SEVERN TRENT WATER AUTHORITY

DRAINAGE BENEFITS AND FARMER UPTAKE

MAIN REPORT

Silsoe College,
Silsoe,
Bedfordshire.
MK45 4DT

J. Morris
T.M. Hess
A.M. Ryan
P.B. Leeds-Harrison

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SYNOPSIS

As part of Severn Trent Water Authority's need to improve managerial decision on future projects, post appraisals of completed projects have been instigated. These can involve either a comprehensive review of all aspects of the project or, alternatively, can consider key parameters only. In the case of agricultural land drainage schemes key parameters have been identified as the benefits resulting from schemes and the rate of uptake of these benefits by farmers. The investment of public funds in improved agricultural land drainage is normally justified in terms of the resultant net increase in the value of agricultural production.

The realisation of potential benefits depends mainly on the response of individual farmers to the improved opportunities provided. Predicting farmers' response is, perhaps, the most critical and difficult part of the pre-investment appraisal of a proposed drainage improvement scheme. As this is a largely unresearched topic, a research project was established with Silsoe College for the work to be carried out over a two year period finishing in April 1984.

For this project a study of 16 agricultural land drainage improvement schemes carried out by the Severn Trent Water Authority over the last two decades was made in order to identify and explain the actual nature and rate of uptake of potential benefits attributable to improved drainage. By means of a single visit farm survey, farming practice and performance have been described in physical terms for the pre and post-scheme situation for each year of project life on over 850 blocks of land, covering over 5,500 hectares and incorporating 170 farms. A grassland model was developed to evaluate changes in drainage status and grassland and livestock management. Physical estimates have been converted to monetary values using enterprise gross margins and fixed cost budgets adjusted to suit site-specific circumstances.

Uptake of agricultural benefits was considered in terms of field drainage installation, change of land use and net financial benefit. The observed variations in the nature and rate of uptake

were compared statistically with field, farm and farmer variables. The nature (ie. the value) of uptake was shown to be associated with the length of occupancy of the land and the farm; the pre-scheme land used intensity; farm type and size; and security of land tenure. Farmer characteristics were important where land use remained in grass. The rate (timing) of benefit uptake was found to be dependent upon a large number of variables which may be summarised under the heads of; the potential offered by the scheme; the length of occupancy; the nature of post-scheme land use; the locational and edaphic characteristics of the field; and farmer characteristics.

The rate of financial uptake was found to follow an "S" shaped curve after the effects of "automatic" benefits (such as reduced flood damage or extended grazing) were excluded. Although variations in the observed nature (value) of uptake could be partially explained using simple uni-variant classifications (eg. by farm type), the rate (timing) of uptake does not vary greatly between situations. A single curve of uptake has, therefore, been presented which may be used to phase the uptake of benefits over the life of the scheme.

At individual scheme level the sum of constituent farm level benefits attributable to the improvements were set against scheme costs to provide a measure of project worthwhileness using conventional cost benefit procedures. The most successful schemes have often been those where informal or formal groups (such as Internal Drainage Boards) existed to provide support, particularly improved arterial drainage.

The findings of the study suggest that the approach to future pre-investment appraisal should be in terms of defining "benefit scenarios" for specified field, farm and farmer characteristics and using the derived uptake curve as a means of phasing aggregate scheme level benefits over the project life.

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List of Abbreviations

ADAS	Agricultural Development and Advisory Service
CLA	Country Landowners Association
EHF	Experimental Husbandry Farm
FDEU	Field Drainage Experimental Unit
GRI	Grassland Research Institute
IDB	Internal Drainage Board
MAFF	Ministry of Agriculture, Fisheries and Food
MLC	Meat and Livestock Commission
N	Nitrogen
NFU	National Farmers Union
SPSS	Statistical Package for the Social Sciences
STWA	Severn Trent Water Authority
TFA	Tenant Farmers Association

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Drainage Benefits and Farmer Uptake

CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND

The investment of public funds in agricultural land drainage is usually justified in terms of the expected net increase in the value of agricultural production due to the improvement. The actual realisation of these agricultural benefits mainly depends on the response of individual farmers to the opportunities provided by improved drainage. Observations of existing land drainage schemes reveal considerable variation in the actual nature and rate of benefit uptake. However, because there has been little detailed post-investment evaluation of benefit uptake, the reasons for this variation remain largely unexplained. An understanding of the factors influencing farmer uptake of drainage benefits is essential at the pre-investment stage where the prediction of likely uptake pattern is critical to the selection and ranking of agricultural drainage and improvement schemes.

It was in this context that Silsoe College (formerly the National College of Agricultural Engineering) was invited by the Severn Trent Water Authority (STWA) to submit a research proposal to investigate the nature and rate of uptake of agricultural benefits by farmers following the completion of STWA land drainage improvement projects. Silsoe submitted such a proposal to the Authority in June 1981 entitled "Drainage Benefits and Farmer Uptake". This proposal put forward terms of reference and an outline methodology for a 27 month study to evaluate and explain the nature and rate of benefit uptake on selected STWA schemes with a view to improving future STWA benefit assessment and scheme selection methods. The proposal was accepted and the study commenced in October 1981.

1.2 OBJECTIVES AND METHODS

The overall objectives of the study are as follows:

(i) To evaluate the actual nature and rate of farmer uptake of agricultural benefits on selected STWA land drainage improvement schemes, and the resultant overall technical, financial and economic performance of the schemes.

(ii) To identify, on the basis of the above, the factors which determine and explain the nature and rate of farmer uptake of agricultural benefits from land drainage improvement schemes.

(iii) To provide guidelines by which STWA can:

(a) predict the likely agricultural benefits of a proposed scheme,

(b) determine the best ways of achieving the most desirable pattern of farmer uptake of benefits afforded by land drainage improvement schemes,

(c) identify, using technical and financial criteria, the most appropriate field drainage strategies for specified drainage/agricultural situations,

(d) monitor and evaluate the performance of existing and future schemes.

Following a preliminary study (Stage I) to assess the feasibility and justification for the main enquiry, a detailed assessment was made of benefit uptake at field, farm and scheme level within the benefit areas of 16 land drainage schemes (Stage II), followed by the analysis and interpretation of results (Stage III). The terms of reference for the stages are explained in Annexe I, and the methods and sources used are documented in Annexe III.

1.3 ACKNOWLEDGEMENTS

During the study, the Silsoe team has received the cooperation and assistance of many individuals and organisations, and particularly the 170 farmers interviewed. Attention is drawn to the list of acknowledgements given in Appendix I.

1.4 THE STRUCTURE OF THE REPORT

The Main Report summarises the objectives, methods, results and conclusions of the study. Reference is made throughout to supporting Annexes which provide more detail.

Chapters 2 and 3 of the Main Report discuss the context of land drainage and the work todate on agricultural benefit and cost assessment. Chapter 4 summarises the methodology used to measure and evaluate drainage benefit uptake. Chapter 5 describes the location and characteristics of the schemes studied and outlines their agricultural characteristics, within the context of UK agriculture as a whole. Chapter 6 considers agricultural field drainage design criteria and reports on procedures for estimating field drainage costs. The results of the analysis of factors influencing the nature and rate of benefit uptake are given in Chapter 7, and an evaluation of land drainage schemes is contained in Chapter 8. Chapter 9 considers the implications of the study's findings for STWA policy guidelines.

A Glossary of terms used in this report is presented in Appendix II.

CHAPTER 2

THE DRAINAGE PROBLEM

2.1 INTRODUCTION

Whilst water is essential for agricultural crop production, too much can restrict crop growth and limit cropping activities. The basic aim of agricultural drainage is to alleviate or prevent the problems caused by excess water in order to facilitate more productive agriculture. This Chapter briefly considers the impact of poor drainage on agriculture, the causes of the drainage problem, and possible solutions.

2.2 THE IMPACT OF POOR DRAINAGE ON AGRICULTURE

Poor drainage, whether flood inundation, or waterlogging, can reduce crop yields by restricting plant growth, physically damaging the crop, and/or impeding field access for machinery or livestock.

2.2.1 The Effects of Excess Water on the Plant

The effect of poor drainage on plant growth, discussed in Annexe II.2.1, can be summarised in terms of:

- oxygen deficiency in the soil resulting in restricted plant growth or even plant death,
- restricted rooting depth,
- inefficient use of nitrogen producing a yellowing of green plants,
- lower soil temperatures, causing delays in germination and growth,
- the production of toxic elements by bacterial activity in anaerobic conditions,

- an increase in the risk of plant disease,

- damage to the crop in the case of submersion,

The net result of the above will often be to cause a reduction in productivity or harvested yield. The magnitude of this effect will depend upon:

- the species of plant and its tolerance to waterlogging,

- the timing of the flood or waterlogging event, in terms of stage of growth and climatic season,

- the severity of the event, in terms of the depth of flooding or height of water table,

- the duration of the event.

2.2.2 The Effects of Excess Water on Soil Conditions

High water tables cause a reduction in the strength of the upper layers of the soil, thus restricting the soil's capacity to withstand the loads applied by tractors, implements or livestock (see Annexe II.3.3).

Poor drainage reduces the number of days on which the soil is fit for traffic or the use of soil engaging implements, and increases the risk of untimeliness in critical operations. In many respects, the requirements for moving machinery and working the soil may impose stricter drainage requirements than the crop itself, particularly given the tendency towards larger and more sophisticated equipment, and the need to avoid soil compaction and structural degradation which can further exacerbate drainage problems and cause yield losses.

For grassland systems poor drainage increases poaching liability, delays the grazing season, and prevents early nitrogen application.

2.3 THE CAUSES OF DRAINAGE PROBLEMS

Four situations can be identified in which excessive soil moisture is a constraint to agricultural production.

(a) Excessive soil moisture following the inundation of low lying agricultural land by sea water in response to high tides or tidal surges, ie. the coastal flooding problem.

(b) Excessive soil moisture due to the inundation of flood plain land as a result of river flow in excess of bankfull capacity in periods of high discharge, ie. the fluvial flooding problem.

(c) The presence of seasonally or permanently high water tables in the soil due to high water levels in local watercourses, ie. the arterial drainage problem.

(d) Temporarily high water tables in the soil due to slow rates of soil-water movement after heavy rainfall, ie. the field drainage problem.

2.4 LAND DRAINAGE RESPONSIBILITIES AND SOLUTIONS

The 'coastal flooding' problem ((a) above) has generally been excluded from this study because of the very small area of coastline within the STWA catchments. The 'fluvial flooding' and 'arterial drainage' problems ((b) and (c) above) are essentially land drainage problems and responsibility for the execution of works to control them is apportioned amongst Water Authorities, District and County Councils, Internal Drainage Boards and riparian owners, according to the status of the watercourse (see Annexe I.4). Fluvial flooding control involves increasing the bankfull capacity of the channel, either by the construction of artificial floodbanks or by channel excavation. Arterial drainage problems require the lowering of water levels in the watercourses by resectioning, regrading, the removal of weirs and constrictions, or pumping.

Responsibility for field drainage ((d) above) rests with the farmer or landowner (Annexe I.5) and may involve the cutting of open ditches, the installation of underdrainage systems, and secondary treatments such as mole ploughing. Effective field drainage, however, is dependant upon adequate land drainage. Water levels in arterial watercourses must be low enough to provide an adequate outfall with sufficient freeboard to prevent, or at least minimize outfall submergence (unless pumped field drainage is used), and the frequency and duration of flooding must be low enough to minimise the risk of underdrainage surcharge.

Drainage design criteria are discussed in Chapter 5.

CHAPTER 3

THE BENEFITS OF IMPROVED LAND DRAINAGE FOR AGRICULTURE

3.1 INTRODUCTION

Investment in land drainage improvement is justified in terms of increased agricultural productivity and financial net returns. This Chapter summarises the principal benefits of drainage, the factors which determine financial net returns, and the context in which drainage benefits manifest themselves. Evidence from previous studies is briefly reviewed.

3.2 THE BENEFITS OF IMPROVED DRAINAGE FOR AGRICULTURE

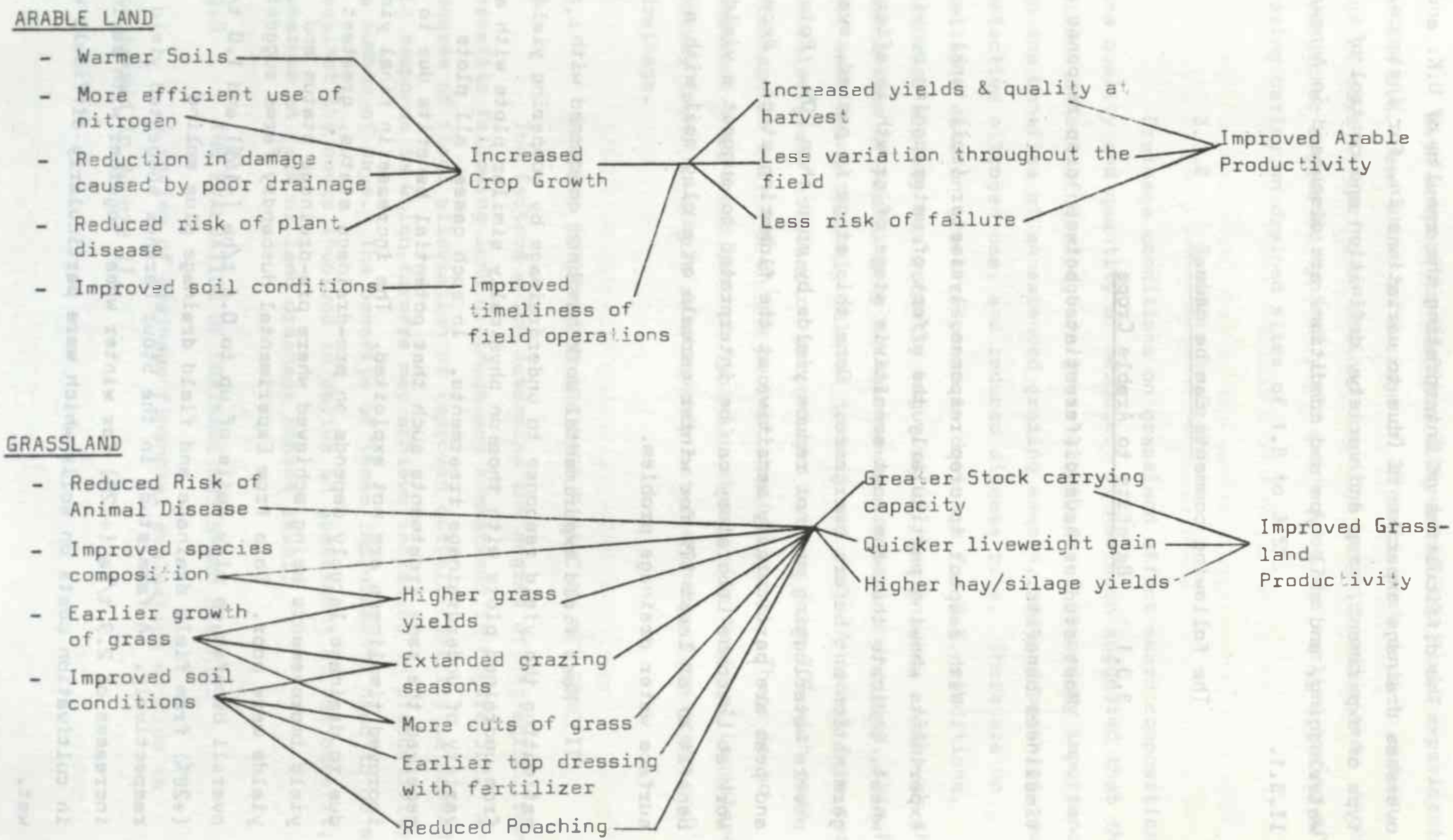
The principal benefits of improved drainage for grass and arable enterprises are discussed in detail in Annexe II and summarised in Figure 3.1. They are essentially the obverse of the detrimental impacts of poor drainage enumerated in Chapter 2, section 2.1. The benefits can be generalised in terms of improvements in the (soil/plant/water) growing environment, the alleviation of crop damage, and the improvement in the trafficability and workability of soils.

3.3 EVIDENCE OF THE BENEFITS OF IMPROVED DRAINAGE

A review of studies to assess the benefits of improved drainage is contained in Annexe II. More is known about the drainage requirements of crops than the yield benefits attributable to drainage.

The bulk of drainage studies deal with waterlogging effects rather than those of flooding. A previous (1972) review of drainage experiments in England and Wales concluded that there was little statistically sound evidence for increased yields following drainage due to the lack of replications and the short duration of many experiments. It has been argued that experimental results from overseas, even if they are statistically sound, have limited application to the British environment.

Figure 3.1. The Benefits of Improved Drainage for Arable and Grassland Uses



The difficulties of interpreting the results of U.K. and overseas drainage experiments (due to variations in, for instance, type of experiment, crop and variety, definition and control of waterlogging, and soil type and condition) are discussed in Annexe II.3.1.

The following comments can be made.

3.3.1 Benefits to Arable Crops

Most studies have differentiated between crop response and timeliness benefits.

With respect to crop response, lysimeter (soil tank) experiments showing particularly the effect of waterlogging on winter wheat, indicate that the most sensitivie stage of growth is after germination but before emergence. Once this stage is passed, even severe waterlogging may not reduce yields by more than 20%. Potatoes and peas are particularly sensitive at the flowering stage. Recent work at Letcombe Laboratory can be interpreted to suggest a yield benefit of at least 17% for winter cereals on a clay soil with a surface water drainage problem.

Most field experimental work has been concerned with estimating the yield response to underdrainage by comparing yields from undrained plots with those on physically similar plots with a variety of underdrainage treatments. In such cases, all plots received the same treatments such that potential benefits due to improved timeliness are not exploited. The increase in final yield due to drainage largely depends on pre-drainage status, greatest yield improvements being achieved where pre-drainage status and yields were poor. Data from Experimental Husbandry Farms suggest an overall benefit on clay soils of up to 0.6 t/ha (+16%) and 1.0 t/ha (+28%) from field drainage and field drainage plus moling respectively. A farm study in the Stour Marshes suggested yield increases of 2.9 t/ha (+72%) for winter wheat together with savings in cultivation costs on soils which were particularly difficult when wet.

