10 (10 yr)	

* *Not necessary unless detailed information and assessment re*

W/o Maintenance FRP (years) 40 **N/A**

Total Flood Cost (£) 41 **0**

Do-nothing
Net Return Less Flood Cost (£) 41a **-1124**
(Box 35 - box 41)

Note: All table numbers and references relate to R&D Note 511, Guidelines for the Justification of River Maintenance

MAINTENANCE EXPENDITURE

	42	43	44	45	46	47
Maintenance Activity	Unit Cost (£)	No. of Units (specify)	Cost/Reach/ Activity (£)	Interval Between Maintenance Activities (years)	Amortisation Value at 6 % Discount Rate *(Box 45, Table 18)*	Annual Cost (£) *(Box 44 * box 46)*
						95

	Total annual cost/reach (£)	*(Sum box 47)*		48	95
	Benefit Area (ha)	*(Box 6)*		49	25.2
	Total annual maintenance cost/ha	*(Box 48 / box 49)*		50	4

BENEFITS OF MAINTENANCE

Design Standard (With maintenance)	Net return less flood costs	*(Box 24a)*	(£)	51	10
Do Nothing (Without maintenance)	Net return less flood costs	*(Box 41a)*	(£)	52	-1124
Change in Net Benefit Due to Maintenance		*(Box 51 - box 52)*	(£)	53	1134
Net Benefit of Maintenance	Change in net benefit less total annual maintenance costs	*(Box 53 - box 49 or 50)*	(£)	54	1039
	Benefit : cost ratio	*(Box 53/box 48)*			11.9

Note: All table numbers and references relate to R&D Note 511, Guidelines for the Justification of River Maintenance

GENERAL INFORMATION

River 1a **PENSARN DRAIN**

Reach Code 1b **01**

Reach Length (km) 2 **0.687**

Dominant Substrate Type:-
Gravel, Sand or Silt
(Treat clay as silt)
3 **SILT (CLAY)**

Floodplain -
Rising (>1 %) or Flat (< 1 %)
4 **FLAT**

Catchment Size
Large (> 25 sq. km)
Small (< 25 sq. km)
5 **SMALL**

Benefit Area (ha)
(Area deriving benefit from maintenance)
6 **34.4**

Dominant Land Use Type (LUT)
(Table 1)
7 -

Dominant Soil Type 9 **CLAY/LOAM**

Varied Land Use Types (LUT)
(Table 1)

LUT		7 % Benefit Area as decimal	8a Does the LUT flood ?	8b If yes, % that floods (as decimal)
1	Ext grass	**25.8**	**NO**	-
2	Int grass	**8.59**	**NO**	-
3	Grass/arable			
4	All cereals			
5	Cereal/oil seed			
6	Cereal/root			
7	Horticulture			
8	Other			

Note: All table numbers and references relate to R&D Note 511, Guidelines for the Justification of River Maintenance

DESIGN STANDARD

Average Bed Width (m) — 10: **0.8**

Average Channel Depth (m) — 11: **1.5**

% Weed Cover (In channel, submerged & floating weed) — 12: 0 (Emergent vegetation only)

Freeboard (m) — 13: **1.2**

Watertable Depth (m) *(Box 4, 9, 13 & Figure 1 or 2)* — 14: **0.4**

Drainage Status *(Box 14 & Table 4)* — 15: **BAD**

Economic Net Return *(Table 5, using Box 7 & Box 15)*

			16
For either :-	Dominant land use	(£/ha)	
		(£)	
or :-	Varied land use	(£/ha)	**0.43**
		(£)	**14.75**

LUT	16a Net Return (£/ha)	16b Weighted Net Return
1	**-81**	**-2090**
2	**245**	**2105**
3		
4		
5		
6		
7		

Bankfull Discharge (Qbf) (cumecs) — 17:

* Regional Growth Curve Area *(Figure 3)* — 18:

* Mean Annual Flood (Q bar) (cumecs) — 19:

* Qbf/Q bar (cumecs) *(Box 17 / Box 19)* — 20:

* Flooding Envelopes

* % BA with different flood return periods (years)

(Table 6 or 7, boxes 5, 7, 15)

FRP (yr)	21 % area of each LUT that floods	21a Flooded Area (ha)	22 Flood Cost (£/ha)	22a Total Flood Cost (£) *(Box 21a * box 22)*
0				
1 - 2				
3 - 5				
6 - 10				
> 10 (10 yr)				
(15 yr)				
(20 yr)				
(25 yr)				
(30 yr)				
			Total	

* *Not necessary unless detailed information and assessment is required*

Flood Return Period (years) — 23: **N/A**

Total Flood Cost (£) — 24: **0**

Design Net Return Less Flood Cost *(Box 16 - box 24)* (£) — 24a: **15**

Note: All table numbers and references relate to R&D Note 511, Guidelines for the Justification of River Maintenance

MAINTENANCE REGIME

Widening, change in width, expressed in metres and as a % , (including cutting of banks and emergent vegetation)	25a (m) **0.4**	25b (%) **50**	
Deepening, change in depth, expressed in metres and as a %	26a (m)	26b (%)	
Weedcutting, % cover removed (Submerged & floating weed)		27	
Change in freeboard, expressed in metres and as a % (Table 8 - 15, & boxes 25, 26, 27)	28a (m) **0.108**	28b (%) **9**	(Table 9)
Change in Qbf , expressed in metres and as a % (Table 8 - 15, & boxes 25, 26, 27)	29a (m)	29b (%)	

Note: All table numbers and references relate to R&D Note 511, Guidelines for the Justification of River Maintenance

"DO NOTHING" (WITHOUT MAINTENANCE)

W/o Maintenance Width (m) 30 **0.4**
(Box 10 - box 25a)

W/o Maintenance Depth (m) 31
(Box 11 - box 26a)

W/o Maintenance Freeboard (m) 32 **1.09**
(Box 13 - box 28a)

W/o Maintenance Watertable Depth (m) 33 **0.25**
(Box 4, 9, 32, Table 3, Figure 1 or 2)

W/o Maintenance Drainage Status 34 **VERY BAD**
(Table 4, box 33)

Economic Net Return (W/o maintenance)
(Table 5, box 8, 34)