With respect to trafficability benefits, field experiments in the U.K. have shown an average of 25 extra work days in autumn, and 27 days in spring on drained compared to undrained sites. Another researcher suggested typical yield gains from the earlier sowing of spring barley on drained sites of 1.8 to 3.5%.

3.3.2 Benefits to Grass

Drainage conditions on grassland affect sward composition, and quality and quantity of herbage. It has been suggested that the direct effect of drainage on grass growth is of secondary importance to the benefits of an extended grazing season, reduced poaching, more effective nitrogen use, and reduced disease risk. There are no reliable data on grass response to drainage for U.K. conditions, although a study has recently begun at GRI North Wyke. Although the mechanisms of poaching by animal hooves are well understood, this has not been quantitatively related to soil wetness. A recent farm survey revealed grass utilisation percentages varying from 70% with good drainage to only 44% on the poorest drained sites. There is no evidence that these are not typical values. The National Grassland Survey found no simple relationship between energy from grass and drainage.

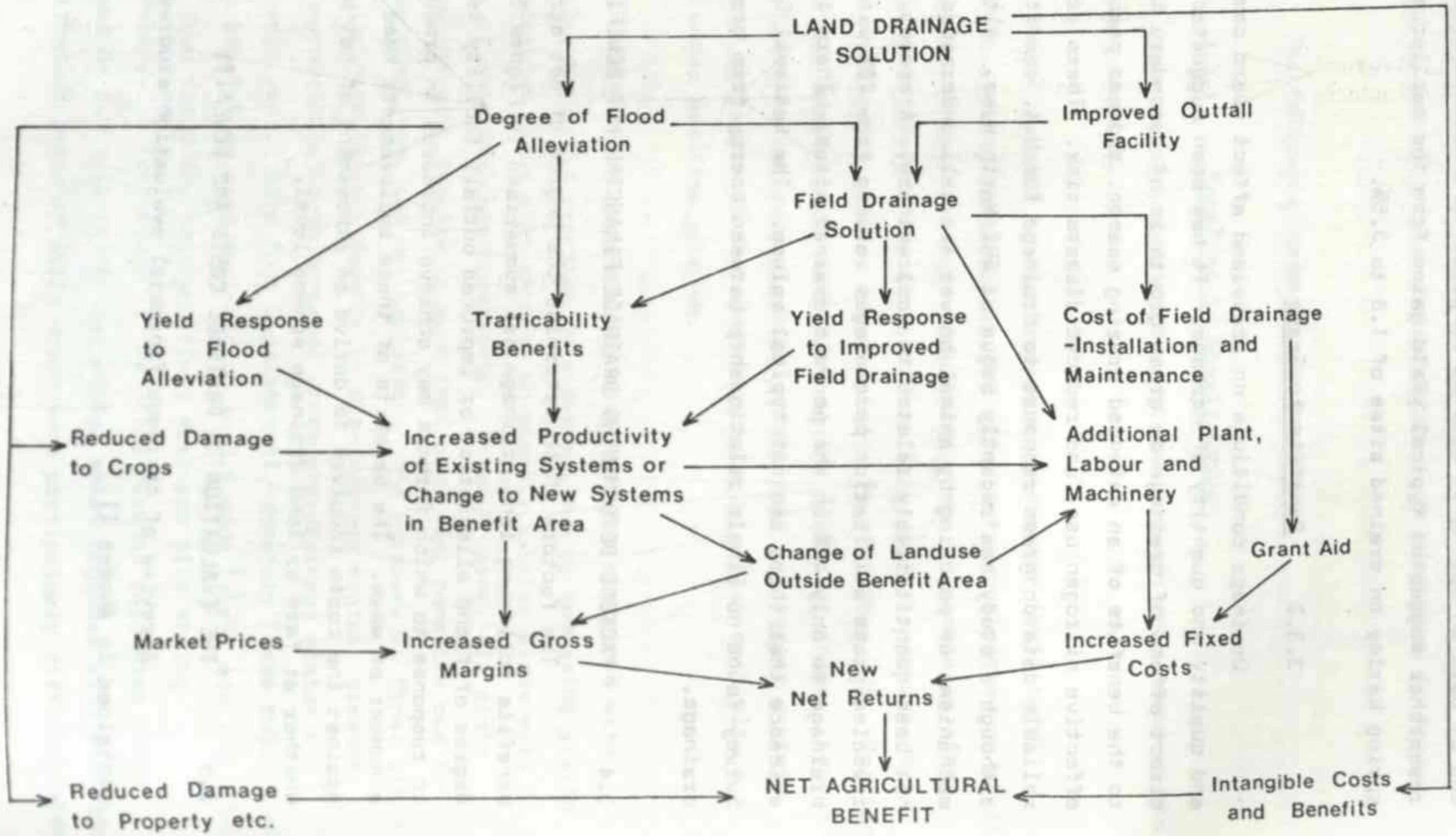
3.4 FACTORS DETERMINING DRAINAGE FINANCIAL NET BENEFIT

The factors which determine the degree of net agricultural benefits following land drainage are summarised in Figure 3.2. A degree of flood alleviation or improved outfall facility is provided in response to which farmers may achieve increases in productivity in a number of ways. The benefits of these improvements need to be set against the costs involved to derive an assessment of net benefit, whether at farm or land drainage scheme level.

3.5 THE EVALUATION OF DRAINAGE COSTS AND BENEFITS

A review of drainage financial evaluation studies is contained in Annexe II.

Figure 3.2 : DETERMINATION OF DRAINAGE BENEFITS AT FARM LEVEL



3.5.1 Field Drainage

In the U.K. attention has focussed on the results of FDEU experimental sites and Experimental Husbandry Farms (EHF) (Annexe II.5). Field drainage has been worthwhile for grassland or arable situations where previously poor drainage had kept yields below 'normal' for the particular enterprise/soil type. The 'worthwhileness' of drainage has been sensitive to a broad range of factors; field drainage design, input and output prices, the cost of field drainage, grant aid, taxation levels, and the appraisal technique itself. The results from the Drayton EHF suggest that the payback periods for field drainage investments on clay soils range from one to 13 years, depending on the type of drainage and appraisal technique.

The evaluation of field drainage systems using actual farm level results has proved difficult because of inaccurately defined 'controls' against which performance can be assessed, and because few farms keep the detailed records of pre- and post-drainage conditions and yields required to allow reliable appraisal. The results of such studies show, however, that where the pre-drainage condition imposed severe land use or yield constraints, return on investment is high and payback period low.

3.5.2 Land Drainage

Most land drainage evaluation has been pre-investment and predictive. As land drainage works often involve the commitment of public funds, there has been a pressure to vindicate expenditure by financial, and more latterly economic, appraisal of likely benefits and costs before work begins.

In agricultural situations, the bulk of the benefits are attributable to the 'enhancement' of land productivity and value, and most pre-investment studies have used either the increase in financial net returns or the appreciation of land value (theoretically a capitalised value of the former) as a measure of benefit.

Being largely predictive exercises, the main criticisms levelled at land drainage evaluation studies relate to the often arbitariness and optimism of benefit assessment, particularly with respect to the nature and rate of uptake, to the artificiality of using financial prices for assessing public sector investments, to the failure to include 'external', largely environmental impacts, and to the lack of a standard approach to evaluation, where the appraisal technique itself can become a planning variable (see Annexe II.6.4).

3.6 FARMER UPTAKE OF LAND DRAINAGE BENEFITS

3.6.1 The Nature and Rate of Benefit Uptake

From the point of view of farmer response, the agricultural benefits of land drainage can be defined in terms of 'automatic' and 'potential' benefits. Automatic benefits are those that are realised immediately on completion of an improvement scheme, such as reduced flood damage costs, and do not require investment on the part of the farmer. Potential benefits are those which are at the discretion of the farmer and require a conscious decision on his part to change farming practice or commit investment funds to realise the potentials. The opportunity to install underdrainage to enable land use change is a potential which may or may not be realised over time. The type of potential benefits, and the time over which they are realised provides the basis for estimating the nature and rate of uptake of benefits following land drainage improvement.

3.6.2 The Context of Benefit Uptake

In the context of the farm as a business, the physical benefits of land drainage manifest themselves in a number of ways, which provide a framework for assessment.

(a) The reclamation case:

Where drainage is so poor as to preclude commercial agricultural use, the benefits of improvement are readily apparent from the additional net output of enterprises made possible.

(b) Improved production from existing land use:

The previously enumerated benefits of drainage for arable and grassland activities allow intensification of, and increased net returns from, existing enterprises..

(c) Change in land use:

Improved drainage may enable the introduction of financially attractive enterprises whose drainage needs could not previously be met. This may require the installation of field drains in addition to river and arterial works.

(d) Reduced costs:

Improved drainage can reduce the costs associated with flood damage, poor field working conditions, and unreliable grazing seasons.

(e) Benefits to the whole farm:

Benefits due to improved drainage on one part of the farm may generate indirect benefits on other parts, or to the farm as a whole. For instance, increased and more accessible grass production in lowland pastures could release higher areas for arable production whilst maintaining herd size.

3.6.3 Previous Studies of Uptake

There has been little 'ex-post' evaluation of land drainage works and consequently little evaluation of the nature and rate of uptake of potential benefits of improved drainage (see Annexe II.8). A number of American studies have looked at land use change following land drainage improvements, with inconclusive results. The nature, but not the rate, of land use change in response to flood alleviation has been studied in S.W. Scotland. In recent years, ADAS have collected data on the area and date of grant aided underdrainage, but no estimates are available of resultant benefits, or of benefits not associated with field drainage. Sociological studies have identified farm and farmer factors that are generally associated with innovation in agriculture. Thus, while it is possible to suggest in general terms the characteristics which are likely to influence uptake, it has not been possible to explain, quantify, and thereby predict, the nature of this influence. Hence the justification for the present study.

CHAPTER 4

METHODOLOGY FOR BENEFIT AND UPTAKE ASSESSMENT

4.1 INTRODUCTION AND SCOPE

The 3 main objectives of the study are to identify and measure the nature and rate of uptake of benefits attributable to land drainage improvements, to identify and explain the nature of factors which influence uptake at field, farm and scheme level, and to undertake an evaluation of selected STWA land drainage schemes. These 3 objectives are necessarily inter-related, as are the methods used to satisfy them. In essence, the approach has identified the extra inputs (costs) and extra outputs (benefits) attributable to observed changes in drainage conditions at field and farm level in the context of 16 selected STWA schemes implemented over the last 24 (mainly 12) years. This Chapter summarises the data needs, sources, collection methods, and analytical procedures used in the course of the enquiry.

4.2 DATA NEEDS, SOURCES AND COLLECTION METHODS

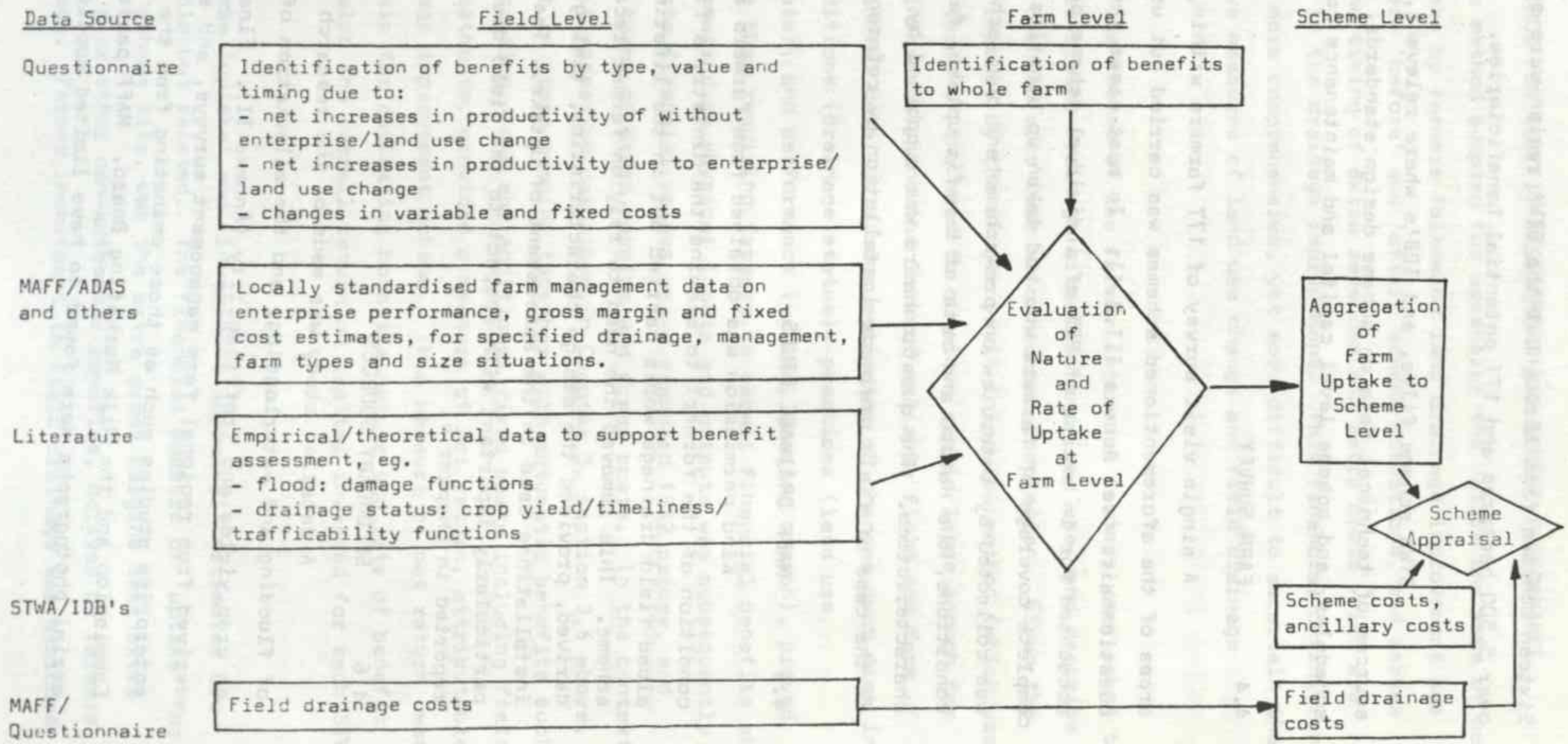
The data requirements and sources for drainage benefit assessment and scheme appraisal are summarised in Figure 4.1 and discussed in detail in Annexe III. Basically, they relate to a description of pre-scheme and post-scheme drainage conditions, farming and land use practices, with a view to assessing changes attributable to land and/or field drainage improvements. A detailed farm survey has been the major source of physical farm level data, which for reasons of practicality, has been converted to net financial benefit using standardised enterprise budgets.

4.3 SELECTION OF STWA SCHEMES

The criteria for selecting land drainage schemes for evaluation required them to be separately identifiable projects to which benefits and costs could be attributed , to have been justified primarily in terms of agricultural benefits, and to be of sufficient maturity (in age or uptake) to allow meaningful evaluation.

FIGURE 4.1

Data Sources for the Evaluation of Uptake and Scheme Appraisal



Sixteen schemes from throughout the STWA region were selected covering over 5,500 hectares and 177 potential beneficiaries.

STWA scheme files, and IDB's where relevant, were the main sources of technical data on scheme design standards, implementation schedules, and scheme level capital and maintenance costs.

4.4 FARM SURVEY

A single visit survey of 177 farmers within the benefit areas of the aforementioned schemes was carried out using a structured questionnaire (see Annexe III.2.1). In most cases these farmers accounted for in excess of 90% of individual scheme benefit areas, and complete coverage of farmers who had taken up benefits. Information was collected by interview on pre-scheme and post-scheme drainage conditions, the nature and rate of benefit uptake, farm and farmer characteristics. The questionnaire was supported by field survey, and in the case of field drainage installation by reference to MAFF files.

4.5 MAFF DRAINAGE FILES

Kind permission was obtained from farmers and MAFF (on condition of the former) to examine the Ministry's files on grant aided field drainage works carried out in the lifetime of the STWA scheme. This removed the need to rely on farmer recall. Data so derived, provided the design characteristics, timing and cost of installations used in the assessment of uptake. The data were particularly important with respect to the field drainage studies reported in Chapter 6.

4.6 SECONDARY SOURCES

A detailed study was made of the research into the effects of flooding and waterlogging, and the alleviation of these problems, on crop yields and trafficability (Annexe II). Financial data were derived from regional farm management surveys, and specialist enterprise studies such as those emanating from the Meat and Livestock Commission and the Milk Marketing Board. MAFF parish statistics and aerial photographs were found to have limited application.

4.7 METHOD FOR BENEFIT ASSESSMENT AND SCHEME PERFORMANCE

The method adopted for assessing the nature and rate of net benefits uptake by farmers following land drainage improvement has been to compare 'before' and 'after' scheme situations, and assess the extent and timing of extra revenues and extra costs which are attributable to the drainage improvement. This financial definition of uptake is more comprehensive, yet more difficult to ascertain than the indicative measures of land use change and field drainage installation.

In the course of the farmer interview farmers were asked to recall the pre-scheme drainage situation and land use, and describe how this had changed over time since scheme completion. Given the restrictions imposed by the single visit interview method (which was justified in terms of the need to obtain a sample large enough for statistical inference), and the lack of reliable field and farm specific financial data, obtaining estimates of changes over time in physical conditions (drainage status), practices (land use, fertilizer rate), and performance (yields, grazing season), proved more feasible than requiring farmers to recall financial benefits and costs. Information on physical inputs and outputs was subsequently translated into financial values using standard 1982 prices, and expressed in terms of gross margins and fixed costs. In the context of the benefit scenarios described in Chapter 3, section 3.6 above, the increment in gross margin, together with automatic benefits such as extended grazing, less any additional fixed costs including field drainage investments, provided a measure of net return, attributable to the drainage improvement scheme. This measure of net return was used as a basis for estimating both the nature and rate of benefit uptake, and also the overall return on capital invested for each STWA scheme.

These 'uptake' and 'investment appraisal' estimates are distinguishable but related. The financial measure of 'uptake' for each year of scheme life, was the extra gross margins less extra fixed costs, plus other non-automatic benefits, derived by farmers from the scheme. Farmer investment in field drainage was excluded from this definition of uptake. With respect to investment appraisal, for each year of scheme life, the previously defined 'uptake' benefits were combined with automatic benefits and reductions in flood damage costs attributable to the scheme. From this was deducted the cost of field drainage and the 'without-project' returns that would have been obtained in the benefit area in the absence of any improvement. The resultant stream of net benefit, termed the net agricultural cash flow, was set against the stream of scheme level capital and recurrent costs, and discounted over scheme life at the relevant rate to derive a measure of net present value for the scheme as a whole.

In accordance with MAFF guidelines, the method adopted a quasi-financial viewpoint using prevailing farm gate prices (to the base September 1982), except for drainage investments which were taken before grant. Consideration has been given, however, to the use of economic prices for agricultural commodities.

4.8 PARTICULAR PROBLEMS IN BENEFIT ASSESSMENT

Two particular problems in the assessment of financial net benefit are worthy of comment. First, the difficulty of assessing the effect on farm fixed costs of changes in farming system; second, the difficulty of assessing the benefits of improved drainage for grassland.

4.8.1 Gross Margins and Fixed Costs

The conventional definitions of farm gross margins and fixed costs reduces their validity for assessing marginal enterprise changes (see Annexe V.2.4). The main criticism is that the definition of variable costs in the calculation of the gross margin is not sufficiently comprehensive and excludes such items as extra plant and machinery operating costs, and direct labour expenses, which are likely to be reasonably constant per unit of activity, and thus likely to increase with the level of activity.

To overcome these problems a distinction has been made between gross margins, semi-fixed costs, and total fixed costs. The gross margin is taken to be the conventional farm management definition. Semi-fixed costs per unit of activity are items of recurrent expenditure associated with the use of existing fixed resources (eg. machinery operating costs). Total fixed costs per unit of activity combine the latter with a charge for capital investment (eg. machinery depreciation). If farmers reported an increase in regular labour, machinery and buildings, and/or the use of contractors, total fixed costs were charged. Otherwise semi-fixed costs were considered appropriate. The rates for estimated semi- and fixed costs are based on farm management survey and enterprise study reports (see Annexe V).

The distinction between semi- and fixed costs is most problematic in the case of labour. Because theoretical standard man day requirements exceeded regular family and hired workers by a factor of 1.7 and because intensification is likely to increase labour peaks, labour was charged as a semi-fixed cost (see Annexe V.2.5).

4.8.2 Grassland Productivity

Eighty per cent of the pre-scheme and 50% of the post-scheme land use involved grass. Assessing the productivity of a given area of grassland requires detailed records of the kind not usually kept on most farms, namely, turnout dates and liveweights, liveweight gains or milk yields at grass, livestock unit grazing days, diet supplementation, conservation dry matter yields and energy values. The efforts of researchers, however, have shown that for given environmental conditions, grass production is largely a function of nitrogen application (see Annexe IV). Given that farmers are better able to estimate fertiliser input than physical livestock output, N can be used as a proxy for grass productivity.

For this purpose a physical model, described in Annexe IV, has been developed which, drawing on the results of research at the Grassland Research Institute, estimates the physical productivity of grassland in terms of utilised metabolisable energy (UME) on the basis of site class (soil type, rainfall), drainage status (flooding, waterlogging), poaching risk, N fertilizer use, and conservation (hay, silage, number of cuts). Estimates for UME production so derived were compared with figures from the most reliable national surveys (see Annexe IV.5.1.2) and the results confirm the validity of the model.

For a given site class, an improvement in drainage status, combined with an increase in nitrogen application encouraged by earlier access, results in increased energy from grass. This extra energy has been converted into an increase in stocking rate for given types of livestock assuming standardised grass energy requirements per head. The increase in stocking rate has then been converted into increased livestock gross margins and fixed costs as previously described. The additional costs of forage production and conservation, and the benefits of extra grazing days have also been incorporated in the measure of net return.

4.9 EXPLAINING THE NATURE AND RATE OF UPTAKE

The data collected during the farm survey, relating to physical field and farm level factors were combined with the data derived from the benefit assessment procedures and stored on a computer based data logging and retrieval system using the Statistical Package for Social Scientists (SPSS).

The statistical analysis of uptake was carried out on the aggregated data set for 880 blocks of land and 177 farmers.

Financial net return was taken as the main definition of uptake and statistical analysis proceeded to identify field, farm, and farmer factors which explained variation in the nature of uptake (the size of net returns), and the rate of uptake (the timing of net returns). The statistical methods used and the results obtained are summarised in Chapter 7.

4.10 CRITIQUE AND SENSITIVITY

Critiques of the methodology used for benefit assessment and scheme evaluation are contained in Annexe V and Annexe IX respectively. The implications of critical assumptions has been tested by way of sensitivity analysis in Annexe V.

CHAPTER 5

BACKGROUND TO THE STUDY AREA

5.1 INTRODUCTION

This Chapter comments briefly on the agricultural policy and changes within the sector over the relevant period, describes the main characteristics of farming within the STWA benefit areas, and summarises the main features of the schemes studied and farmer response to the improved drainage opportunities afforded.

5.2 AGRICULTURAL POLICY FRAMEWORK AND AGRICULTURAL CHANGE

Over the last 3 decades, agricultural policy has used pricing and subsidies to pursue an expansionist policy justified in terms of increasing self-sufficiency in indigenous foods. In response, agricultural output has continually increased, whilst the sector has undergone rapid structural change involving specialisation, less but larger farms, and a much reduced workforce. Despite Government support, increasing costs have reduced aggregate incomes, with the dairy and livestock sectors being the hardest hit. The intensification of farming, in which improved land drainage has played an important role, has been one means of maintaining farm profitability (see Annexe VII).

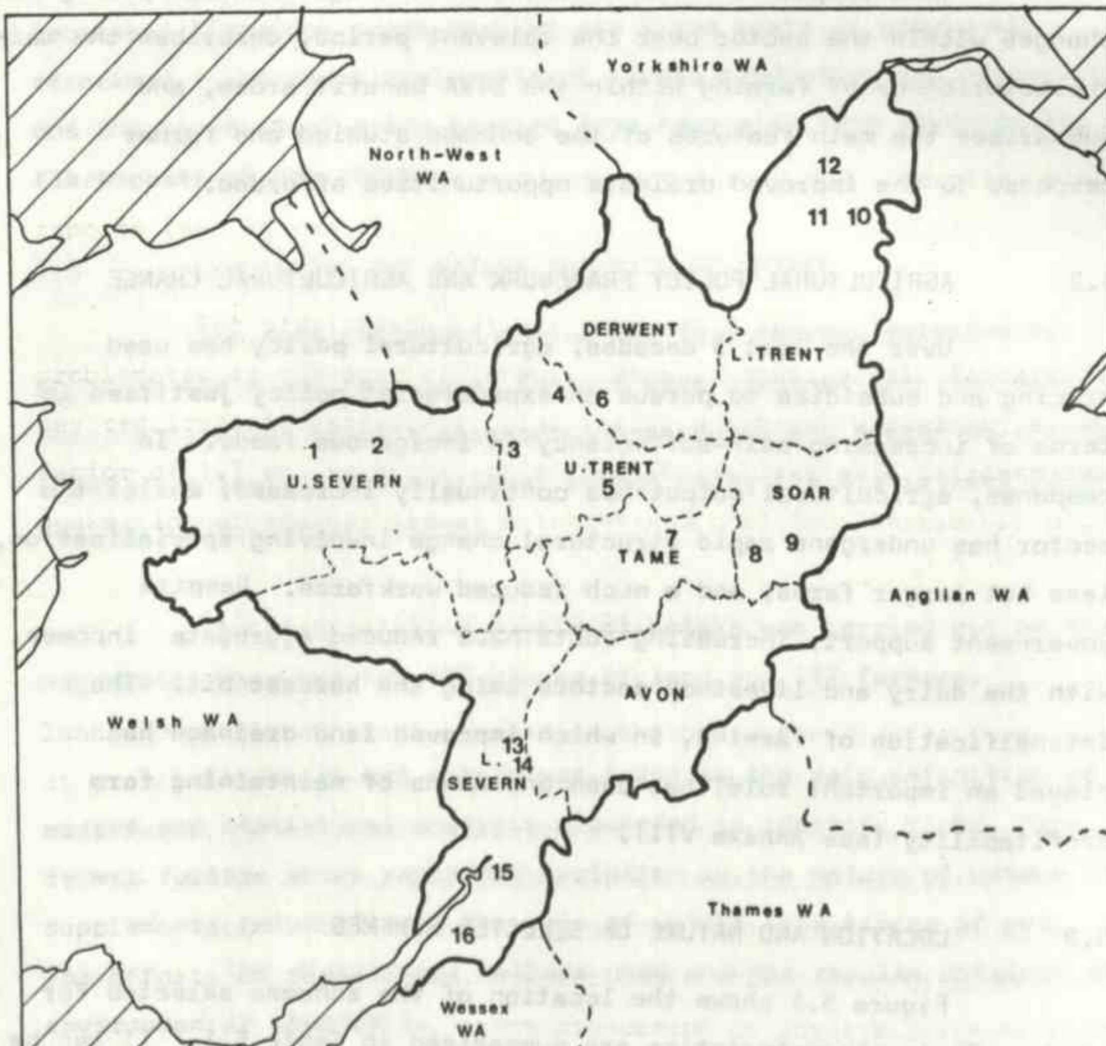
5.3 LOCATION AND NATURE OF SELECTED SCHEMES

Figure 5.1 shows the location of the schemes selected for study. Their characteristics are summarized in Table 5.1. It can be seen that the survey has covered a diversity of areas and included a broad range of schemes that typically represent the nature of works carried out by STWA and other Water Authorities.

Table 5.2 contains a summary of farm type, farm size, tenure, and percentage of the farm in the benefit area by scheme. Farms were predominantly dairy, and average farm size was 105 hectares, with 42% of the total farm area in the scheme benefit area. Some 56% of fields in the benefit area were owner occupied. The distribution of farm types reflects regional farming systems, with more cropping

Figure 5.1

SEVERN-TRENT WATER AUTHORITY:
Land Drainage Divisions & Selected Schemes



U. SEVERN DIVISION

1. R. Morda
2. Sleap Brook

U. TRENT DIVISION

3. Doley Brook
4. R. Blithe
5. R. Trent (Alrewas)

DERWENT DIVISION

6. R. Tean

TAME DIVISION

7. R. Sence (Temple Mill)

SOAR DIVISION

8. R. Soar (Sharnford)
9. R. Sence (Kilby Bridge)

L. TRENT DIVISION

10. R. Trent (Beckingham Marsh)
11. R. Idle (Mattersey)
12. R. Idle (Misson)

L. SEVERN DIVISION

13. R. Severn (Ripple)
14. R. Severn (Bushley)
15. Epney Rhine
16. Oldbury

TABLE 5.1

Summary of Scheme Characteristics

STWA Divison	Watercourse	Reach	Length (km)	Date of Commencement	Nature of Major Works	Area of Benefit[1]	Capital Cost per Hectare of Benefit (£)[2]
U. Severn	R. Morda	Morton Bridge to Vyrnwy Confluence	9.8	November 1971	Channel excavation and realignment; improvement of both Morda Outfalls; raising of banks.	431	522
U. Severn	Sleap Brook	Fiddler's Bridge to Roden Confluence	4.5	January 1974	Channel resectioning and regrading; culvert replacement.	945	178
U. Trent	Doley Brook	Hell Hole Wood to Ruels Pools	5.6	November 1973	Channel regrading and culvert replacement.	198	368
U. Trent	R. Blithe	Blythe Bridge to Cresswell	6.5	1972	Channel regrading, resectioning and realignment; weir installation and culvert replacement.	77	799
U. Trent	R. Trent	Yoxall Bridge to Alrewas	6.5	1976	Weir and sluice removal; channel regrading and rationalization; outfall improvement.	464	532
Derwent	R. Tean	Stramshall Mill to Dove Confluence	3.7	1977	Channel regrading and outfall realignment; ramp construction.	138	1452
Tame	R. Sence	Temple Mill	1.5	November 1972	Channel realignment to by-pass mill; channel regrading.	73	1296
Soar	R. Soar	Sharnford to Croft	9.5	February 1978	Channel resectioning and regrading, and realignment; culvert replacement.	370	1331
Soar	R. Sence	Wistow to Kilby Bridge	8.3	December 1973	Channel resectioning and regrading; weir removal.	256	740
L. Trent	R. Trent	Beckingham Marsh	6.7	April 1960	Floodbank rationalization and strengthening; pumping of arterial watercourses.	919	1877
L. Trent	R. Idle	Mattersey to Bawtry	8.0	August 1981	Channel resectioning and regrading; construction of minor embankments.	309	653
L. Trent	R. Idle	Bawtry to Idle Stop	10.7	August 1979	Channel resectioning and regrading; construction of minor embankments.	480	513
L. Severn	R. Severn	Saxon's Lode to Mythe Hook (Ripple)	4.9	1975	Floodbank improvement and outfall replacement.	244	1134
L. Severn	R. Severn	Bushley to Upper Lode	4.9	1972	Floodbank improvement and outfall replacement.	129	567
L. Severn	Epney Rhine	Lapper Ditch	-	April 1972	Separation of upland and lowland runoff; improvements and pumping of lowland drains.	145	966
L. Severn	Oldbury	S. Pumping Area	-	1978	Separation of upland and lowland runoff; improvement and pumping of lowland drains.	448	1281

Notes:

(1) As defined following farm survey (see Annexe IX).

(2) Brought to common 1982 price base using PWNR Index; cost after contributions but including capital expenditure by non-farmer third parties (eg. Local Authority, IDB) and where appropriate a proportion of costs of 'regional' works (eg. pumping of the River Idle or tidal sluices at Oldbury).

TABLE 5.2

Sampled Farms by Scheme, Farm Type, Size and Tenure

Scheme	Area Surveyed (ha)	Number of Farmers Interviewed	Mean* Farm Size (ha)	Mean SMD Requirement	Type of Farm : % of Farms						Mean % of Farm in Benefit Area	Field Tenure : % of Area			
					Dairy	Live-stock	Cropping	Mixed	Other	No Data		Owned	Tenanted	Summer let	Other
Sharnford	299	14	56	581	43	29	7	14	7	-	46	77	21	1	-
Kilby Bridge	279	9	100	989	67	-	-	11	2	-	51	73	25	2	-
Doley Brook	231	10	107	1873	50	30	10	10	-	-	32	50	50	-	-
Alrewas	363	13	81	958	46	8	23	15	-	8	33	34	63	3	-
Blithe	77	7	44	488	57	29	-	14	-	-	29	96	-	4	-
Morda	431	23	68	607	61	22	4	-	4	9	42	53	23	1	23
Sleap Brook	945	18	83	892	50	11	22	6	-	11	59	81	6	2	11
Beckingham	801	14	174	640	7	21	72	-	-	-	30	14	86	-	-
Mattersey	314	10	171	1230	20	-	80	-	-	-	24	41	59	-	-
Misson	505	10	353	2227	20	10	70	-	-	-	30	44	6	-	50
Tea	194	9	42	422	67	22	-	-	-	11	48	100	-	-	-
Temple Mill	90	2	172	1672	100	-	-	-	-	-	19	-	100	-	-
Ripple	257	8	70	267	12	38	-	25	25	-	48	85	14	-	1
Bushley	134	7	93	473	14	4	14	14	14	-	27	58	-	-	42
Oldbury	384	14	49	1064	86	7	-	-	7	-	60	74	23	4	-
Epney	115	2	182	1648	50	-	50	-	-	-	35	50	37	12	-
Total	5417	170	105	926	46 (41)*	18 (14)	22 (31)	6 (10)	5 (2)	3 (2)	42	56	34	1	9

* Weighted by area in benefit.

farms in the eastern part of the STWA area. A more detailed review of farming in the study area is given in Annexe VII, Section 4.

Table 5.3 summarises the pre- and post-scheme flood risk and drainage status for each scheme, together with the extent of underdrainage.

TABLE 5.3

Drainage Status and Change

Scheme	Pre-Scheme Flood Risk - % of Area					Pre-Scheme Drainage Status - % of Area				Under-Drainage - % of Area				Change in Flood Frequency - % of Area			
	Did Not Flood	1 in 5	1 in 2 to 1 in 5	One per Year	One per Year	Rarely Wet	Occasion -ally Wet	Commonly Wet	Usually Wet	Un-drained	Drained Pre-Scheme	Drained Post-Scheme	Re-drained	No Floods	Reduce	Same	Increase
Sharnford	52	-	-	3	44	54	36	7	4	14	66	-	21	100	-	-	-
Kilby Bridge	33	-	-	1	65	-	59	36	5	4	79	-	18	36	4	54	6
Doley Brook	63	-	-	13	24	18	26	35	22	39	43	-	19	84	5	10	-
Alrewas	57	-	-	17	27	61	18	17	3	89	11	-	-	56	17	27	-
Blithe	19	6	-	-	75	5	-	45	50	5	64	5	27	100	-	-	-
Morda	47	-	2	4	47	16	34	33	18	54	23	13	9	90	1	-	9
Sleap Brook	91	-	1	1	7	12	43	36	9	40	35	11	14	99	1	-	-
Beckingham	2	98	-	-	-	-	35	22	43	13	13	45	29	2	-	98	-
Mattersey	7	2	-	12	79	3	16	13	68	41	11	48	-	100	-	-	-
Misson	15	-	2	27	56	-	25	26	48	67	-	33	-	84	6	7	2
Tean	46	-	23	-	31	4	64	18	14	15	78	4	3	83	14	3	-
Temple Mill	39	-	-	-	61	-	19	31	50	20	11	-	70	100	-	-	-
Ripple	14	1	-	2	83	4	22	63	10	80	10	-	10	24	65	-	10
Bushley	8	-	-	24	69	-	31	63	6	15	33	63	-	7	89	4	-
Oldbury	48	13	-	14	25	-	20	69	11	84	13	3	-	94	6	-	-
Epney	39	14	-	-	47	20	18	31	31	45	3	49	4	100	-	-	-
Total	39	17	1	7	36	13	31	33	22	42	26	19	13	68	9	21	2
Valid Cases (%)	← 95 →					← 87 →				← 89 →				← 93 →			

CHAPTER 6

FIELD DRAINAGE DESIGN, PRACTICE AND COSTS

6.1 INTRODUCTION

A subsidiary objective of the study was to examine the design and costing of underdrainage installations with a view to developing an estimating procedure of use to River Engineers in the pre-investment appraisal of proposed schemes. This Chapter summarises the enquiry and findings. It is supported by Annexe VI.