			35
For either :-	Dominant land use	(£/ha)	
		£	
or :-	Varied land use	(£/ha)	**-45**
		£	**-1532**

LUT	35b Net Return (£/ha)	35a Weighted Net Return
1	**-103**	**-2657**
2	**131**	**1125**
3		
4		
5		
6		
7		

W/o Maintenance Bankfull Discharge (Qbf) (cumecs) 36
(Box 17 - box 29)

* W/o Maintenance Qbf/Q bar (cumecs) 37
(Box 36 / box 19)

* Flooding Envelopes
* % BA with different flood return periods (years)
(Table 6 or 7, boxes 5, 7, 34)

FRP (yr.)	38 % area of each LUT that floods	38a Flooded Area (ha)	39 Flood Cost (£/ha)	39a Total Flood Cost (£) *(Box 38a * box 39)*
0				
<1				
1 - 2				
3 - 5				
6 - 10 (6 yr)				
7 - 10 (8 yr)				
> 10 (10 yr)				
			Total	

* *Not necessary unless detailed information and assessment required*

W/o Maintenance FRP (years) 40 **N/A**

Total Flood Cost (£) 41 **0**

Do-nothing
Net Return Less Flood Cost (£) 41a **-1532**
(Box 35 - box 41)

Note: All table numbers and references relate to R&D Note 511, Guidelines for the Justification of River Maintenance

MAINTENANCE EXPENDITURE

Maintenance Activity	42 Unit Cost (£)	43 No. of Units (specify)	44 Cost/Reach/ Activity (£)	45 Interval Between Maintenance Activities (years)	46 Amortisation Value at 6 % Discount Rate *(Box 45, Table 18)*	47 Annual Cost (£) *(Box 44 * box 46)*
						412

Total annual cost/reach (£)	*(Sum box 47)*		48	**412**
Benefit Area (ha)	*(Box 6)*		49	**34.4**
Total annual maintenance cost/ha	*(Box 48 / box 49)*		50	**12**

BENEFITS OF MAINTENANCE

Design Standard (With maintenance)	Net return less flood costs	*(Box 24a)*	(£)	51	**15**
Do Nothing (Without maintenance)	Net return less flood costs	*(Box 41a)*	(£)	52	**-1532**
Change in Net Benefit Due to Maintenance		*(Box 51 - box 52)*	(£)	53	**1547**
Net Benefit of Maintenance	Change in net benefit less total annual maintenance costs	*(Box 53 - box 49 or 50)*	(£)	54	**1135**
	Benefit : cost ratio	*(Box 53/box 48)*			**3.8**

Note: All table numbers and references relate to R&D Note 511, Guidelines for the Justification of River Maintenance

GENERAL INFORMATION

River	1a	**TOWYN SPLASHOVER DRAIN**	Reach Code	1b **01**

Reach Length (km) — 2 — **1.073**

Dominant Substrate Type:- Gravel, Sand or Silt (Treat clay as silt) — 3 — **SILT (CLAY)**

Floodplain - Rising (>1 %) or Flat (< 1 %) — 4 — **FLAT**

Catchment Size Large (> 25 sq. km) Small (< 25 sq. km) — 5 — **SMALL**

Benefit Area (ha) *(Area deriving benefit from maintenance)* — 6 — **21.4**

Dominant Land Use Type (LUT) *(Table 1)* — 7 — -

Dominant Soil Type — 9 — **CLAY**

Varied Land Use Types (LUT) *(Table 1)*

LUT		7 % Benefit Area as decimal	8a Does the LUT flood ?	8b If yes, % that floods (as decimal)
1	Ext grass	**16.05**	**NO**	-
2	Int grass	**5.35**	**NO**	-
3	Grass/arable			
4	All cereals			
5	Cereal/oil seed			
6	Cereal/root			
7	Horticulture			
8	Other			

Note: All table numbers and references relate to R&D Note 511, Guidelines for the Justification of River Maintenance

DESIGN STANDARD

Average Bed Width (m)	10	1.5
Average Channel Depth (m)	11	2.4
% Weed Cover (In channel, submerged & floating weed)	12	0 (Emergent vegetation only)
Freeboard (m)	13	2
Watertable Depth (m) *(Box 4, 9, 13 & Figure 1 or 2)*	14	0.4
Drainage Status *(Box 14 & Table 4)*	15	BAD

Economic Net Return
(Table 5, using Box 7 & Box 15)

For either :-	Dominant land use	(£/ha) (£)	16	
or :-	Varied land use	(£/ha) (£)		1 11

LUT	16a Net Return (£/ha)	16b Weighted Net Return
1	-81	-1300
2	245	1311
3		
4		
5		
6		
7		

Bankfull Discharge (Qbf) (cumecs)	17	
* Regional Growth Curve Area *(Figure 3)*	18	
* Mean Annual Flood (Q bar) (cumecs)	19	
* Qbf/Q bar (cumecs) *(Box 17 / Box 19)*	20	

* Flooding Envelopes
* % BA with different flood return periods (years)
(Table 6 or 7, boxes 5, 7, 15)

FRP (yr)	21 % area of each LUT that floods	21a Flooded Area (ha)	22 Flood Cost (£/ha)	22a Total Flood Cost (£) *(Box 21a * box 22)*
0				
1 - 2				
3 - 5				
6 - 10				
> 10 (10 yr)				
(15 yr)				
(20 yr)				
(25 yr)				
(30 yr)				
			Total	

* *Not necessary unless detailed information and assessment is required*

Flood Return Period (years)		23	N/A
Total Flood Cost	(£)	24	0
Design Net Return Less Flood Cost *(Box 16 - box 24)*	(£)	24a	11

Note: All table numbers and references relate to R&D Note 511, Guidelines for the Justification of River Maintenance

MAINTENANCE REGIME

	25a (m)	25b (%)	
Widening, change in width, expressed in metres and as a % , (including cutting of banks and emergent vegetation)	0.75	50	
	26a (m)	26b (%)	
Deepening, change in depth, expressed in metres and as a %			
		27	
Weedcutting, % cover removed (Submerged & floating weed)			
	28a (m)	28b (%)	
Change in freeboard, expressed in metres and as a % (Table 8 - 15, & boxes 25, 26, 27)	0.18	9	(Table 9)
	29a (m)	29b (%)	
Change in Qbf , expressed in metres and as a % (Table 8 - 15, & boxes 25, 26, 27)			

Note: All table numbers and references relate to R&D Note 511, Guidelines for the Justification of River Maintenance