6.2 FIELD DRAINAGE DESIGN AND PRACTICE

The object of drainage design both with respect to arterial and field drainage is to control the water table within limits best suited to agricultural production.

Rational drainage design uses drainage theory to predict the depth and intensity (spacing) of underdrainage according to soil, aquifer and climatic conditions. Design charts were produced for deep permeable, shallow fine textured, and peat soils respectively according to the theoretical method described in Appendix VI.A. It was considered that this design procedure could be used at the scheme planning stage to determine length of pipework needed, and thus estimate likely costs.

It was confirmed, however, during the course of the study that actual drainage design and installations are based on tradition rather than theory. In particular, where drainage theory suggests considerable variation in drain spacing according to soil permeability, drainage practice reveals a much more modest variation around the mean of 18 m found in this study (see Annexe VI.3.2). Furthermore it was found that reliable estimates of some physical variables needed for theoretical design, particularly concerning the soil's hydraulic conductivity and the depth to the impermeable layer, could only be established by detailed site investigation. For these reasons an alternative system for estimating field drainage costs was sought.

6.3 FIELD DRAINAGE COSTS

As an alternative to a design based procedure, a statistical analysis of field drainage data collected during the farm survey and from MAFF files was undertaken in an attempt to derive a method for estimating field drainage costs based on simple, easily measurable factors. The method and results are described in Annexe VI.3.3.

The costs of all field drainage schemes were reduced to per hectare values in constant 1982 prices. Where separately identified, the cost of ancillaries was removed from total costs.

The mean cost was found to be £700/ha but the standard deviation was high (£274) and the range between £300 and £1,600.

Four factors were found to have a significant effect upon the cost per hectare of underdrainage. These were:

Region (reflecting spacial variation in costs),
Use of permeable fill,
Drain spacing,
Ancillaries (hedging and ditching).

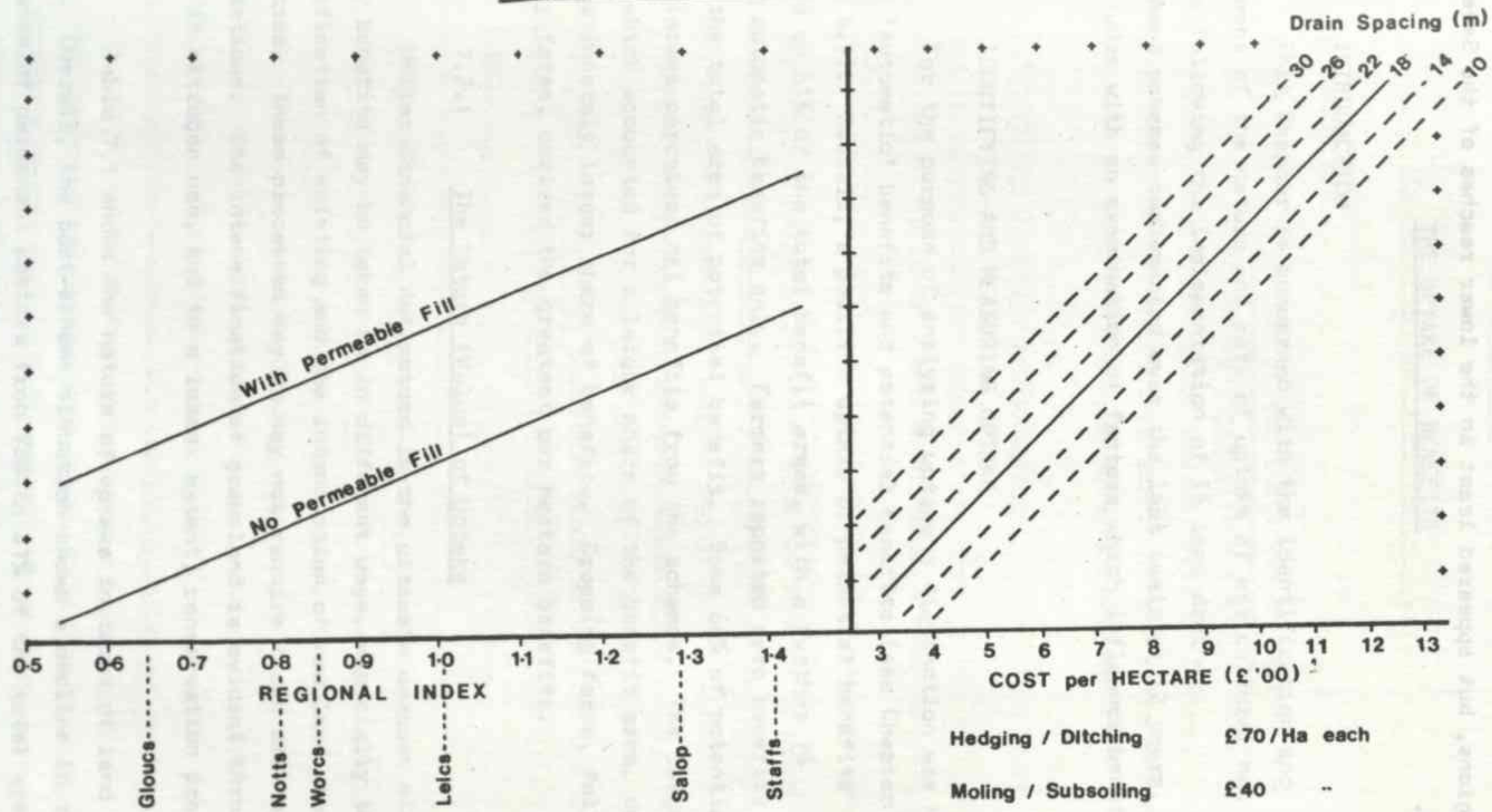
Regional factors, possibly reflecting variations in local competition and demand for drainage, and the use of permeable backfill were the main influences accounting for two-thirds of the observed variation in cost per hectare.

A stepwise multiple regression produced a function based upon the above 4 variables and accounted for 75% of the observed variation in drainage cost. This has been converted to a nomograph for rapid cost estimation (Figure 6.1).

6.4 DRAINAGE CONTRACTORS

A brief survey of 12 drainage contractors confirmed the aforementioned observations (Annexe VI.4). Drain depth varied between soils, but not so much drain spacing. Most contractors do their own design, to standards which are safely within theoretical

Fig 6.1 : ESTIMATION OF UNDERDRAINAGE COST[1]



1. 1982 prices.

needs. Costs are based on length of pipework, and varied little within regions, but appeared least in the lower reaches of the Severn and Trent.

CHAPTER 7

THE UPTAKE OF BENEFITS

7.1 INTRODUCTION

This Chapter is concerned with the identification and measurement of the nature and rate of uptake of agricultural net benefits following the implementation of 16 land drainage improvement schemes implemented over the last (mainly) 12 years. It concludes with an examination of factors which influence benefit uptake.

7.2 IDENTIFYING AND MEASURING UPTAKE

For the purpose of analysing uptake a distinction was made between 'automatic' benefits and potential benefits (see Chapter 3, section 6.1). Overall, a positive uptake of potential benefits occurred on 51% of the total benefit areas, with a further 7% showing automatic benefits only. Farmers reported zero benefits on 42% of the total area of potential benefit. Some 66% of potential beneficiaries perceived net benefits from the schemes. The larger farms, which accounted for a larger share of the benefit area, derived a proportionately larger share of benefits. Cropping farms, followed by dairy farms, derived the greatest per hectare benefits.

7.2.1 The Nature (Value) of Uptake

Whilst financial net return is the ultimate measure of uptake, benefits may be taken up in different ways, especially the intensification of existing and the introduction of new land use activities. These processes may or may not require field drainage installations. The intensification of grassland is evident through change in nitrogen use, and to a lesser extent, conservation practices.

Table 7.1 shows the nature of uptake in terms of land use change. Overall, the post-scheme situation shows a decline in the importance of permanent pasture from 75% to 47% of the total area, and the increase in arable and arable/ley from 16% to 43%. If rough grazing is arbitarily ascribed the lowest land use rating, and

Table 7.1

Land Use Change

Scheme	Pre-Scheme Land Use - % of Area						Post-Scheme Land Use - % of Area						Land Use Change - % of Area		
	Rough Grass	Permanent Pasture	Temporary Grass	Arable /Ley	Crops	Non Agric.	Rough Grass	Permanent Pasture	Temporary Grass	Arable /Ley	Crops	Non Agric.	Decline	No Change	Improved
Sharnford	-	63	14	19	4	-	-	56	15	25	4	-	-	93	7
Kilby Bridge	5	87	-	-	-	8	-	86	-	5	-	8	-	82	10
Doley Brook	8[1]	55	2	26	-	9	8[1]	50	6	19	13	4	5	73	20
Alrewas	-	57	34	-	9	-	-	56	34	-	10	-	-	99	1
Blithe	8	92	-	-	-	-	-	84	16	-	-	-	-	77	23
Morda	-	86	5	8	1	-	-	73	12	13	2	-	7	73	20
Sleap Brook	-	63	-	7	17	14[2]	-	31	7	22	34	5[2]	6	48	43
Beckingham	3	68	1	-	28	-	-	18	-	-	82	-	-	46	54
Mattersey	-	62	-	5	33	-	-	30	6	8	56	-	-	70	30
Misson	6	83	-	-	6	4	-	25	-	5	64	5	-	33	65
Tean	-	91	8	-	-	1	-	66	8	12	-	14[4]	-	75	10
Temple Mill	-	81	-	-	-	19[3]	-	10	-	72	-	19[3]	-	10	72
Ripple	-	86	-	2	7	4	-	73	-	4	19	4	-	82	14
Bushley	-	95	-	5	-	-	-	31	-	31	38	-	-	34	66
Oldbury	-	93	1	2	1	4	-	89	4	3	1	4	-	95	4
Epney	-	87	13	-	-	-	-	39	-	57	4	-	-	39	61
Total	2	75	4	5	11	4	1	47	7	12	31	3	2	64	32
Valid Cases (%)	← 98 →						← 99 →						← 99 →		

1. Doley Common
2. Sleap Airfield
3. Sibson Wold
4. A50 By-pass

TABLE 7.2

Drainage Status and Change

Scheme	Pre-Scheme Flood Risk - % of Area					Pre-Scheme Drainage Status - % of Area				Under-Drainage - % of Area				Change in Flood Frequency - % of Area			
	Did Not Flood	1 in 5	1 in 2 to 1 in 5	One per Year	One per Year	Rarely Wet	Occasion -ally Wet	Commonly Wet	Usually Wet	Un-drained	Drained Pre-Scheme	Drained Post-Scheme	Re-drained	No Floods	Reduce	Same	Increase
Sharnford	52	-	-	3	44	54	36	7	4	14	66	-	21	100	-	-	-
Kilby Bridge	33	-	-	1	65	-	59	36	5	4	79	-	18	36	4	54	6
Doley Brook	63	-	-	13	24	18	26	35	22	39	43	-	19	84	5	10	-
Alrewas	57	-	-	17	27	61	18	17	3	89	11	-	-	56	17	27	-
Blithe	19	6	-	-	75	5	-	45	50	5	64	5	27	100	-	-	-
Morda	47	-	2	4	47	16	34	33	18	54	23	13	9	90	1	-	9
Sleap Brook	91	-	1	1	7	12	43	36	9	40	35	11	14	99	1	-	-
Beckingham	2	98	-	-	-	-	35	22	43	13	13	45	29	2	-	98	-
Mattersey	7	2	-	12	79	3	16	13	68	41	11	48	-	100	-	-	-
Misson	15	-	2	27	56	-	25	26	48	67	-	33	-	84	6	7	2
Tean	46	-	23	-	31	4	64	18	14	15	78	4	3	83	14	3	-
Temple Mill	39	-	-	-	61	-	19	31	50	20	11	-	70	100	-	-	-
Ripple	14	1	-	2	83	4	22	63	10	80	10	-	10	24	65	-	10
Bushley	8	-	-	24	69	-	31	63	6	15	33	63	-	7	89	4	-
Oldbury	48	13	-	14	25	-	20	69	11	84	13	3	-	94	6	-	-
Epney	39	14	-	-	47	20	18	31	31	45	3	49	4	100	-	-	-
Total	39	17	1	7	36	13	31	33	22	42	26	19	13	68	9	21	2
Valid Cases (%)	← 95 →					← 87 →				← 89 →				← 93 →			

permanent pasture, temporary grass, arable/leys, and continuous cropping represent an increasing order of land use intensity, then land use moved to a higher order category on 32% of the total area.

In terms of field drainage (Table 7.2), some 32% (+1,400 ha) of the total benefit areas had new underdrainage post-scheme (of which 40% was redraining). A total of 26% of the area had drains pre-dating the schemes. Forty-two percent of the total benefit areas remained undrained.

With respect to grassland, an increase in nitrogen use attributable to drainage improvement occurred on 50% of the post-scheme grass area, mostly by between 50 and 100 kg/ha. Conservation changes occurred on 24% of the grass area.

The relative share of total financial net benefits, expressed in additional gross margins and extra net returns is summarised in Table 7.3. Sixty-five percent of additional net revenue was associated with land use change, and 63% was associated with post-scheme underdrainage. Over 80% of extra net returns on grassland were associated with extra nitrogen, and some 44% with a change of conservation method.

The order of extra benefits per hectare are also apparent from Table 7.3. The greatest average benefits were associated with land use change and with field drainage installation.

Whilst land use change and new field drainage each occurred on about one-third of the total benefit areas the same sites were not necessarily involved. Sixty percent of the drainage installation was on sites which have changed land use.

TABLE 7.3

Distribution of Benefits

Distribution of Benefits from Land Use Change - All Sites

Shift[1]	% of Benefit		Average Benefit/ha		Area %
	Δ Gross Margin	Δ Net Return	Δ Gross Margin	Δ Net Return	
0	40	35	68	46	67
1	4	3	117	69	4
2	13	12	217	136	8
3	37	43	252	212	18
4	2	2	432	275	1
5	6	5	429	247	2
Total	100	100	122	87	100

Distribution of Benefits from Drainage - All Sites

Post-Scheme Drainage	% of Benefit		Average Benefit £/ha		Area %
	Δ Gross Margin	Δ Net Return	Δ Gross Margin	Δ Net Return	
None	39	37	69	47	68
Drained	61	63	232	172	32
Total	100	100	122	87	100

Distribution of Benefits from Increased Nitrogen - Grassland

Change in "N" Rate	% of Benefit		Average Benefit £/ha		Area %
	Δ Gross Margin	Δ Net Return	Δ Gross Margin	Δ Net Return	
None	10	19	12	14	50
Upto 50 kg	3	4	30	23	7
50-100 kg	19	19	44	27	25
100-150 kg	26	24	148	87	10
150-200 kg	5	6	112	78	2
Over 200 kg	42	30	418	184	6
Total	100	100	59	36	100

Distribution of Benefits from Change in Grass Conservation - Grassland

Change in Conservation	% of Benefit		Mean Benefit £/ha		Area %
	Δ Gross Margin	Δ Net Return	Δ Gross Margin	Δ Net Return	
No change	41	56	30	24	76
Increased cuts	4	2	99	40	2
Hay to silage	23	12	158	50	8
Grazing to silage	14	6	78	19	10
Hay to grazing	18	24	247	195	4
Total	100	100	55	33	100

1. The shift in land use class is calculated as the numerical value of the post-scheme class minus the pre-scheme class. Classes were coded as follows: 0 - not used, 1 - rough pasture, 2 - permanent grass, 3 - temporary grass, 4 - crop/ley rotation, 5 - crops, 6 - horticulture.

7.2.2 The Rate of Uptake

The rate of uptake is concerned with the time in years after scheme implementation that potential benefits are taken up. At field level 3 situations can be identified; firstly, where uptake is zero, secondly, where uptake is gradual (as in the case of gradual increases in fertilizer use), and thirdly, where uptake is abrupt. The latter situation was defined where over 50% of the gross margin increment occurred in one year.

Table 7.4 shows that 75% of benefit uptake occurred abruptly. Statistical analysis showed that the timing of abrupt uptake was significantly (at 0.1%) correlated with the timing of land use change and underdrainage.

7.2.3 Uptake Curves

All of the observed additional net returns were reduced to per hectare values, and expressed according to 'project' years ranging from one to 25. As the years progress, the sample varies from 5557 hectares in year one to 941 hectares in years 13 to 25. The mean incremental net benefit was plotted to derive the overall uptake curve shown in Figure 7.1, which displays the nature (height of curve) and rate of (shape of curve) uptake.

Once 'automatic' benefits accruing in the first year of scheme life are accounted for, potential benefits appear to be taken up according to an S-shaped curve. After initial slow uptake, uptake accelerates during years 6 to 9 after which it levels off. Sample size restricts the observed curve to 12 years, but data for one scheme with a longer life, suggested that the curve could be extrapolated to year 16 by which time the rate of change of uptake approached zero.