"DO NOTHING" (WITHOUT MAINTENANCE)

30 W/o Maintenance Width (m) **0.75**
(Box 10 - box 25a)

31 W/o Maintenance Depth (m)
(Box 11 - box 26a)

32 W/o Maintenance Freeboard (m) **1.82**
(Box 13 - box 28a)

33 W/o Maintenance Watertable Depth (m) **0.2**
(Box 4, 9, 32, Table 3, Figure 1 or 2)

34 W/o Maintenance Drainage Status **VERY BAD**
(Table 4, box 33)

Economic Net Return (W/o maintenance)
(Table 5, box 8, 34)

			35
For either :-	Dominant land use	(£/ha)	
		£	
or :-	Varied land use	(£/ha)	-45
		£	-952

35b LUT	35a Net Return (£/ha)	Weighted Net Return
1	**-103**	**-1653**
2	**131**	**701**
3		
4		
5		
6		
7		

36 W/o Maintenance Bankfull Discharge (Qbf) (cumecs)
(Box 17 - box 29)

37 * W/o Maintenance Qbf/Q bar (cumecs)
(Box 36 / box 19)

* Flooding Envelopes
* % BA with different flood return periods (years)
(Table 6 or 7, boxes 5, 7, 34)

FRP (yr.)	38 % area of each LUT that floods	38a Flooded Area (ha)	39 Flood Cost (£/ha)	39a Total Flood Cost (£) *(Box 38a * box 39)*
0				
<1				
1 - 2				
3 - 5				
6 - 10 (6 yr)				
7 - 10 (8 yr)				
> 10 (10 yr)				
			Total	

* *Not necessary unless detailed information and assessment required*

40 W/o Maintenance FRP (years) **N/A**

41 Total Flood Cost (£) **0**

41a Do-nothing
Net Return Less Flood Cost (£) **-952**
(Box 35 - box 41)

Note: All table numbers and references relate to R&D Note 511, Guidelines for the Justification of River Maintenance

MAINTENANCE EXPENDITURE

	42	43	44	45	46	47
Maintenance Activity	Unit Cost (£)	No. of Units (specify)	Cost/Reach/ Activity (£)	Interval Between Maintenance Activities (years)	Amortisation Value at 6 % Discount Rate *(Box 45, Table 18)*	Annual Cost (£) *(Box 44 * box 46)*
						457

Total annual cost/reach (£)	*(Sum box 47)*	48	457
Benefit Area (ha)	*(Box 6)*	49	21.4
Total annual maintenance cost/ha	*(Box 48 / box 49)*	50	21

BENEFITS OF MAINTENANCE

Design Standard (With maintenance)	Net return less flood costs	*(Box 24a)*	(£)	51	11
Do Nothing (Without maintenance)	Net return less flood costs	*(Box 41a)*	(£)	52	-952
Change in Net Benefit Due to Maintenance		*(Box 51 - box 52)*	(£)	53	963
Net Benefit of Maintenance	Change in net benefit less total annual maintenance costs	*(Box 53 - box 49 or 50)*	(£)	54	506
	Benefit : cost ratio	*(Box 53/box 48)*			2.1

Note: All table numbers and references relate to R&D Note 511, Guidelines for the Justification of River Maintenance

GENERAL INFORMATION

River	1a **TOWYN SPLASHOVER EAST**	Reach Code	1b **01**
Reach Length (km)	2 **0.517**		
Dominant Substrate Type:- Gravel, Sand or Silt (Treat clay as silt)	3 **SILT (CLAY)**		
Floodplain - Rising (>1 %) or Flat (< 1 %)	4 **FLAT**		
Catchment Size Large (> 25 sq. km) Small (< 25 sq. km)	5 **SMALL**		
Benefit Area (ha) *(Area deriving benefit from maintenance)*	6 **13.4**		
Dominant Land Use Type (LUT) *(Table 1)*	7 -		
Dominant Soil Type	9 **CLAY**		

Varied Land Use Types (LUT)
(Table 1)

LUT		7 % Benefit Area as decimal	8a Does the LUT flood ?	8b If yes, % that floods (as decimal)
1	Ext grass	**10.03**	**NO**	-
2	Int grass	**3.34**	**NO**	-
3	Grass/arable			
4	All cereals			
5	Cereal/oil seed			
6	Cereal/root			
7	Horticulture			
8	Other			

Note: All table numbers and references relate to R&D Note 511, Guidelines for the Justification of River Maintenance

DESIGN STANDARD

Average Bed Width (m) — 10: **1.3**

Average Channel Depth (m) — 11: **2.4**

% Weed Cover (In channel, submerged & floating weed) — 12: **0** (Emergent vegetation only)

Freeboard (m) — 13: **2.1**

Watertable Depth (m) *(Box 4, 9, 13 & Figure 1 or 2)* — 14: **0.45**

Drainage Status *(Box 14 & Table 4)* — 15: **BAD**

Economic Net Return
(Table 5, using Box 7 & Box 15)

For either :- Dominant land use (£/ha) (£) — 16:

or :- Varied land use (£/ha) **0.44**
(£) **5.87**

LUT	16a Net Return (£/ha)	16b Weighted Net Return
1	**-81**	**-812**
2	**245**	**818**
3		
4		
5		
6		
7		

Bankfull Discharge (Qbf) (cumecs) — 17:

* Regional Growth Curve Area *(Figure 3)* — 18:

* Mean Annual Flood (Q bar) (cumecs) — 19:

* Qbf/Q bar (cumecs) *(Box 17 / Box 19)* — 20:

* Flooding Envelopes
* % BA with different flood return periods (years)
(Table 6 or 7, boxes 5, 7, 15)

FRP (yr)	21 % area of each LUT that floods	21a Flooded Area (ha)	22 Flood Cost (£/ha)	22a Total Flood Cost (£) *(Box 21a * box 22)*
0				
1 - 2				
3 - 5				
6 - 10				
> 10 (10 yr)				
(15 yr)				
(20 yr)				
(25 yr)				
(30 yr)				
			Total	

* *Not necessary unless detailed information and assessment is required*

Flood Return Period (years) — 23: **N/A**

Total Flood Cost (£) — 24: **0**

Design
Net Return Less Flood Cost *(Box 16 - box 24)* (£) — 24a: **6**

Note: All table numbers and references relate to R&D Note 511, Guidelines for the Justification of River Maintenance