A similar approach was adopted to derive uptake curves for land use change and underdrainage. These are shown in Figures 7.2 and 7.3. Although both curves demonstrate an S-shape, comparing the observed rate of change with a linear trend, land use change is generally higher in earlier years, whereas, the rate field drainage having levelled off after early installations, increases quite steeply

TABLE 7.4

Types of Benefit Uptake

Type of Uptake	% of Sites	% of Benefit[1]	% of Area
Negative or zero uptake	52	-	44
Abrupt uptake[2]	35	75	37
Gradual uptake	14	25	15
Total	100	100	100

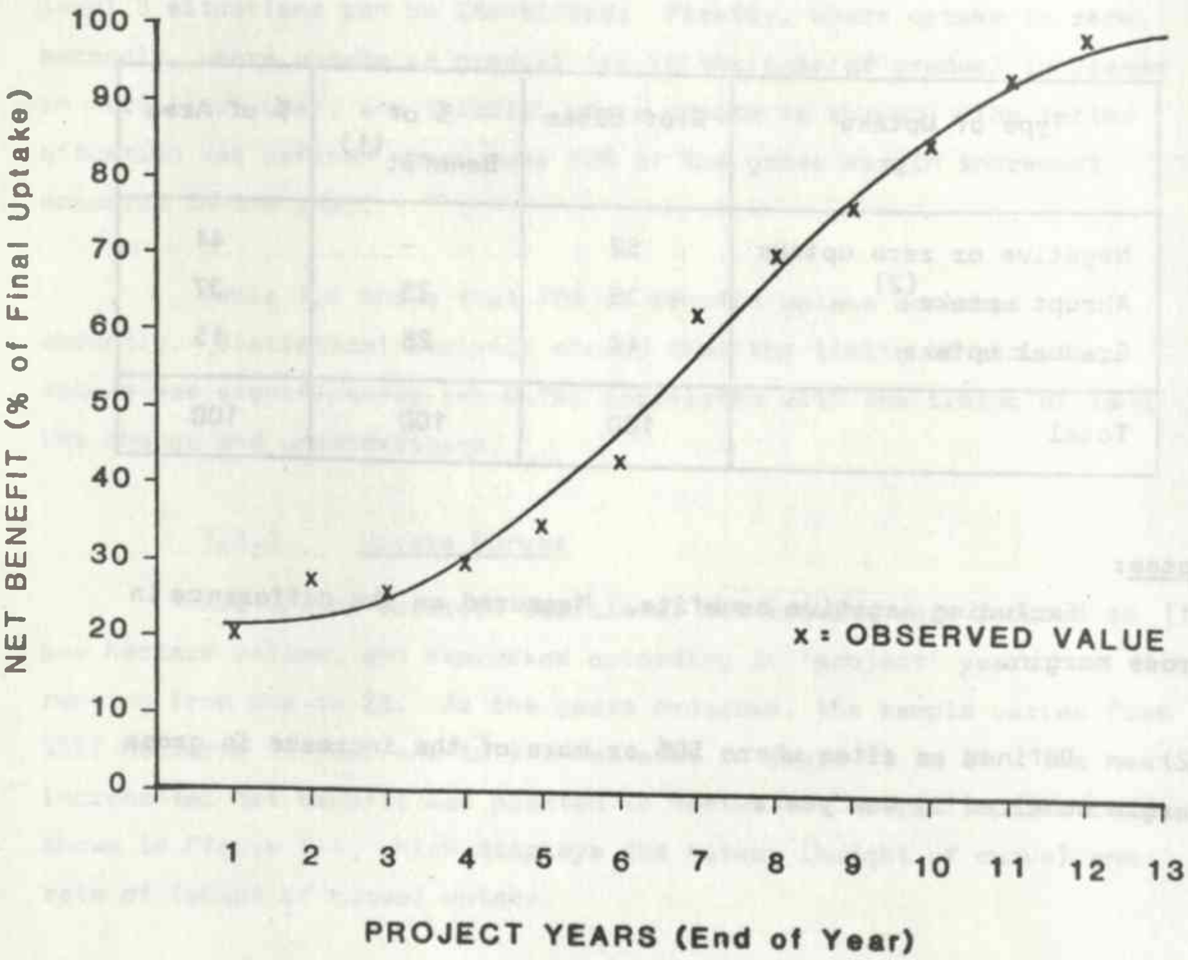
Notes:

(1) Excluding negative benefits. Measured as the difference in gross margin.

(2) Defined as sites where 50% or more of the increase in gross margin occurred in one year.

FIGURE 7.1

Aggregate Uptake Curve



Year	1	2	3	4	5	6	7	8	9	10	11	12
Sample size (% of total area)	100	100	94	94	85	78	73	69	63	58	36	32

Figure 7.2 :MEAN UPTAKE CURVE : DRAINAGE

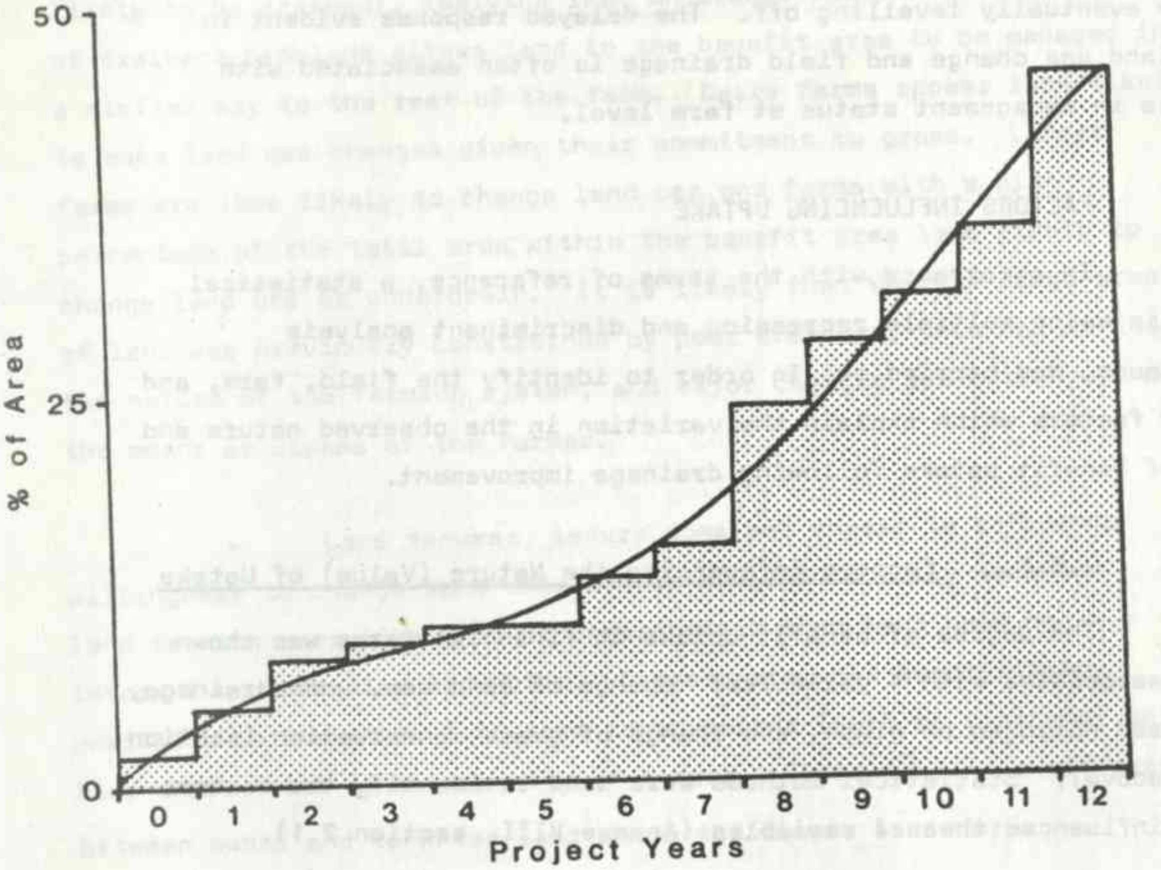
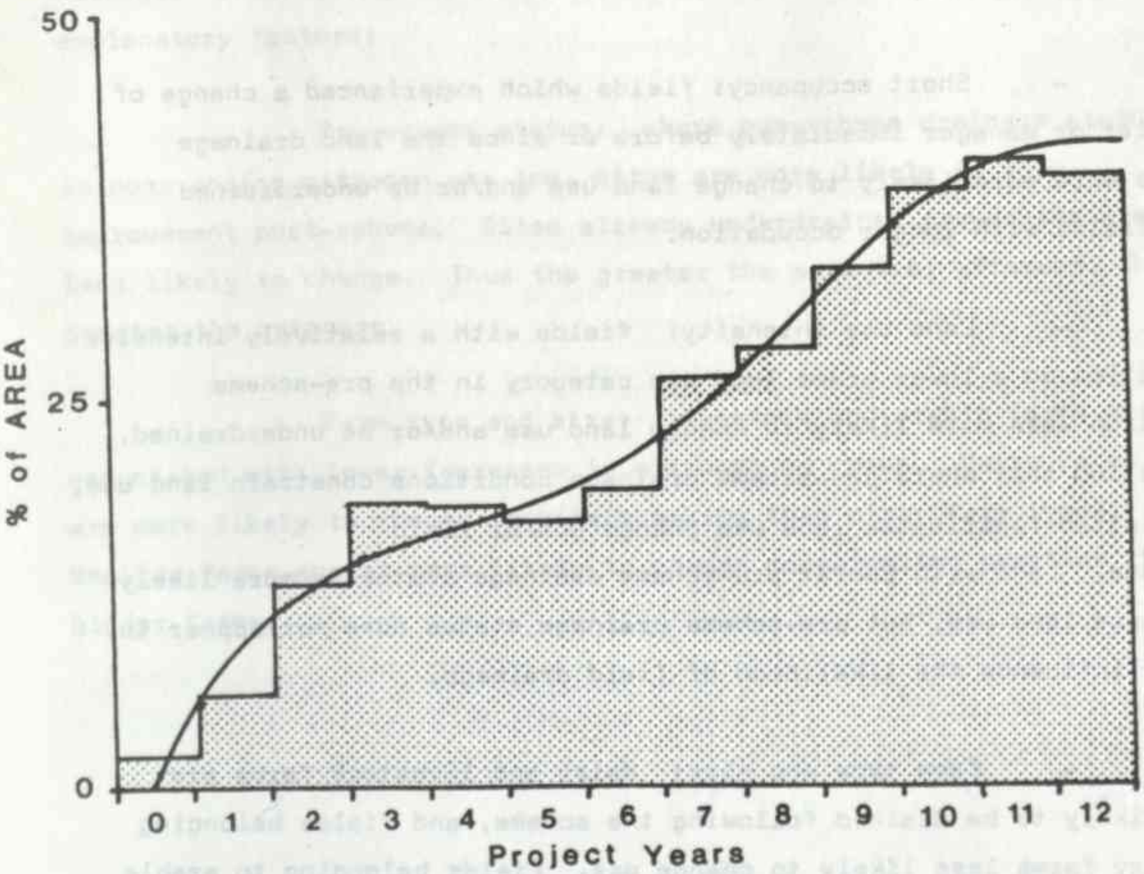


Figure 7.3:MEAN UPTAKE CURVE : LANDUSE CHANGE



before eventually levelling off. The delayed response evident in both land use change and field drainage is often associated with changes in management status at farm level.

7.3 FACTORS INFLUENCING UPTAKE

In accordance with the terms of reference, a statistical analysis using multiple regression and discriminant analysis techniques, was carried out in order to identify the field, farm, and farmer factors which explain the variation in the observed nature and rate of benefit uptake following drainage improvement.

7.3.1 Factors Influencing the Nature (Value) of Uptake

The degree of benefit uptake in financial terms was shown to be associated with 4 variables; change of land use, underdrainage, increased nitrogen on grass, and change of grass conservation (section 7.2.1 above). Statistical methods were used to identify the factors which influenced these 4 variables (Annexe VIII, section 2.1).

Land use change and drainage were found to have similar explanatory factors:

- Short occupancy: fields which experienced a change of occupier or manager immediately before or since the land drainage scheme were more likely to change land use and/or be underdrained than fields with longer occupation.

- Land use intensity: fields with a relatively intensive production on a lower order land use category in the pre-scheme situation were more likely to change land use and/or be underdrained, suggesting that where pre-scheme drainage conditions constrain land use, alleviation facilitates land use change and/or field drainage. Land with poorer pre-scheme drainage status is more likely to change land use, but pre-scheme drainage status does not appear to unduly influence the likelihood of field drainage.

- Farm type and size: dairy and livestock farms are less likely to be drained following the scheme, and fields belonging to dairy farms less likely to change use. Fields belonging to arable farms are more likely to change use after the scheme (but no more likely to be drained), implying that on arable farms the alleviation of drainage problems allows land in the benefit area to be managed in a similar way to the rest of the farm. Dairy farms appear less likely to make land use changes given their commitment to grass. Larger farms are less likely to change land use and farms with a high percentage of the total area within the benefit area less likely to change land use or underdrain. It is likely that where a large area of land was previously constrained by poor drainage, this has defined the nature of the farming system, and major changes are often beyond the means or wishes of the farmer.

- Land tenure: tenure does not appear to influence willingness to change land use, but owned land or fully tenanted land is much more likely to be underdrained than land held on informal or irregular tenancies. Farmers are, not surprisingly, unwilling to invest in long-term improvements (such as drainage) on land where there is no security of tenure. There is little difference between owned and tenanted land where the tenure is secure.

The intensification of grassland, through a change in nitrogen use or grass use/conservation method displays the following explanatory factors:

- Pre-scheme status: where pre-scheme drainage status is poor and/or nitrogen use low, sites are more likely to show improvement post-scheme. Sites already underdrained pre-scheme are less likely to change. Thus the greater the potential afforded, the greater the response.

- Farm type and size: livestock and arable farms are associated with lower increases in nitrogen on grass. Dairy farms are more likely to change to silage making than other farm types. Smaller farms appear more likely to change conservation practice than bigger farms.

- Farmer characteristics: younger farmers, particularly those who have attended agricultural training courses and/or have formal qualifications in agriculture, are more likely to take up benefits on grassland, than older farmers. Farmers who show a greater degree of social participation (ie. membership of/representation on committees of farmer groups) demonstrate a greater uptake of grassland benefits.

- Farm management: a change in management status (eg. from father to son) since the scheme is associated with the increase of nitrogen use. The move out of hay cutting is more likely to happen on farms which are part of a larger multi-holding business.

7.3.2 Factors Influencing the Rate (Timing) of Uptake

The conventional approach of studies into the rate of adoption of new and improved practices has concentrated upon farm and farmer characteristics, drawing the distinction between those factors associated with innovators and laggards. This approach is not directly applicable to drainage benefits where the uptake occurs in many different ways and different degrees of potential benefit may be taken up at different times. Many farmers may take up different types of benefit at different times on different parts of their farm. A farmer could be a laggard in one field and an innovater in another!

Given the observed relationship between the timing of uptake and the timing of land use change and/or underdrainage, regression analysis was used to attempt to explain variations in the timing of the latter 2 dependant variables in terms of field, farm, and farmer factors. To achieve a reasonable degree of accuracy (R^2 = 0.8 and 0.65) over 10 factors had to be included (Annexe VIII, section 3.1). The main explanatory factors for the timing of uptake (in terms of land use change and underdrainage) are summarised as follows:

- Change in flood frequency: a high pre-scheme and low post-scheme flood frequency encourages early uptake of potential benefits.

- Pre-scheme underdrainage: sites which were drained prior to the scheme are associated with later uptake.

- Distance of the field from the farm: uptake is earlier on sites nearer the farm than those further away.

- Soil type: uptake of land use change and drainage appears to have been later on peat soils and drainage also appears to have been later on loam soils.

- Length of occupancy prior to the scheme: short occupancy is associated with earlier uptake, however land belonging to farms which have changed management status since the scheme appear to have a later uptake (mainly reflecting the timing of change in relation to the scheme date).

- Post-scheme land use and drainage: earlier uptake is associated with higher order post-scheme land uses, suggesting that the more major changes occur earlier. Similarly sites that are drained post-scheme tend to change land use earlier in the life of the scheme than others.

- Farmer characteristics: early land use change is associated with educated and formally qualified farmers, older farmers and farms which are one of a number of holdings. (Younger farmers came in, and made their influence felt later in the scheme). Early drainage is associated with owned, rather than tenanted, fields, and interestingly a stronger emphasis placed by the farmer on the 'way of life' rather than profit maximization.

As an overview, the rate of uptake appears to be influenced by 5 main factors. Firstly, and most important, the earliest uptake occurs where drainage status (flooding and waterlogging) improves most, and therefore potential benefit is greatest. Secondly, the greater the degree of actual uptake (associated with land use change and under-drainage) the earlier this occurs. Thirdly, a change in occupancy about the time of scheme implementation encourages early uptake (a change in management in the course of the scheme encourages uptake soon after the change). Fourthly, fields closer to the farm tend to be improved earlier than the more distant ones. Distance from the farmstead particularly influences land use and management on dairy farms, nearby fields are primarily used for milking cows, more distant often fragmented fields are used for young or dry stock, and conservation. Finally, some of the characteristics of farmers associated with innovativeness (education, social participation, business motivation) do partly explain the timing of uptake, but care needs to be exercised in their interpretation. For instance, those farmers who placed greater emphasis on 'farming for profit' tended to drain later than those who saw 'farming as a way of life'. However, it was sometimes apparent that the more financially successful and secure farmers, many of whom had taken up early benefits, were able at least to express a disregard for high profits, compared to their less financially fortunate, and possibly less innovative, counterparts.

7.4 PREDICTING UPTAKE

The preceding analysis has been concerned with explaining the observed variation in benefit uptake with a view to improving the accuracy of predicting both the nature of and rate of future uptake in response to proposed land drainage improvements.

7.4.1 Predicting the Nature (Value) of Uptake

With respect to the nature of farmer response, the analysis has identified factors which influence the degree of likely uptake. Two approaches to prediction could be used; firstly, one based on the statistically derived regression equations into which local values for the explanatory factors can be fed to derive estimates of likely uptake; secondly, one based on a 'benefit scenario' approach which, for those factors which are seen to explain uptake, such as potential improvement in physical drainage status, generates a set of field/farm/farmer benefit budgets to indicate likely uptake.

7.4.2 Predicting the Rate (Timing) of Uptake

With respect to the rate of uptake, that is the shape of the uptake curve in reaching the degree of uptake just referred to, consideration was given to deriving uptake rates for different field/

farm/farmer factors so that site specific rates could be predicted. With this in mind, the aggregate data set for the entire field and farm sample (see 7.1 above) was used to derive suites of uptake curves for different factors (see Annexe VIII, section 4), eg. a suite of curves predicting uptake rate for fields with different pre-scheme drainage status. Such a suite is only useful if the scatter about the individual curves is less than that about the aggregate curve, and the criterion variable is easily measurable at the pre-scheme stage (as for example, post-scheme change of management would not be).