MAINTENANCE REGIME

	25a (m)	25b (%)	
Widening, change in width, expressed in metres and as a %, (including cutting of banks and emergent vegetation)	0.65	50	
	26a (m)	26b (%)	
Deepening, change in depth, expressed in metres and as a %			
		27	
Weedcutting, % cover removed (Submerged & floating weed)			
	28a (m)	28b (%)	
Change in freeboard, expressed in metres and as a % (Table 8 - 15, & boxes 25, 26, 27)	0.189	9	(Table 9)
	29a (m)	29b (%)	
Change in Qbf, expressed in metres and as a % (Table 8 - 15, & boxes 25, 26, 27)			

Note: All table numbers and references relate to R&D Note 511, Guidelines for the Justification of River Maintenance

"DO NOTHING" (WITHOUT MAINTENANCE)

W/o Maintenance Width (m) *(Box 10 - box 25a)*	30	**0.65**
W/o Maintenance Depth (m) *(Box 11 - box 26a)*	31	
W/o Maintenance Freeboard (m) *(Box 13 - box 28a)*	32	**1.91**
W/o Maintenance Watertable Depth (m) *(Box 4, 9, 32, Table 3, Figure 1 or 2)*	33	**0.28**
W/o Maintenance Drainage Status *(Table 4, box 33)*	34	**VERY BAD**

Economic Net Return (W/o maintenance)
(Table 5, box 8, 34)

			35
For either :-	Dominant land use	(£/ha)	
		£	
or :-	Varied land use	(£/ha)	**-44**
		£	**-596**

LUT	35b Net Return (£/ha)	35a Weighted Net Return
1	**-103**	**-1033**
2	**131**	**438**
3		
4		
5		
6		
7		

W/o Maintenance Bankfull Discharge (Qbf) (cumecs) *(Box 17 - box 29)*	36	
* W/o Maintenance Qbf/Q bar (cumecs) *(Box 36 / box 19)*	37	

* Flooding Envelopes
* % BA with different flood return periods (years)
(Table 6 or 7, boxes 5, 7, 34)

FRP (yr.)	38 % area of each LUT that floods	38a Flooded Area (ha)	39 Flood Cost (£/ha)	39a Total Flood Cost (£) *(Box 38a * box 39)*
0				
<1				
1 - 2				
3 - 5				
6 - 10 (6 yr)				
7 - 10 (8 yr)				
> 10 (10 yr)				
			Total	

* *Not necessary unless detailed information and assessment required*

W/o Maintenance FRP (years)		40	**N/A**
Total Flood Cost	(£)	41	**0**
Do-nothing Net Return Less Flood Cost *(Box 35 - box 41)*	(£)	41a	**-596**

Note: All table numbers and references relate to R&D Note 511, Guidelines for the Justification of River Maintenance

MAINTENANCE EXPENDITURE

	42	43	44	45	46	47
Maintenance Activity	Unit Cost (£)	No. of Units (specify)	Cost/Reach/ Activity (£)	Interval Between Maintenance Activities (years)	Amortisation Value at 6 % Discount Rate *(Box 45, Table 18)*	Annual Cost (£) *(Box 44 * box 46)*
						366

Total annual cost/reach (£)	*(Sum box 47)*		48	**366**
Benefit Area (ha)	*(Box 6)*		49	**13.4**
Total annual maintenance cost/ha	*(Box 48 / box 49)*		50	**27**

BENEFITS OF MAINTENANCE

Design Standard (With maintenance)	Net return less flood costs	*(Box 24a)*	(£)	51	**6**
Do Nothing (Without maintenance)	Net return less flood costs	*(Box 41a)*	(£)	52	**-596**
Change in Net Benefit Due to Maintenance		*(Box 51 - box 52)*	(£)	53	**602**
Net Benefit of Maintenance	Change in net benefit less total annual maintenance costs	*(Box 53 - box 49 or 50)*	(£)	54	**236**
	Benefit : cost ratio	*(Box 53/box 48)*			**1.6**

Note: All table numbers and references relate to R&D Note 511, Guidelines for the Justification of River Maintenance

GENERAL INFORMATION

River — 1a **TOWYN SPLASHOVER WEST** — Reach Code 1b **01**

Reach Length (km) — 2 **1.073**

Dominant Substrate Type:-
Gravel, Sand or Silt
(Treat clay as silt) — 3 **SILT (CLAY)**

Floodplain -
Rising (>1 %) or Flat (< 1 %) — 4 **FLAT**

Catchment Size
Large (> 25 sq. km)
Small (< 25 sq. km) — 5 **SMALL**

Benefit Area (ha) — 6 **11.9**
(Area deriving benefit from maintenance)

Dominant Land Use Type (LUT)
(Table 1) — 7 -

Dominant Soil Type — 9 **CLAY**

Varied Land Use Types (LUT)
(Table 1)

LUT		7 % Benefit Area as decimal	8a Does the LUT flood ?	8b If yes, % that floods (as decimal)
1	Ext grass	**8.89**	**NO**	-
2	Int grass	**2.97**	**NO**	-
3	Grass/arable			
4	All cereals			
5	Cereal/oil seed			
6	Cereal/root			
7	Horticulture			
8	Other			

Note: All table numbers and references relate to R&D Note 511, Guidelines for the Justification of River Maintenance

DESIGN STANDARD

Average Bed Width (m) — 10: **1.25**

Average Channel Depth (m) — 11: **2**

% Weed Cover (In channel, submerged & floating weed) — 12: **0** (Emergent vegetation only)

Freeboard (m) — 13: **1.7**

Watertable Depth (m) *(Box 4, 9, 13 & Figure 1 or 2)* — 14: **0.2**

Drainage Status *(Box 14 & Table 4)* — 15: **VERY BAD**

Economic Net Return *(Table 5, using Box 7 & Box 15)*

			16
For either :-	Dominant land use	(£/ha)	
		(£)	
or :-	Varied land use	(£/ha)	**-44**
		(£)	**-527**

LUT	16a Net Return (£/ha)	16b Weighted Net Return
1	**-103**	**-916**
2	**131**	**389**
3		
4		
5		
6		
7		

Bankfull Discharge (Qbf) (cumecs) — 17:

* Regional Growth Curve Area *(Figure 3)* — 18:

* Mean Annual Flood (Q bar) (cumecs) — 19:

* Qbf/Q bar (cumecs) *(Box 17 / Box 19)* — 20:

* Flooding Envelopes
* % BA with different flood return periods (years)
(Table 6 or 7, boxes 5, 7, 15)

FRP (yr)	21 % area of each LUT that floods	21a Flooded Area (ha)	22 Flood Cost (£/ha)	22a Total Flood Cost (£) *(Box 21a * box 22)*
0				
1 - 2				
3 - 5				
6 - 10				
> 10 (10 yr)				
(15 yr)				
(20 yr)				
(25 yr)				
(30 yr)				
			Total	

* *Not necessary unless detailed information and assessment is required*

Flood Return Period (years) — 23: **N/A**

Total Flood Cost (£) — 24: **0**

Design Net Return Less Flood Cost (£) *(Box 16 - box 24)* — 24a: **-527**

Note: All table numbers and references relate to R&D Note 511, Guidelines for the Justification of River Maintenance

MAINTENANCE REGIME

	25a (m)	25b (%)	
Widening, change in width, expressed in metres and as a %, (including cutting of banks and emergent vegetation)	0.625	50	
	26a (m)	26b (%)	
Deepening, change in depth, expressed in metres and as a %			
		27	
Weedcutting, % cover removed (Submerged & floating weed)			
	28a (m)	28b (%)	
Change in freeboard, expressed in metres and as a % (Table 8 - 15, & boxes 25, 26, 27)	0.108	9	(Table 9)
	29a (m)	29b (%)	
Change in Qbf, expressed in metres and as a % (Table 8 - 15, & boxes 25, 26, 27)			

Note: All table numbers and references relate to R&D Note 511, Guidelines for the Justification of River Maintenance

"DO NOTHING" (WITHOUT MAINTENANCE)

W/o Maintenance Width (m) *(Box 10 - box 25a)*	30	**0.625**
W/o Maintenance Depth (m) *(Box 11 - box 26a)*	31	
W/o Maintenance Freeboard (m) *(Box 13 - box 28a)*	32	**1.55**
W/o Maintenance Watertable Depth (m) *(Box 4, 9, 32, Table 3, Figure 1 or 2)*	33	**0**
W/o Maintenance Drainage Status *(Table 4, box 33)*	34	**VERY BAD**

Economic Net Return (W/o maintenance)
(Table 5, box 8, 34)

			35
For either :-	Dominant land use	(£/ha)	
		£	
or :-	Varied land use	(£/ha)	**-44**
		£	**-527**

LUT	35b Net Return (£/ha)	35a Weighted Net Return
1	**-103**	**-916**
2	**131**	**389**
3		
4		
5		
6		
7		

W/o Maintenance Bankfull Discharge (Qbf) (cumecs) *(Box 17 - box 29)*	36	
* W/o Maintenance Qbf/Q bar (cumecs) *(Box 36 / box 19)*	37	

* Flooding Envelopes
* % BA with different
flood return periods (years)
(Table 6 or 7, boxes 5, 7, 34)

FRP (yr.)	38 % area of each LUT that floods	38a Flooded Area (ha)	39 Flood Cost (£/ha)	39a Total Flood Cost (£) *(Box 38a * box 39)*
0				
<1				
1 - 2				
3 - 5				
6 - 10 (6 yr)				
7 - 10 (8 yr)				
> 10 (10 yr)				
			Total	

* *Not necessary unless detailed information and assessment required*

W/o Maintenance FRP (years)		40	**N/A**
Total Flood Cost	(£)	41	**0**
Do-nothing Net Return Less Flood Cost *(Box 35 - box 41)*	(£)	41a	**-527**

Note: All table numbers and references relate to R&D Note 511, Guidelines for the Justification of River Maintenance

MAINTENANCE EXPENDITURE

	42	43	44	45	46	47
Maintenance Activity	Unit Cost (£)	No. of Units (specify)	Cost/Reach/ Activity (£)	Interval Between Maintenance Activities (years)	Amortisation Value at 6 % Discount Rate *(Box 45, Table 18)*	Annual Cost (£) *(Box 44 * box 46)*
						525

Total annual cost/reach (£) *(Sum box 47)* 48 **525**

Benefit Area (ha) *(Box 6)* 49 **11.9**

Total annual maintenance cost/ha *(Box 48 / box 49)* 50 **44**

BENEFITS OF MAINTENANCE

Design Standard (With maintenance) Net return less flood costs *(Box 24a)* (£) 51 **-527**

Do Nothing (Without maintenance) Net return less flood costs *(Box 41a)* (£) 52 **-527**

Change in Net Benefit Due to Maintenance *(Box 51 - box 52)* (£) 53 **0**

Net Benefit of Maintenance Change in net benefit less total annual maintenance costs *(Box 53 - box 49 or 50)* (£) 54 **-525**

Benefit : cost ratio *(Box 53/box 48)* **0.0**

Note: All table numbers and references relate to R&D Note 511, Guidelines for the Justification of River Maintenance

DESIGN STANDARD

Average Bed Width (m) 10

Average Channel Depth (m) 11

% Weed Cover (In channel, submerged & floating weed) 12

Freeboard (m) 13

Watertable Depth (m) 14
(Box 5, 7, 13 & Figure 1 or 2)

Drainage Status 15
(Box 14 & Table 4)

Using Dominant Land Use
Drainage Benefit Area (ha) 16

Economic Net Return 17
(Box 8, 15, Table 5)
(£/ha)
(£)

Using Varied Land Use
(Box 9, 15, Table 5)

		18 Drainage Benefit Area (ha)	19 Economic Net Return (£/ha)	20 (£)
1	Ext. pasture			
2	Int. pasture			
3	Grass/arable			
4	All cereals			
5	Cereal/oil seed			
6	Cereal/root			
7	Horticulture			

Total Economic Net Return 21
(Sum of Box 20) (£)

Bankfull Discharge (Qbf) (cumecs) 22

Regional Growth Curve Area 23
(Figure 3)

Mean Annual Flood (Q bar) (cumecs) 24

Qbf/Q bar (cumecs) 25
(Box 22 / Box 24)

These data are not
required unless
the flood return
periods are not known
and estimates cannot
be used.