Suites of curves were compiled to predict the timing of uptake of financial benefit using as criterion variables the factors previously shown to influence the timing of land use change and underdrainage. However, such curves (eg. showing a difference in the rate of financial benefits taken up by farmer age class, or pre-scheme drainage status) did not provide a significantly improved estimate of uptake rate over that provided by the aggregate curve (Figure 7.1) when measured in terms of the standard error of the estimate. This was not surprising as an attempt at multiple regression had been able to explain less than 40% of the observed variation in the timing of financial benefit uptake.

Attention was then given to producing suites of uptake curves to predict the timing of land use change and underdrainage, because the latter were shown to be particularly associated with financial benefit uptake. Again, suites of curves for selected criterion variables (such as land use change by soil type, or by distance from farm) provided no better estimate of timing than the aggregate curve. This was not surprising because the regression equations explaining the rate of land use change and underdrainage, although providing an overall good fit, contained a multiplicity of factors, no one of which exerted any predominant influence. Whilst the suites of uptake curves point to some interesting comparisons between field/farm/farmer characteristics as they might influence the timing of uptake response, the shape of the aggregate curve remains the best statistically based estimate of uptake rate.

CHAPTER 8

SCHEME EVALUATION

8.1 INTRODUCTION

Each of the 16 STWA land drainage schemes selected for evaluation can be viewed as separately identifiable investment projects, to which benefits and costs can be ascertained over time.

This Chapter, supported by Annexe VIII, section VIII.5 and Annexe IX, describes the main benefit and cost parameters for scheme appraisal, summarises the findings of the scheme level evaluation, and comments on the factors which appear to determine scheme performance.

8.2 SCHEME LEVEL BENEFIT AND COST PARAMETERS

The schemes listed in Table 5.1 above were enacted to fulfil specified objectives usually relating to the alleviation of flooding and/or the provision of improved outfall facilities. The general criterion for justification has, however, been financial net return, and since 1974, the explicit requirement that project benefits recover project costs when discounted at the Treasury's prevailing discount rate for public sector investments. This discounted cash flow procedure for investment appraisal was applied to the ex-post evaluation of the STWA schemes. The main benefit and cost parameters were as follows.

8.2.1 Net Agricultural Cash Flow

The net agricultural cash flow at scheme level included the sum of farm level net agricultural benefits, and savings in flood damage costs, less without-project returns and farm level expenditure on field drainage.

8.2.1.1 Net Agricultural Benefits:

The estimate of net agricultural benefits attributable to a scheme is the sum of the estimated financial value of benefit uptake at field and farm level within the scheme's boundary of influence, usually but not always the Medway Letter Line. Valuations have been made in 1982 financial prices and the relativities that occurred at that time.

The purpose of evaluation was to comment on scheme performance todate and not attempt future uptake predictions. Estimates of actual uptake are available for each year of scheme life up to the present time (1984) after which they are assumed constant for the remaining part of a 30 year life. If this assumption prejudices a scheme, the increase in net agricultural benefits necessary over remaining life to enable the scheme to break even are identified, and this can be put in the context of latent response or unexploited scheme potential.

8.2.1.2 Flood Damage Reduction:

The net benefits accruing to farmers at scheme level of reduced flooding and consequent savings in losses to standing crops, livestock, property, and time spent clearing debris, have been included in the scheme appraisal. The extent of these savings depend on the changes of flood risk and the flood event cost for pre- and post-scheme land use situations. Reliable hydrologic data for return period prediction were lacking in most cases.

8.2.1.3 Without-Project Benefits:

On the assumption that those farmers who took up benefits attributable to the scheme could have obtained some share of the farming sector's general productivity improvement on their benefit area fields without a change in drainage status, these without-project benefits have been levied at 1% compound per year of the average pre-scheme net returns up to year 1984, after which like net agricultural benefits, they are assumed to remain constant.

8.2.1.4 Field Drainage Costs:

The cost before grant of field drainage installations, obtained from MAFF files, have been charged for the year in which they occurred. The costs of private pumping, extra secondary treatment, and irrigation where relevant, have also been included.

8.2.2 Scheme Level Costs

8.2.2.1 Capital Costs:

Actual recorded capital costs at outturn prices for each scheme were converted to 1982 prices using the Public Sector Non-Roads Index. These costs include the initial cost of providing the drainage improvement, compensation payments, third party (eg. IDB) investments and costs associated with environmental protection. Contributions from local authorities for non-agricultural improvements are deducted from capital costs. Where joint costs are apparent, as for example where schemes share the services of pumping stations, costs have been apportioned according to share of likely benefits.

8.2.2.2 Recurrent Costs:

Expenditure on scheme incremental repairs and maintenance has been charged, together with reported operating costs of lowland pumping stations where relevant.

8.3 SCHEME FINANCIAL APPRAISAL

For each scheme, the estimated net agricultural cash flow has been set against the stream of capital and recurrent costs, and discounted at 5% over a 30 year project life.

Tables 8.1 and 8.2 summarise the financial performance of the 16 schemes.

On the basis of observed uptake todate and the assumption that benefits continue at their 1984 levels over the remainder of a 30 year project life, 7 of the 16 schemes recover costs and appear profitable at the 5% discount rate. These are the Doley, Morda, Sleap, Mattersey, Misson, Bushley and Epney schemes. One further scheme, Beckingham Marshes, is sufficiently marginal to justify satisfying the 5% rule. Five of these schemes are wholly or partly within IDB areas, and 2 others have informal farmer drainage groups.

On 3 schemes, Kilby Bridge, Blithe and Temple Mill, the internal rate of return is between 0% and 5%, the present levels of uptake would need to more than double over remaining project life for them to break even. The remaining schemes: Sharnford, Alrewas, Tean,

TABLE 8.1

Summary of Scheme Performance

Scheme	Capital Cost £ per ha of Benefit Area[1]		Field Drainage Investment £ per ha of Benefit Area	Performance Todate[2]			Projected to Full Development[3]		Remarks
	Estimated	Actual		NPV at 5% £'000	IRR %	Switch Value	NPV at 5% £'000	IRR %	
Sharnford	1080	1331	90	-482	$-\infty$	8.5	-422	-8.0	23% increase in costs.
Kilby Bridge	541	740	84	-54	2.2	1.5	60	5.5	Includes anticipated increased flood damage in without-project benefits. 37% increase in costs.
Doley Brook	970	368	161	16	6.7	0.88	16	6.7	62% saving in costs (incl. bridge not rebuilt).
Alrewas	548[4]	532[4]	0	-175	-4.0	2.5	-124	0.1	Anticipated arterial works on non-main river not carried out.
Blithe	683	799	82	-24	1.75	1.75	-24	1.75	
Morda	511	522	122	61	7.4	0.82	61	7.4	Part in IDB.
Sleap	203[4]	178[4]	125	81	8.3	0.8	81	8.3	Excluding benefits to Sleap Airfield. Local Drainage Group.
Beckingham	-	1877	275	-27	4.6	1.02	-27	4.6	IDB.
Mattersey	-	653	188	325	16.0	0.57	-	-	IDB.
Misson	-	513	135	54	6.7	0.9	-	-	IDB.
Tean	1323	1452	27	-253	-11.4	7.0	-217	-3.9	25 ha out of production during road construction.
Temple Mill	619	1296	525	-29	2.7	1.25	-29	2.7	Anticipated arterial works on non-main river not carried out. 109% increase in costs.
Ripple	660	1134	56	-182	-3.9	3.75	-167	-1.9	72% increase in costs.
Bushley	673	567	240	78	11.3	0.63	78	11.3	Local Drainage Group.
Oldbury	692[5]	1208[5]	15	-427	-4.8	2.9	-140	3.0	75% increase in costs. IDB.
Epney	905[5]	1013[5]	130	66	8.0	0.75	66	8.0	IDB.

1. Capital costs brought to 1982 levels using PWNR index.
2. Observed performance todate with benefits continuing at their 1984 level for remainder of project life.
3. Projected of full development (see Annexe IX, section 4.6).
4. STWA costs per ha of direct benefit only.
5. Whole project costs.

TABLE 8.2

Summary of Benefits by Scheme

Scheme	Date of Commencement of Works	No. of Farmers in Benefit Area	No. of Farmers Taking Up Benefits	Benefit Area (ha)[1]	Extra Net Returns (£/ha)	Flood Damage Reduction (£/ha/year)	Increase in Gross Margin (%)	Increase in Net Returns (%)	Extra GM/ha as % of Potential	Ranking (based on extra net returns/ha)
Sharnford	1978	14	4	370	13	1.49	4	5	6	16
Kilby Bridge	1974	9	7	256	40	22.41	28	19	29	12
Doley Brook	1973	10	8	198	70	0	24	29	29	8
Alrewas	1976	13	2	464	22	2.48	15	11	n/a	13
Blithe	1971	7	7	77	90	2.39	56	53	37	6
Morda	1972	23	10	431	62	2.44	26	37	26	10
Sleap	1973	17	12	945	66	0.14	30	30	20	9
Beckingham	1960	14	10	919	231	-4.88	123	168	70	1
Mattersey	1982	10	8	309	166	11.55	96	89	65	3
Misson	1980	10	9	480	84	0	n/a	53	n/a	7
Tean	1977	8	3	138	22	5.94	13	29	12	13
Temple Mill	1972	2	2	73	142	3.83	80	73	69	5
Ripple	1975	8	6	244	22	20.10	20	16	10	13
Bushley	1972	7	5	129	148	5.81	67	119	47	4
Oldbury	1978	14	12	448	50	8.59	17	24	22	11
Epney	1971	2	2	145	183	7.72	109	91	73	2

1. The Area used for investment appraisal which may not be the same as the benefit area defined at feasibility stage nor the area covered by the farm survey.

Ripple and Oldbury, produce negative rates of return. The increase in net agricultural returns over remaining project life needed to break even varying between the two-times present levels in the case of the Alrewas to more than ten-times in the case of Sharnford.

Some of the poor performing schemes are immature and further potential benefits may be taken up in time. To derive an estimate of uptake at full development, the aggregate uptake curve (Figure 7.1) was used to predict likely increases in benefits over remaining project life (see Annexe IX.4.5). As shown in Table 8.1, with the exception of the Kilby Bridge scheme, this procedure does not significantly affect overall scheme worthwhileness at the 5% discount rate.

Average capital costs per hectare varied considerably with the nature of the drainage problem and the engineering solution, such that simple relationships between, say, benefit area and capital cost per hectare are not discernible.

For 5 schemes large increases in costs above those predicted at the design stage contributed towards the poor financial performance.

Large variations are apparent between schemes in terms of actual uptake expressed in £/hectare, or as a percentage of full potential uptake. The latter is based on an assessment of land capability and local farming practice and reflects the kind of potential uptake that might be identified at the planning stage. For reasons discussed in Annexe IX, section 4.4, this relative measure of uptake requires cautious interpretation, particularly in that some farmers were also operating at below potential in the pre-scheme situation.

In the majority of schemes the distribution of benefits is skewed in favour of a small number of beneficiaries but not always in proportion to their relative share of the benefit area.

8.4 FACTORS INFLUENCING INDIVIDUAL SCHEME PERFORMANCE

For given capital cost features, the main factors determining scheme financial performance are the size and timing of net agricultural benefits. The latter, will be dependant on the incidence of field, farm, and farmer factors known to influence uptake, found within the boundary of a scheme (see Annexe VIII, section 5). At field level net agricultural returns have been greatest where the scheme has provided a significant improvement in drainage status, and physical conditions, particularly soils, have been conducive to improvement or land use change. The more successful schemes are particularly associated with large areas that were of the lowest drainage class before the scheme. The 7 schemes showing the highest extra net returns per hectare had more than 30% of their area classified as 'usually wet' pre-scheme.

At farm level, changes in farm management and/or occupancy have particularly influenced scheme performance. On the Bushley scheme, for instance, the major beneficiary involved a partnership between 2 farmers formed shortly after the scheme. On the Misson, one farming company acquired a large part of the benefit area immediately prior to and largely in anticipation of the scheme, and subsequently changed farming methods radically. The schemes showing the greatest average net returns also demonstrated the lowest mean percentage of total farm size in the benefit area.

At scheme level the main factors influencing the uptake of benefits, in addition to field and farm level factors found within the confines of a particular benefit area, relate to the presence of formal or informal organisations providing drainage services within the benefit area. Seven of the 8 schemes which break even at 5% involve such organisations, 5 are in IDB areas (3 of which are pumped) and 2 contain informal drainage groups which collectively undertake watercourse improvement and in one case emergency pumping when necessary. It is in these schemes that farmers are aware of the potential afforded by improved drainage particularly by the demonstration effect on adjoining IDB areas, where there is much pressure exerted by farmers and land drainage committees for improvement, where drainage contractors are more readily available, and where follow-up work on arterial drains or pumping is done quickly to satisfy a latent demand.

With respect to scheme costs, it is perhaps fortuitous that the 7 schemes with the highest financial performance generally displayed the lowest capital cost per hectare, but more importantly they also offered the greatest potential benefit per £ capital cost.

8.5 CRITIQUE AND SENSITIVITY

The major criticism of the benefit assessment method is that it relies heavily on farmer recall, and where data are lacking, involves the use of simplifying assumptions and procedures.

The main simplifying assumptions have related to the use of nitrogen as a basis for estimating grassland productivity, the use of constant 1982 prices, and the conversion of physical data derived from farm survey into financial values using standardised livestock and arable gross margins, semi- and total fixed costs estimates.

Sensitivity analysis tested for the effect of crop prices, yield levels, and grass utilisation percentages, and showed that a $\pm$1% change in these variables had a more than proportionate effect on net returns, especially where full fixed costs were charged. The use of economic prices for internationally traded crop commodities reduced gross margins to about 65-75% of their financial farmgate values.

The most critical assumption in the benefit assessment procedure is whether extra semi- or total fixed costs should be charged against the gross margin improvements obtained, and where they are charged whether the standard rates are a good estimate of reality. Semi-fixed costs (including labour) were charged in all cases and total fixed costs were charged only where farmer reported additional investment costs. The latter occurred on 18% of the farms surveyed. It is assumed that errors of over and under estimation due to the use of standard fixed costs have a cancelling effect.

The observation here that extra fixed costs have a critical effect on the value of net benefit, and that little information is presently available on which to predict the behaviour of fixed costs for specified farm circumstances, suggests that further work is needed on the monitoring of fixed costs to assist the planning process (see Chapter 9).

Despite these criticisms, because the concern has been with incremental benefits and costs, the estimate of net benefit attributable to a given degree of drainage improvement is not unduly affected by errors in estimating the absolute baseline situation providing the relative order of improvement has been judged correctly.

CHAPTER 9

POLICY IMPLICATION

The findings of the study have a number of implications for future STWA land drainage evaluation.

9.1 PRE-INVESTMENT APPRAISAL

The analysis of uptake supports the need for a reasonably indepth survey of the benefit area at the pre-investment stage to assess field/farm/farmer characteristics identified as being important determinants of uptake response. This would involve farm surveys, supported by secondary data sources, along the lines of those adopted in this study, to evaluate in particular, the pre-scheme drainage and land use situation, agricultural drainage requirements, and likely uptake. The latter two are of course interactive. Land drainage scheme design and justification can then proceed in this context. The fact that the most successful schemes from an uptake viewpoint have been those where pre-drainage status has been poor and a major constraint on farming, where the scheme has provided a significant improvement, and where there has been pressure from farmers themselves to have drainage conditions improved, suggests a context for pre-investment field work, design and appraisal.

With respect to predicting the nature of uptake, the most suitable approach is the development of 'benefit scenarios' or budgets reflecting different values for the influential field/farm/farmer variables, eg. the likely degree of extra net returns associated with a given improvement in drainage status on a given size and type of farm. Having identified the aggregate degree of uptake at scheme level, the phasing of benefits can be based on the shape of the observed uptake curve.

The present exercise has largely been explanatory rather than predictive, but it is anticipated that statistically defined relationships could be combined with financially defined benefit scenarios to derive a more confident basis for prediction than has previously been available (see section 9.5).

Another important message from the study is the necessity to bring together at the planning stage the representatives of all the parties responsible for scheme design, implementation and successful conclusion, namely STWA, MAFF, Local Authorities, IDB's, and farmers. Farmers are not always aware the scheme is being done for them, and their needs do not always seem to feature strongly in scheme design. A number of schemes have been frustrated particularly because follow-up work by third parties on brook or culvert improvements, which were assumed would happen and to which benefits have been ascribed, have not materialised.

9.2 WAYS OF INFLUENCING UPTAKE

It might be argued that under present conditions of relative surplus production in the agricultural sector, Regional Water Authorities should not undertake to generate demand for improved land drainage beyond that already expressed by farmers. Once a scheme has been justified on the basis of an objective assessment of uptake, however, consideration should be given to supporting the exploitation of benefits by as many potential beneficiaries as possible. The process of creating farmer awareness of drainage benefits, or improving his access to technical assistance or services, are best pursued through existing organisations such as ADAS, IDB's, NFU, TFA, CLA, drainage contractors, and farmer discussion groups. It was apparent from the farm survey that greatest uptake occurred where there were either formal or informal drainage organisations, and the greatest frustrated response where farmers had found it difficult to join together to undertake collective improvements.

It is not suggested that River Engineers should chivvy farmers to respond positively to their engineering efforts, but more a matter of making sure that, for a scheme that is well conceived, actual improvements provided are as designed, follow-up works by third parties are carried out, and farmers are made aware (through existing farmer support organisations) of the potential benefits afforded.

9.3 DRAINAGE DESIGN

The study has provided a methodology for field drainage design for specified site conditions together with a statistically based cost estimating procedure using MAFF records of underdrainage within the benefit areas. The contractor survey confirmed that current practices are unlikely to change in the foreseeable future. These estimating methods can be used for calculating field drainage costs at the scheme design stage for investment appraisal purposes.