Using Dominant Land Use
Flooding Benefit Area (ha) 26

Flood Return period (yrs) 27
* Select from 0, 1-2, 3-5, 6-10 or > 10 years

Flood Cost 28
(Table 6 or 7, Box 8, 15, 26, 27)
(£/ha)
(£)

Using Varied Land Use
(Table 6 or 7, Box 15, 29, 30)

		29 Flooding Benefit Area (ha)	30 Flood Return Period (yr.) *	31 Flood Cost (£/ha)	32 (£)
1	Ext. pasture				
2	Int. pasture				
3	Grass/arable				
4	All cereals				
5	Cereal/oil seed				
6	Cereal/root				
7	Horticulture				

* Select from 0, 1-2, 3-5, 6-10 or > 10 years

Total Flood Cost 33
(Sum of Box 32) (£)

Benefit Area Value 34
(Economic net return less flood costs)
(Box 17 or 21 - Box 28 or 33)
(£/ha)
(£)

Note: Further information is presented in R&D Note 511, Guidelines for the Justification of River Maintenance (Dunderdale & Morris, 1996b). References and table numbers relate to this document. Additions and alterations from the original record sheet are shown in red. The box numbers have also changed from those in the original document.

DESIGN STANDARD

Average Bed Width (m)	10	**1.25**
Average Channel Depth (m)	11	**1.5**
% Weed Cover (In channel, submerged & floating weed)	12	**0** (Emergent vegetation only)
Freeboard (m)	13	**1.2**
Watertable Depth (m) *(Box 4, 9, 13 & Figure 1 or 2)*	14	**0.4**
Drainage Status *(Box 14 & Table 4)*	15	**BAD**

Economic Net Return
(Table 5, using Box 7 & Box 15)

			16
For either :-	Dominant land use	(£/ha)	
		(£)	
or :-	Varied land use	(£/ha)	1
		(£)	7

LUT	16a Net Return (£/ha)	16b Weighted Net Return
1	**-81**	**-1061**
2	**245**	**1068**
3		
4		
5		
6		
7		

Bankfull Discharge (Qbf) (cumecs)	17	
* Regional Growth Curve Area *(Figure 3)*	18	
* Mean Annual Flood (Q bar) (cumecs)	19	
* Qbf/Q bar (cumecs) *(Box 17 / Box 19)*	20	

* Flooding Envelopes
* % BA with different flood return periods (years)
(Table 6 or 7, boxes 5, 7, 15)

FRP (yr)	21 % area of each LUT that floods	21a Flooded Area (ha)	22 Flood Cost (£/ha)	22a Total Flood Cost (£) *(Box 21a * box 22)*
0				
1 - 2				
3 - 5				
6 - 10				
> 10 (10 yr)				
(15 yr)				
(20 yr)				
(25 yr)				
(30 yr)				
			Total	

* *Not necessary unless detailed information and assessment is required*

Flood Return Period (years)		23	**N/A**
Total Flood Cost	(£)	24	**0**
Design Net Return Less Flood Cost *(Box 16 - box 24)*	(£)	24a	**7**

Note: All table numbers and references relate to R&D Note 511, Guidelines for the Justification of River Maintenance

MAINTENANCE REGIME

	25a (m)	25b (%)	
Widening, change in width, expressed in metres and as a %, (including cutting of banks and emergent vegetation)	0.625	50	
	26a (m)	26b (%)	
Deepening, change in depth, expressed in metres and as a %			
		27	
Weedcutting, % cover removed (Submerged & floating weed)			
	28a (m)	28b (%)	
Change in freeboard, expressed in metres and as a % (Table 8 - 15, & boxes 25, 26, 27)	0.108	9	(Table 9)
	29a (m)	29b (%)	
Change in Qbf, expressed in metres and as a % (Table 8 - 15, & boxes 25, 26, 27)			

Note: All table numbers and references relate to R&D Note 511, Guidelines for the Justification of River Maintenance

"DO NOTHING" (WITHOUT MAINTENANCE)

W/o Maintenance Width (m) *(Box 10 - box 25a)*	30	**0.625**
W/o Maintenance Depth (m) *(Box 11 - box 26a)*	31	
W/o Maintenance Freeboard (m) *(Box 13 - box 28a)*	32	**1.09**
W/o Maintenance Watertable Depth (m) *(Box 4, 9, 32, Table 3, Figure 1 or 2)*	33	**0.25**
W/o Maintenance Drainage Status *(Table 4, box 33)*	34	**VERY BAD**

Economic Net Return (W/o maintenance)
(Table 5, box 8, 34)

			35
For either :-	Dominant land use	(£/ha)	
		£	
or :-	Varied land use	(£/ha)	**-45**
		£	**-778**

35b LUT	35a Net Return (£/ha)	Weighted Net Return
1	**-103**	**-1349**
2	**131**	**571**
3		
4		
5		
6		
7		

W/o Maintenance bankfull discharge (Qbf) (cumecs) *(Box 17 - box 29)*	36	
* W/o Maintenance Qbf/Q bar (cumecs) *(Box 36 / box 19)*	37	

* Flooding Envelopes
* % BA with different flood return periods (years)
(Table 6 or 7, boxes 5, 7, 34)

FRP (yr.)	38 % area of each LUT that floods	38a Flooded Area (ha)	39 Flood Cost (£/ha)	39a Total Flood Cost (£) *(Box 38a * box 39)*
0				
<1				
1 - 2				
3 - 5				
6 - 10 (6 yr)				
7 - 10 (8 yr)				
> 10 (10 yr)				
			Total	

* *Not necessary unless detailed information and assessment required*

W/o Maintenance FRP (years)		40	**N/A**
Total Flood Cost	(£)	41	**0**
Do-nothing Net Return Less Flood Cost *(Box 35 - box 41)*	(£)	41a	-778

Note: All table numbers and references relate to R&D Note 511, Guidelines for the Justification of River Maintenance

MAINTENANCE EXPENDITURE

Maintenance Activity	42 Unit Cost (£)	43 No. of Units (specify)	44 Cost/Reach/ Activity (£)	45 Interval Between Maintenance Activities (years)	46 Amortisation Value at 6 % Discount Rate *(Box 45, Table 18)*	47 Annual Cost (£) *(Box 44 * box 46)*
						582

	Total annual cost/reach (£)	*(Sum box 47)*		48 582
	Benefit Area (ha)	*(Box 6)*		49 17.4
	Total annual maintenance cost/ha	*(Box 48 / box 49)*		50 33