9.4 MONITORING AND EVALUATION

Many of the criticisms of the procedures adopted in this study must relate to the assumptions necessitated by the reliance on a single visit interview whereby farmers were asked to recall past conditions and events. Many of these problems would not arise if a system of frequent visit farm surveys was set up to provide on-going monitoring and ex-post evaluation of selected schemes. The information requirements (Annexe III) of the present study of uptake provides the checklist of field/farm/farmer/and scheme level factors and units of measurement which would need to be incorporated, initially in an inventory of the baseline, pre-scheme situation, and subsequently in the on-going monitoring of change. Given that the present study of uptake provides a statistically based estimate of response, it is considered that on-going monitoring and evaluation should follow a more indepth, case study enquiry into the important benefit scenario situations identified herein, and referred to in section 9.1 above. Repeated annual visits to selected farms on selected schemes is probably the most cost effective basis for monitoring, supported by interim telephone reporting. Such monitoring would allow the timely recording of physical data, and allow more accurate calculations of financial implications, particularly regarding fixed costs. In some instances, paying for farmer subscription to an enterprise recording scheme (such as MLC beef costing services) may provide measures of performance not easily available by other means, particularly for grassland. Special attention would be needed to devising easily recordable measures of drainage condition which indicate changes in drainage status in relation to river and arterial improvements, and standards of maintenance, and field drainage practices. The evaluation procedure would not only allow an assessment of the extent to which a particular scheme was meeting its objectives in terms of design standards, follow-up work and farmer response, but would generate a catalogue of detailed case histories for use in predicting uptake under similar circumstances elsewhere. To be useful, ex-post evaluation must feed back into the planning process, and preferably those with a hand in the latter should have experience or at least be exposed to the former.

In addition to the indepth monitoring of selected farms it is considered that a simple monitoring and evaluation procedure be devised for each scheme at the planning stage. This procedure would require at least one visit to each farmer beneficiary in the first year of scheme life to record farmers' perceptions of the impact of scheme on drainage status, and outstanding drainage problems, particularly with respect to follow-up work. Subsequent monitoring could be conducted through selected farmers and/or land drainage committees. It was apparent from the farm survey that very few farmers had seen or corresponded with River Engineers after scheme completion, and where they had it was usually to exchange ideas on litigation and claims for compensation. A very simple ex-post monitoring procedure would pay dividends in terms of ensuring that schemes meet original design standards, including follow-up work, creating farmer awareness of potential benefits, identifying the need for and timing of maintenance work, and improving the data base for future scheme planning.

9.5 FURTHER WORK

It is considered that the range of lowland schemes evaluated within the present STWA study is sufficiently comprehensive to allow the results of the analysis of uptake to be extended to other regions. However, 2 types of scheme have not been covered, namely those involving large IDB areas away from main rivers, and those involving fenland-type areas. An assessment of benefit uptake on such schemes would help to confirm that the general findings of the present study are applicable beyond the boundaries of the STWA region.

For reasons discussed in section 9.4 above, further work on ex-post evaluation should concentrate on an in-depth, case study monitoring of selected farms representing important benefit situations.

The study has pointed to the need for consistent guidelines and operating procedures for data collection, analysis, planning and evaluation methods for the agricultural appraisal of land drainage capital and maintenance works.

The methodology developed in the course of the present study combined important physical, agricultural and financial data relationships to develop benefit scenarios for site specific field, farm and farmer variables. This provides the basis for a computer-based 'black box' model, designed for use by river engineers and others, and applicable to scheme appraisal at different levels of sophistication ranging from reconnaissance surveys to detailed project preparation. It is hoped to continue research and development along these lines.

APPENDIX I

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- AFRC, Grassland Research Insitute, Permanent Pasture Division, North Wyke.

- AFRC, Letcombe Laboratory, Wantage.

- Soil Survey of England and Wales, Harpenden.

- Nature Conservancy Council, Divisions.

- South Gloucestershire IDB, Thornbury.

- Laneham IDB, Doncaster.

- Meat and Livestock Commission, Milton Keynes.

- Milk Marketing Board, Thames Ditton.

- Potato Marketing Board, London.

- Silsoe College computer staff, especially E.C. Doyle and P.R.G. Higginbottom.

- Silsoe College staff, especially Miss A.E. Arnold.

- Cranfield Computer Centre.

APPENDIX II

GLOSSARY OF TERMS

A. Farm Management and Miscellaneous Terms

AVAILABLE WATER CAPACITY (AWC) The amount of water a soil may hold per unit of depth which is available for extraction by crops (see Annexe IV, Appendix A).

CONSERVATION SYSTEM (OF GRASS) The method by which grass (or other forage crop) cut in summer is stored for winter feed. Generally as hay or silage.

DRAINAGE STATUS A classification based upon the likely, or usual, wetness of the soil which may be expressed in qualitative (eg. 'good') or quantitative (eg. watertable within top 70 cm of the soil for less than 30 days in any one year) terms.

DRY MATTER YIELD The yield of a crop expressed as a weight of dry matter. This provides a more realistic method of describing yield, particularly of grass, where total (ie. wet matter) weights are highly sensitive to variations in moisture content.

FIELD CAPACITY The amount of moisture that a soil will hold after natural (gravity) drainage. Further moisture may only be removed by evaporation and transpiration.

FIELD DRAINAGE Techniques employed to assist the rapid conveyance of water from the soil into arterial watercourses. This generally includes the laying of tile or plastic pipes within the soil and/or secondary treatments such as MOLING or SUBSOILING (see Annexe I.4).

FIXED COST Costs which in the short run do not vary with output. These costs are borne even if there is no output.

FREEBOARD (OF FIELD DRAINS) The distance between drain outfall and mean waterlevel in the field ditch.

GRASSLAND SITE CLASS A system of classification of sites developed by the Grassland Research Institute based upon summer rainfall and soil AVAILABLE WATER CAPACITY. Sites may range from 'Poor' to 'Very Good' reflecting the volume of water available to the plant during the growing season (see Annexe VI.3.2).

GRASS UTILIZATION Not all the grass grown in the field is available for use by the animal as there may be losses in the field or during CONSERVATION. Utilization is generally expressed as a percentage of total METABOLIZABLE ENERGY.

GRAZING LIVESTOCK UNIT (GLU) A system of defining LIVESTOCK UNITS based upon the energy requirement from grass in a representative diet for a given stock type and management system as a proportion of the energy requirement from grass of a 550 kg liveweight Friesian cow yielding 5,000 litres per year (ie. 33,350 MJ/year). (See Annexe V.3.4). This excludes energy from supplementary feeds and allows changes in grass production to be related directly to STOCKING RATES.

GROSS MARGIN (GM) GROSS OUTPUT less the variable costs directly associated with that level of output. The gross margin is a measure of extra revenues and extra costs per unit of enterprise activity, and is usually expressed per unit of a fixed resource, eg. £/ha.

GROSS OUTPUT The monetary value of the physical output of a farm enterprise, including production retained for on-farm use, usually expressed per unit of activity, eg. £/ha.

HYDRAULIC CONDUCTIVITY (K) The rate (in m/day) at which water may move through a soil profile. This may be either laterally, or, more usually in a drainage context, vertically.

INNOVATOR One who is early to make changes (to his farming system) in response to new opportunities.

LAGGARD One who is late to make changes (to his farming system) in response to new opportunities.

LAND CAPABILITY CLASSIFICATION The assessment of the productive capacity of land based upon limitations to use imposed by the soil, climate or topography.

LAND USE SHIFT A measure of the magnitude of change in land use based upon a nominal system of ordering from 1 (rough grazing) to 6 (horticulture). See Annexe VIII.2.

LAND USE SUBSTITUTION A situation where improvements in the productivity of land in a benefit area can release other land for other uses, eg. improved drainage in lowland pasture allows earlier access and higher stocking, enables the maintenance of herd size on a reduced area, and increased arable cropping on land outside the benefit area previously required for grass production.

LIVESTOCK UNIT A method of expressing livestock numbers upon the basis of their energy requirements. Different classes of animals are related to a standard livestock unit which, for convenience, is usually taken as the type of dairy cow, most numerous in the U.K. The standard used by MAFF is 'the energy allowance for the maintenance of a 600 kg Friesian cow and the production of a 40 kg calf, and 4,500 litres of milk at 3.6% of butterfat and 8.6% solids-non-fat'. This equates to 48,000 Megajoules (MJ) of METABOLISABLE ENERGY (ME) per year. A 24-month grass beef animal, requiring 21,600 MJ of ME per year is therefore 45% of a Livestock Unit; an average ewe, 10% and so on.

LYSIMETER A piece of laboratory equipment consisting of a tank enclosing a monolith of soil and a growing crop. Water inputs and outputs are monitored and controlled to examine the effects of artificially high or low watertables on the crop.

MEDWAY LETTER LINE The boundary of the benefit area of a land drainage improvement scheme defined upon the basis of The 'Medway' Letter as a line 2.44 m (8 feet) above the level of the highest known flood (for non-tidal areas). In practice it is generally extended to the field boundary above the Medway Letter Line to include the whole field. The 'Medway' Letter (MAFF, June 1933) originally referred to the definition of the boundary of the Upper and Lower Medway Internal Drainage Districts.

METABOLIZABLE ENERGY The processes of digestion and metabolism whereby an animal obtains its energy are not achieved with complete efficiency and energy is lost in the process in a variety of forms. The energy value of the food less the energy value of the faeces, urine and the combustible gas that is produced from it is termed the Metabolizable Energy.

MOLING A secondary FIELD DRAINAGE treatment used in certain clay soils. Unlined channels are formed by pulling a 'bullet' through the soil. These mole channels generally interconnect with a system of pipe drains by means of a PERMEABLE FILL. In suitable soils, moling provides a cheap means of achieving a very close drain spacing. Mole channels need to be redrawn every five years or so.

NET RETURN (NR) OR NET MARGIN The GROSS MARGIN minus FIXED COSTS. See Annexe V.2.5.

NITROGEN(N), UNITS OF Artificial N is applied either as a 'compound' of Nitrogen (N), Phosphorous (P) and Potassium (K) or as 'straight' N. The 'number' of a compound fertilizer refers to the percentages of N, P and K, eg. an 8-20-16 fertilizer = 8% N, 20% P and 16% K. Straights vary in their N content but 'Nitram' (a common straight fertilizer) contains 35% N. A unit of nitrogen is an imperial measure of weight and equal to 0.01 cwt. Therefore one bag (1 cwt) of 8-20-16 contains 8 units of N. In the metric system units are replaced by kilograms.

NITROGEN APPLICATION RATE The application of NITROGEN is measured in UNITS per acre or Kilograms per Hectare. 100 units/acre = 126 kg/ha.

OPPORTUNITY COST OF GRAZING DAYS The value of grazing days may be measured in terms of net savings in bought feeds and/or savings in conservation costs and/or savings in yarding costs (see Annexe V.3.9).

PARISH RETURNS Agricultural Censuses have been carried out annually by MAFF since 1866. All occupiers are required by law to provide information on land use, livestock numbers and workers on their farm. Individual census returns are confidential but summaries may be obtained at parish level from MAFF or the Public Records Office.

PERMEABLE FILL In soils with a slowly permeable subsoil it is often necessary to lay a band of permeable material (usually gravel) over the drain pipes to within 30-35 cm of the surface. This will assist movement of water to the drains and connect with channels and fissures produced by MOLING or SUBSOILING. The use of permeable fill adds considerably to the cost of a FIELD DRAINAGE scheme.

POACHING Excessive treading of wet soil by animals leading to destructuring of the soil and damage to the sward. (See Annexe II.3.3.2).

POACHING STATUS The susceptibility of a soil to POACHING dependant upon its bearing capacity (see Annexe II.3.3.2, and Annexe IV, Appendix A.IV.2.2).

SEMI FIXED COSTS Costs usually classified as FIXED COSTS yet, in the medium term vary with output. These are items of recurrent expenditure associated with the use of existing fixed resources (eg. machinery fuel and repairs). See Annexe V.2.5.

SPRING FLUSH Grass grows all year round in England, merely slowing in winter, however the bulk of production occurs between April and September. As temperatures rise in spring and there is generally plenty of water available there is a rapid acceleration in grass growth during April and May. This is the spring flush. As summer rainfall rarely matches the crop's demand for water production then falls away during the summer. The wetter (western) parts of Britain also experience an autumn flush. (See Annexe IV.2.1 and A.IV.2.2).

STANDARD MAN DAY (SMD) A Standard Man Day consists of eight hours of adult male labour. Standard Man Day requirements per hectare or head are published by MAFF. The Standard Man Day requirement of a farm is used as a measure of size and the distribution of that requirement amongst enterprises as a measure of farm type.

STOCKING RATE The intensity of grassland productivity can be measured by the number of animals on the farm per area of grass and forage crops. Stocking rates are expressed in terms of LIVESTOCK UNITS per hectare of grass (grassland stocking rate) or of forage plus grass.

SUBSOILING A secondary FIELD DRAINAGE treatment used to increase the HYDRAULIC CONDUCTIVITY of the subsoil by creating cracks and fissures with deep tines.

TIMELINESS Certain agricultural activities are extremely sensitive to the time at which they are carried out. The date of sowing of cereals, for instance, can influence final crop yield. Carrying out these tasks at the optimal time is referred to as timeliness (see Annexe II.3.3.1).

TRAFFICABILITY The capacity of a soil to withstand loads applied by machinery or animals. The trafficability of a soil is therefore a function of both the shear strength of the soil and the nature of the machinery, or type of animal. Poor trafficability can lead to POACHING by livestock and poor TIMELINESS of operations (see Annexe II.3.3).

UPTAKE The realization of potential benefits of land drainage improvement schemes, requiring some investment of resources by the farmer.

UTILIZED METABOLIZABLE ENERGY (UME) Grass yields are measurable in terms of METABOLIZABLE ENERGY (ME) given in megajoules per hectare (MJ/ha). The grass ME production which is not lost, but becomes part of animal production is termed Utilized Metabolizable Energy (see Annexe IV.2.4 and IV.5).

UTILIZATION EFFICIENCY See GRASS UTILISATION.

VARIABLE COST A cost which varies directly with the rate of output, eg. grain drying and storage costs.

WATERLOGGING The presence of a water table at or near the soil surface as opposed to flooding where the water level is above the surface.

B. Project Appraisal Terms

AUTOMATIC BENEFITS Those benefits that do not require any investment by the farmer to be realized, eg. reduced flood damage, extended grazing seasons.

BENEFIT SCENARIO Estimates of the type and value of net benefits associated with typical combinations of pre- and post- improvement drainage status and farming activity, eg. the typical value of a move from extensive grass to arable/ley for given environmental and farming conditions.

DISCOUNTED CASH FLOW (DCF) A method of investment appraisal based on the idea that the value of a sum of money (a cost or benefit) depends upon when it is to be received. It is better to receive money earlier, therefore the later a benefit accrues, or cost is incurred, the lower the value. In Discounted Cash Flow all costs and benefits are brought to PRESENT VALUES using a specific DISCOUNT RATE.

DISCOUNT RATE The rate used in DISCOUNTED CASH FLOW to value future flows of costs and benefits in terms of PRESENT VALUES. For public investments the Discount Rate should reflect the opportunity cost of capital to the economy, and in practice is set by the Treasury.

ECONOMIC APPRAISAL A method of investment appraisal where all costs and benefits are valued in terms of their opportunity cost to the economy.

GUARANTEE SECTOR That part of the European Common Agricultural Policy responsible for farm commodity price support and stabilisation, eg. intervention prices, import levies.

GUIDANCE SECTOR That part of the European Common Agricultural Policy responsible for structural adjustment, eg. improvement grants, retirement incentives.

EX-ANTE PROJECT EVALUATION A project appraisal carried out before the start of the project to assess its expected worthwhileness.

EX-POST PROJECT EVALUATION A project appraisal carried out after the completion of the project to assess its actual worthwhileness.

INTANGIBLE COSTS AND BENEFITS Costs and benefits which do not have a MARKET VALUE, eg. reduced anxiety due to flood alleviation or loss of wildlife habitats.

INTERNAL RATE OF RETURN (IRR) The DISCOUNT RATE which when used to discount the cash flows associated with a project produces a zero NET PRESENT VALUE. An IRR greater than the test DISCOUNT RATE would suggest that the project is worthwhile.

MARKET PRICE The monetary value per unit of a good or service paid by a buyer or received by a seller.

NET AGRICULTURAL CASH FLOW In a project evaluation, the sum of the agricultural benefits minus the on-farm costs of achieving those benefits (such as field drainage costs), for each year of the project life.

NET PRESENT VALUE (NPV) The sum of the PRESENT VALUES of benefits minus the sum of the present value of costs.

PAYBACK PERIOD The period over which the cummulative net revenue from an investment project equals the original investment. This takes no account of the time profile of the cash flow.

POTENTIAL BENEFITS Benefits which require an investment of resources by the farmer in order to be realized, eg. a change of land use. These may or may not be taken-up during the life of the project.

PRESENT VALUE In DISCOUNTED CASH FLOW, the value of a sum of money arising in the future taking account of its time value. The Present Value is equal to

$$\frac{V}{(1 + r)^n}$$

where: V = actual value of the cost or benefit,
r = DISCOUNT RATE,
n = number of years after the project commencement.

PRICE RELATIVE EFFECT A consideration of the extent to which, having removed the effect of inflation, some commodities have become cheaper or more expensive in real terms than other commodities over time.

QUASI-FINANCIAL APPRAISAL An assessment of project worthwhileness using market or financial prices for inputs and outputs except for selected inputs, eg. land and field drainage capital costs where grants are easily identifiable and the costs of these items are charged before grant aid.

SENSITIVITY ANALYSIS A procedure for examining the extent to which the value of an important dependent variable is influenced by the value of an independent variable, eg. the % change in the GROSS MARGIN of dairy cows due to a 1% change in the price of milk.

SHADOW PRICE The real value to the community of the consumption of one more unit of a good or service, or the commitment of one more unit of a resource. Shadow prices are the unit prices used to assess the value of inputs and outputs to the economy as a whole of an investment project. They allow for the fact that because of market conditions, or government subsidies or taxes, market prices may not be a good indicator of real economic value.

SINKING FUND METHOD A method which determines the annual charge which will accumulate with interest over time to generate an investment or replacement fund, ie. the opposite of paying off a loan, expressed as a decimal of the first estimate.

SWITCHING VALUE The required change expressed as a decimal of the first estimate in the value of an important cost/benefit parameter (eg. net agricultural benefit) which will make the investment project break even at the recommended discount rate.