BENEFITS OF MAINTENANCE

Design Standard (With maintenance)	Net return less flood costs	*(Box 24a)*	(£)	51 7
Do Nothing (Without maintenance)	Net return less flood costs	*(Box 41a)*	(£)	52 -778
Change in Net Benefit Due to Maintenance		*(Box 51 - box 52)*	(£)	53 785
Net Benefit of Maintenance	Change in net benefit less total annual maintenance costs	*(Box 53 - box 49 or 50)*	(£)	54 203
	Benefit : cost ratio	*(Box 53/box 48)*		1.3

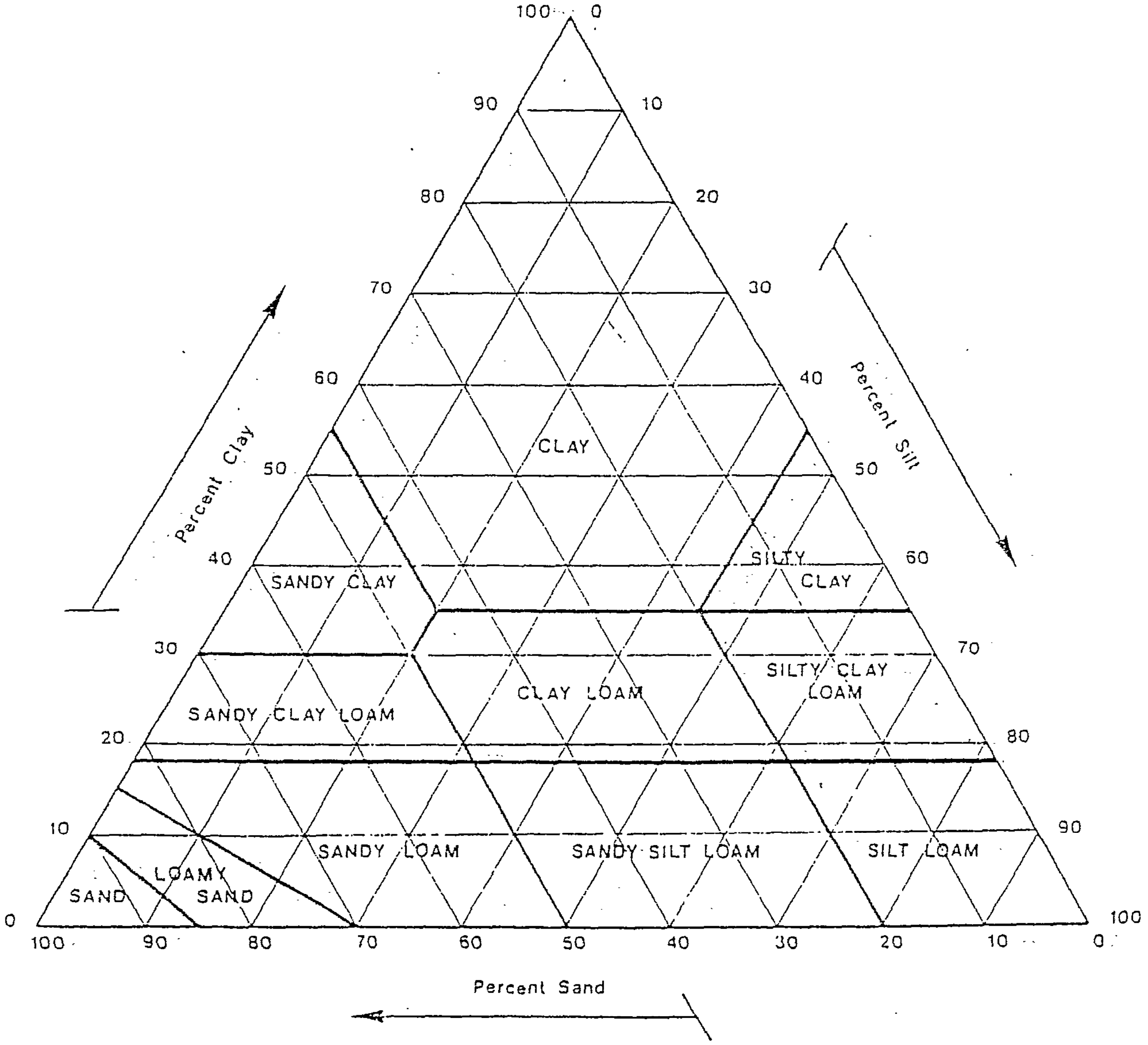
Note: All table numbers and references relate to R&D Note 511, Guidelines for the Justification of River Maintenance

APPENDIX IX SOIL TEXTURE

This Appendix contains a copy of the soil textural diagram. This may be used to classify soil type on the basis of the percentage composition of sand, silt and clay particles.

Source: Landon, JR. (Ed.) (1991). *Booker Tropical Soil Manual.* Longman Scientific and Technical, Harlow, Essex.

First presented within USDA (1951). *Soil Survey Manual.* Handbook 18. USDA, Washington DC.



APPENDIX X RE-DESIGNED RECORD SHEETS FOR THE GUIDELINES

This Appendix contains record sheets for use in the Guidelines. These sheets have been re-designed in view of the comments and suggestions made in Chapter 6.

GENERAL INFORMATION

Is assessment for the Left, Right Bank or Both Banks ?

Watercourse and Reach Code 1

Total Benefit Area (ha) 2
(Total area deriving benefit from maintenance)

Reach Length (km) 3

Dominant Substrate Type:-
Gravel, Sand or Silt (Treat clay as silt) 4

Floodplain -
Rising (>1 %) or Flat (< 1 %) 5

Catchment Size
Large (>2500 ha), Small (<2500 ha) 6

Dominant Soil Type 7

Dominant Land Use Type
(LUT) *(Select from Table 1)* 8

Varied Land Use Types
(LUT) *(Select from Table 1)* 9

	Area (ha)
1 Ext. pasture	
2 Int. pasture	
3 Grass/arable	
4 All cereals	
5 Cereal/oil seed	
6 Cereal/root	
7 Horticulture	

Note: Further information is presented in R&D Note 511, Guidelines for the Justification of River Maintenance (Dunderdale & Morris, 1996b)
Additions and alterations from the original record sheet are shown in red. The box numbers have also changed from those in the original document.

DESIGN STANDARD

Average Bed Width (m) 10

Average Channel Depth (m) 11

% Weed Cover (In channel, submerged & floating weed) 12

Freeboard (m) 13

Watertable Depth (m) 14
(Box 5, 7, 13 & Figure 1 or 2)

Drainage Status 15
(Box 14 & Table 4)

Using Dominant Land Use Drainage Benefit Area (ha) 16

Economic Net Return 17
(Box 8, 15, Table 5)
(£/ha)
(£)

Using Varied Land Use

(Box 9, 15, Table 5)

		18 Drainage Benefit Area (ha)	19 Economic Net Return (£/ha)	20 (£)
1	Ext. pasture			
2	Int. pasture			
3	Grass/arable			
4	All cereals			
5	Cereal/oil seed			
6	Cereal/root			
7	Horticulture			

Total Economic Net Return 21
(Sum of Box 20) (£)

Bankfull Discharge (Qbf) (cumecs) 22

Regional Growth Curve Area 23
(Figure 3)

Mean Annual Flood (Q bar) (cumecs) 24

Qbf/Q bar (cumecs) 25
(Box 22 / Box 24)

These data are not required unless the flood return periods are not known and estimates cannot be used.

Using Dominant Land Use Flooding Benefit Area (ha) 26

Flood Return period (yrs) 27
* Select from 0, 1-2, 3-5, 6-10 or > 10 years

Flood Cost 28
(Table 6 or 7, Box 8, 15, 26, 27)
(£/ha)
(£)

Using Varied Land Use

(Table 6 or 7, Box 15, 29, 30)

		29 Flooding Benefit Area (ha)	30 Flood Return Period (yr.) *	31 Flood Cost (£/ha)	32 (£)
1	Ext. pasture				
2	Int. pasture				
3	Grass/arable				
4	All cereals				
5	Cereal/oil seed				
6	Cereal/root				
7	Horticulture				

* Select from 0, 1-2, 3-5, 6-10 or > 10 years

Total Flood Cost 33
(Sum of Box 32) (£)

Benefit Area Value 34
(Economic net return less flood costs)
(Box 17 or 21 - Box 28 or 33)
(£/ha)
(£)

Note: Further information is presented in R&D Note 511, Guidelines for the Justification of River Maintenance (Dunderdale & Morris, 1996b). References and table numbers relate to this document. Additions and alterations from the original record sheet are shown in red. The box numbers have also changed from those in the original document.

"DO NOTHING" (WITHOUT MAINTENANCE)

40
W/o Maintenance Width (m)
(Box 10 - Box 35a)

41
W/o Maintenance Depth (m)
(Box 11 - Box 36a)

42
W/o Maintenance Freeboard (m)
(Box 13 - Box 38a)

43
W/o Maintenance Watertable Depth (m)
(Box 5, 7, 42, Figure 1 or 2)

44
W/o Maintenance Drainage Status
(Table 4, Box 43)

45
Using Dominant Land Use
Drainage Benefit Area (ha)
(Box 16 or a different area)

46
Economic Net Return
(Box 8, 44, Table 5)
(£/ha)
(£)

Using Varied Land Use

(Box 9, 44, Table 5))

		47 Drainage Benefit Area (ha)	48 Economic Net Return (£/ha)	49 (£)
1	Ext. pasture			
2	Int. pasture			
3	Grass/arable			
4	All cereals			
5	Cereal/oil seed			
6	Cereal/root			
7	Horticulture			

50
Total Economic Net Return, W/o Maintenance
(Sum of Box 49) (£)

51
Bankfull Discharge W/o Maintenance
(Qbf) (cumecs)

52
Qbf/Q bar W/o Maintenance
(cumecs) *(Box 51 / Box 24)*

These data are not
required unless
the flood return
periods are not known
and estimates cannot
be used.

53
Using Dominant Land Use
Flooding Benefit Area (ha)
(Box 26 or a different area)

54
Flood Return period (yrs)
* Select from 0, 1-2, 3-5, 6-10 or > 10 years

55
Flood Cost
(Table 6 or 7, Box 8, 44, 53, 54)
(£/ha)
(£)

Using Varied Land Use

Flooding Benefit Area

(Table 6 or 7, Box 44, 56, 57)

		56 Flooding Benefit Area (ha)	57 Flood Return Period (yr.) *	58 Flood Cost (£/ha)	59 (£)
1	Ext. pasture				
2	Int. pasture				
3	Grass/arable				
4	All cereals				
5	Cereal/oil seed				
6	Cereal/root				
7	Horticulture				

* Select from 0, 1-2, 3-5, 6-10 or > 10 years

60
Total Flood Cost (£)
(Sum of Box 59)

61
Benefit Area Value
(Economic net return less flood costs)
(Box 46 or 50 - Box 55 or 60)
(£/ha)
(£)

Note: Further information is presented in R&D Note 511, Guidelines for the Justification of River Maintenance (Dunderdale & Morris, 1996b). References and table numbers relate to this document. Additions and alterations from the original record sheet are shown in red. The box numbers have also changed from those in the original document.

MAINTENANCE COSTS

Maintenance Activity	Unit Cost (£)	Unit Used (specify)	No. of Units	Cost/Reach/ Activity (£)	Interval Between Maintenance Activities (years)	Amortisation Value at 6 % Discount Rate * *(Box 66, Table 18)*	Annual Cost (£) *(Box 65 * Box 67)*
	62	63	64	65	66	67	68

* If using a different discount rate, please specify

69 Total Annual Cost *(Sum Box 68)* (£)

70 Benefit Area (ha) *(Box 2)*

MAINTENANCE BENEFITS

71 Design Standard (With maintenance) — Net return less flood costs *(Box 34)* (£)

72 Do Nothing (Without maintenance) — Net return less flood costs *(Box 61)* (£)

73 Change in Net Benefit Due to Maintenance *(Box 71 - Box 72)* (£)

74 **Net Benefit of Maintenance** *(Box 73 - Box 69)* (£)

75 **Benefit : cost ratio** *(Box 73 / Box 69)*

Note: Further information is presented in R&D Note 511, Guidelines for the Justification of River Maintenance (Dunderdale & Morris, 1996b)
References and table numbers relate to this document.
Additions and alterations from the original record sheet are shown in red. The box numbers have also changed from those in the original document.