UTILITY ANALYSIS A theoretically based procedure for evaluating the degree of satisfaction or happiness for an individual associated with a given activity or outcome. In traditional economic theory maximising income also maximises utility, and market prices provide good estimates of utility. More recent theory and evidence shows this is not always so.

WITHOUT-PROJECT BENEFITS It is assumed that without the project farming would not remain static and there would be some benefits due to general improvements in agricultural efficiency; eg. improved varieties, machinery or techniques. In the present study, Without-Project Benefits have been taken at 1% compound per year, reflecting general trends in recent years.

C. Statistical Terms

ANALYSIS OF VARIANCE A technique to test whether there are STATISTICALLY SIGNIFICANT differences in the mean value of a variable (measured on an interval scale) between different groups.

BETA-WEIGHT The standardized REGRESSION COEFFICIENT, which provides a measure of the relative contribution of independent variables in a MULTIPLE REGRESSION equation, by removing the effect of different scales of measurement and degrees of scatter.

CHI-SQUARED TEST A technique to test whether the distribution of cases, classified upon the basis of two or more nominal scales, is random or whether there is some relationship between the classifications.

DISCRIMINANT ANALYSIS A technique which attempts to explain the variation in a nominal dependent variable upon the basis of a number of interval scale independent variables, ie. an attempt to discriminate between classes. Examination of the STANDARDISED DISCRIMINANT FUNCTION can reveal which of the independent variables account for most of the variation in the dependent and the EXPLANATION OF VARIANCE (R^2) shows how much of the variation in the dependent variable is explained by the discriminant function.

EXPLANATION OF VARIANCE (R^2) A statistic that describes what proportion of the variation in the dependent variable is explained by the independent variables in ANALYSIS OF VARIANCE, MULTIPLIE REGRESSION, and DISCRIMINANT ANALYSIS.

MULTIPLE CLASSIFICATION ANALYSIS A technique applied to multiple ANALYSIS OF VARIANCE that predicts mean values for each class of one independent variable having accounted for variations in each of the others.

MULTIPLE REGRESSION A technique that attempts to explain variations in a dependent variable upon the basis of a number of independent variables. All variables must be measured on an interval scale. Examination of the BETA-WEIGHTS provides information on the relative contribution of each independent and the EXPLANATION OF VARIANCE (R^2) indicates what proportion of the total variation is explained by the regression equation.

PEARSON'S CORRELATION COEFFICIENT A simple statistic describing the strength of a linear relationship between two ordinal variables. 0 = no linear correlation; ± 1 = perfect linear correlation.

REGRESSION COEFFICIENT A MULTIPLE REGRESSION equation takes the form

$$Y = b_1 x_1 + b_2 x_2 + b_3 x_3 \ldots + b_n x_n + C$$

where: Y is the dependent variable,
x_1 to x_n are the independent variables,
b_1 to b_n are the regression coefficients,
C is a constant.

Thus the regression coefficients are the weightings applied to each independent variable in the regression equation. Unlike the BETA WEIGHTS, these provide no information on the relative contribution of each independent as scales may vary.

STANDARD DEVIATION A simple parameter describing the variation of a variable about the mean score. In a normal distribution 95% of the values will lie within two Standard Deviations of the mean.

STANDARD ERROR OF THE ESTIMATE An expression for the STANDARD DEVIATION of the distance of observed values about a regression line.

STANDARDIZED DISCRIMINANT FUNCTION The discriminant function (similar in form to the MULTIPLE REGRESSION equation) where the coefficients are expressed in standardized form thus removing the effect of different scales of measurement and degrees of scatter.

STATISTICAL SIGNIFICANCE An effect is said to be significant if the value of the statistic used to test the relationship is unlikely to occur by chance; ie. if the probability of it occurring by chance is less than the chosen SIGNIFICANCE LEVEL.

SIGNIFICANCE LEVEL The probability chosen to describe the limits for significance tests. Levels of 5,1 or 0.1 per cent are commonly chosen but are entirely arbitrary. If a relationship is said to be significant at the 1% level there is only a 1 in 100 chance that the observed distribution or relationship occurred at random.

STEPWISE MULTIPLE REGRESSION A technique of MULTIPLE REGRESSION where independent variables are added into the regression equation one by one, beginning with the variable shown, by ANALYSIS OF VARIANCE, to have the most significant effect upon the dependent variable. Further variables are included and at each stage the overall SIGNIFICANCE is tested. Some variables already entered may then be removed. The process is continued until either all variables have been entered or the entry of further variables does not significantly improve the overall EXPLANATION OF VARIANCE.

ANNEXE I

BACKGROUND AND SCOPE

ANNEXE I

BACKGROUND AND SCOPE

Contents

List of Abbreviations

ADAS	Agricultural Development and Advisory Service
IDB	Internal Drainage Board
MAFF	Ministry of Agriculture, Fisheries and Food
STWA	Severn Trent Water Authority

ANNEXE I

BACKGROUND AND SCOPE

I.1 BACKGROUND

The investment of public funds in agricultural land drainage is usually justified in terms of the expected net increase in the value of agricultural production due to the improvement. The actual realisation of these agricultural benefits mainly depends on the response of individual farmers to the opportunities provided by improved drainage. Observations of existing land drainage schemes reveal considerable variation in the actual nature and rate of benefit uptake. However, because there has been little detailed post-investment evaluation of benefit uptake, the reasons for this variation remain largely unexplained. An understanding of the factors influencing farmer uptake of drainage benefits is essential at the pre-investment stage where the prediction of likely uptake pattern is critical to the selection and ranking of agricultural drainage and improvement schemes.

It was in this context that Silsoe College (formerly the National College of Agricultural Engineering) was invited by the Severn Trent Water Authority (STWA) to submit a research proposal to investigate the nature and rate of uptake of agricultural benefits by farmers following the completion of STWA land drainage improvement projects. Such a proposal was submitted to the Authority in June 1981 entitled "Drainage Benefits and Farmer Uptake". This proposal put forward terms of reference and an outline methodology for a 27 month study to evaluate and explain the nature and rate of benefit uptake on selected STWA schemes with a view to improving future STWA benefit assessment and scheme selection methods. The proposal suggested a study comprising 3 stages:

Stage I : A Feasibility Study of the Main Enquiry; definition and review of the problem; data needs, sources and availability; proposal for subsequent stages.

Stage II : Field Work; detailed study of uptake at individual farm and scheme levels, and data analysis.

Stage III : Interpretation of results and formulation of STWA policy guidelines.

The proposal for Stage I was accepted by STWA, and work commenced accordingly in mid-October 1981.

I.2 SCOPE, METHOD AND CONCLUSIONS OF STAGE I

The overall objective for Stage I was to assess the feasibility of and justification for conducting a detailed 2-year study into the nature and rate of farmer uptake of drainage benefits.

In accordance with the terms of reference, the emphasis during Stage I was with the following:

(a) Collating the existing state of knowledge concerning drainage benefits and farmer uptake from published and unpublished sources.

(b) Defining more precisely the objectives and scope of the proposed main enquiry.

(c) Identifying the data requirements and sources (and accessibility) for the main enquiry.

(d) Developing a methodology for the main enquiry, with particular reference to selecting schemes for evaluation, the design and testing of a farmer questionnaire, data collection from secondary sources, data analysis and interpretation, and engineering studies.

A report on the findings of Stage I was submitted to the Authority in March 1982. It concluded that continuing to the main enquiry was justified and a detailed proposal was presented. The findings of Stage I have been included in this report in the appropriate annexes.

I.3 SCOPE OF STAGES II AND III

Stage II of the project commenced in April 1982. The overall objectives were as follows:

(a) To evaluate the actual nature and rate of farmer uptake of agricultural benefits on selected STWA land drainage improvement schemes, and the resultant overall technical, financial and economic performance of the schemes.

(b) To identify, on the basis of the above, the factors which determine and explain the nature and rate of farmer uptake of agricultural benefits from land drainage improvement schemes.

(c) To provide guidelines by which STWA can:

(i) predict the likely agricultural benefits of a proposed scheme,

(ii) determine the best ways of achieving the most desirable pattern of farmer uptake of benefits afforded by land drainage improvement schemes,

(iii) identify using technical and financial criteria the most appropriate field drainage strategies for specified drainage/ agricultural situations,

(iv) monitor and evaluate the performance of existing and future schemes.

Essentially, Stages II and III comprised:

(a) A detailed field study of 16 land drainage improvement schemes that were carried out by STWA or their predecessors, the Severn and Trent River Authorities, over the years 1960-82.

(b) The financial evaluation of benefits arising from these schemes at field, farm and scheme level.

(c) The comparison between costs and benefits to assess the financial performance of the schemes.

(d) A statistical investigation of the field, farm and farmer factors influencing the nature and rate of benefit uptake.

(e) An investigation of the factors influencing the cost of field drainage installations.

(f) A review of the pattern of, and trends in, agriculture in the Severn and Trent catchments over the life of the projects studied, set against national agricultural trends.

(g) A more detailed evaluation of the research evidence for the impacts of poor drainage upon crop, and particularly grass, productivity with a view to modelling the response.

(h) The synthesis of the results of Stage II to formulate policy guidelines.

The methods and sources used are discussed in detail in Annexe III.

I.4 THE AMBIT OF LAND AND FIELD DRAINAGE

The primary function of a river system is to drain the land. Its role in the hydrological cycle is to intercept water that has infiltrated into the soil, or runoff over the surface, and convey it to the estuaries and eventually to the sea. Although hydrologically efficient, the natural drainage system does not always satisfy the needs of man and it is often necessary to modify or supplement the natural drainage system to permit certain uses of the land. For agricultural purposes drainage improvement is necessary when soil wetness is a limitation to the potential use or productivity of a field. Four situations can be identified in which excessive soil moisture is a constraint to agricultural production.

(a) Excessive soil moisture following the inundation of low lying agricultural land by sea water in response to high tides or tidal surges, ie. the coastal flooding problem.

(b) Excessive soil moisture due to the inundation of flood plain land as a result of river flow in excess of bankfull capacity in periods of high discharge, ie. the fluvial flooding problem.

(c) The presence of seasonally or permanently high water tables in the soil due to high water levels in local watercourses, ie. the arterial drainage problem.

(d) Temporarily high water tables in the soil due to slow rates of soil-water movement after heavy rainfall, ie. the field drainage problem.

The aim of all agricultural drainage is the removal, alleviation or prevention of problems caused by excess water.

Land Drainage is concerned with the maintenance and improvement of natural and man-made watercourses to prevent or alleviate problems identified in (a) to (c) above. It therefore includes the alleviation of fluvial and tidal flooding in urban and rural areas. It is also necessary to provide for the effective drainage of agricultural land to ensure efficient crop growth (STWA, 1977), and to provide sufficient freeboard for the installation of field drains. To this end, land drainage works include the construction of flood banks, resectioning and regrading of watercourses, the construction of coastal flood defences, the cutting of new arterial channels and the installation of sluices, pumps, flapped-outfalls and tide-lock gates.

Field Drainage on the other hand, is concerned with assisting the rapid conveyance of water from the soil into the arterial watercourses, in situations where slow rates of soil-water movement would otherwise cause high water tables, particularly after rain ((d) above). This generally involves the laying of tile or plastic pipes within the soil, to convey soil-water, via a system of laterals and mains, into an open or piped ditch that is linked to the natural drainage system. In cases where the natural movement of soil-water is particularly slow, such as in clay soils, secondary treatments (moling or subsoiling) may be used to provide fissures and channels that interconnect via a permeable backfill, with the drain system.

The construction and maintenance of open ditches, and, where necessary, the provision of pumps to lift water from sumps into arterial carriers, also comes under the heading of field drainage.

I.5 POWERS AND RESPONSIBILITIES : LAND DRAINAGE[1]

Under Section 1 of the Land Drainage Act 1976, a duty is imposed upon Water Authorities to exercise a general supervision over land drainage matters in their regions. The permissive powers available to Water Authorities in respect of main rivers are defined by Sections 8 and 17 of the same Act and relate mainly to the promotion of capital and maintenance works.

A Water Authority's control over land drainage matters generally within its area is partially exercised by consenting to various operations in order to ensure that problems do not arise on the drainage system as a result of new works or alteration of existing works.

Water Authorities land drainage income is raised by precept from County Councils and Internal Drainage Boards and expenditure is controlled by a Regional Land Drainage Committee and Local Land Drainage Committees for the Severn and Trent catchments. The Ministry of Agriculture, Fisheries and Food grant aids the Authorities capital expenditure at a rate of 30% in the Severn area and 26% in the Trent area.

District Councils are empowered to carry out improvement works on "non-main" rivers relating to flood alleviation and maintaining flows in watercourses and these powers are similar to those of the Water Authority of main river. Grant is available from the Ministry of Agriculture, Fisheries and Food up to a maximum of 45% of the capital cost.

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1. Thanks to M.L. Yates - S.T.W.A.

County Councils are also empowered to carry out works on "non-main" rivers in a similar manner to District Councils but some important powers are available only at the request of, or by default of, the District Councils. The County Councils may execute land drainage schemes at the request of potential beneficiaries or compulsorily carry out works for the improvement of agricultural land, and apportion the expense amongst those benefiting. These works may be eligible for MAFF grant up to a maximum of 45% of the capital cost.

The Internal Drainage Boards (IDB's) were mostly constituted in the 19th Century and their powers are now defined by the Land Drainage Act 1976. The Boards supervise all drainage and related matters within their Drainage Districts and are empowered to carry out works on intermediate watercourses but not "main" river. Their income is derived from rates levied on land and property within their area and capital improvement schemes are normally eligible for MAFF grant at a rate of 45%. In the STWA area there are 35 Internal Drainage Districts, 27 of which are in the Trent catchment and 8 in the Severn catchment. The Boards consist of elected members and appointees of the District Councils, virtually all of whom have an agricultural interest. However, 3 of the Boards within the STWA area are administered by the Water Authority.

Under certain circumstances, Highway or Navigation Authorities may be required to exercise their statutory responsibility for land drainage matters, but a very large amount of land drainage work is undertaken by riparian owners who are obliged to undertake work that not only benefits themselves but also persons up or downstream.

The Ministry of Agriculture, Fisheries and Food has an important role in the planning and execution of land drainage works through their influence at several stages. The Authority's maximum capital expenditure is determined annually by allocations from MAFF and programmes of work have to be submitted and approved in accordance with Section 24 (1) of the Land Drainage Act 1976. In addition, most capital works are eligible for grant aid.

In order to eliminate land drainage problems, it is necessary to overcome the problems presented by the fragmentation of drainage responsibility amongst the various responsible parties. To this end the STWA, in their Unified Approach to Land Drainage, advocate closer liaison between the various authorities and the extension and rationalization of the 'main-river' system in order to provide a primary network for drainage throughout the region under the control of the Water Authority.

The Water Authorities were obliged under Section 24(5) of the Water Act 1973 to carry out an extensive survey to identify and evaluate land drainage problems on 'main' and 'non-main' watercourses throughout their respective areas. STWA published summaries of the results of their survey in January 1980, in such a way as to allow rapid dissimilation and comparison of costs, cost/benefit ratios and priority categories of each of the problems identified. The Section 24(5) study provides a basis for land drainage planning, and represents an important contribution to the 'Unified Approach'.

I.6 POWERS AND RESPONSIBILITIES : FIELD DRAINAGE

The responsibility for field drainage lies solely with the farmer or land owner, but the design and execution of field drainage works are usually carried out by specialist contractors. Most field drainage work is eligible for grant aid (see Annexe VI, Section 2.8) and to claim support, the farmer must present details of the drainage scheme to the Ministry of Agriculture, Fisheries and Food (MAFF). A sample of all submissions are investigated by the Ministry to ensure that adequate standards of drainage are being maintained. The Ministry, through its advisory service, ADAS, also offer advice and guidance on field drainage matters.

BIBLIOGRAPHY TO ANNEXE I

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ANNEXE II

REVIEW OF DRAINAGE STUDIES

ANNEXE II

REVIEW OF DRAINAGE STUDIES

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List of Abbreviations

ADAS	Agricultural Development and Advisory Service
ARC	Agricultural Research Council
DCF	Discounted Cash Flow
DM	Dry Matter
EHF	Experimental Husbandry Farm
ET	Evapotranspiration
FDEU	Field Drainage Experimental Unit
GRI	Grassland Research Institute
IDB	Internal Drainage Board
IRR	Internal Rate of Return
LGORU	Local Government Operational Research Unit
MAD	Modified Acid Detergent
MAFF	Ministry of Agriculture, Fisheries and Food
ME	Metabolisable Energy
N	Nitrogen
NPV	Net Present Value
RR	Rate of Return
SEW/SOW	An index of water table position/duration
SF	Sinking Fund
STWA	Severn Trent Water Authority
UME	Utilized Metabolizable Energy
USDA	United States Department of Agriculture
WSAC	Water Space Amenity Commission

ANNEXE II

REVIEW OF DRAINAGE STUDIES

II.1 INTRODUCTION

The present study is concerned with the ex-post evaluation of drainage benefits. Information on the pre- and post-scheme levels of production has been gained through a farmer questionnaire. There are, however, a number of difficulties associated with reliance on farmer recall. These include the following:

(a) The farmer may not remember precisely or correctly;

(b) The farm may have changed ownership or management since the scheme; in such cases the interviewed farmer may be unable to supply data for the years before he took over;

(c) Many farmers do not record yields field by field; while a farmer may have a fairly accurate idea of yields over the whole farm each year, he may not be able to distinguish between the productivity of particular fields inside and outside the benefit area.

The evidence in literature for productivity benefits from drainage was therefore studied in order to substantiate the claims made by farmers and to extend data reliably over areas and years for which no first-hand information could be collected.

In the case of grassland there is an additional difficulty in assessing levels of productivity from a farmer's report. The production of arable fields is assessed simply by measuring the harvested yield. For livestock systems it would be necessary at least to know both the stocking rate and either the increment of liveweight gain (for beef cattle) or the milk yield (for dairy cattle). Not only are these quantities rarely known by farmers for a number of years past, but they would still need to be set in context before overall productivity could be assessed. Supplementary information would be required concerning a large number of other factors, such as the extent to which the level of productivity was supported by giving feeds other than grass, the duration and consequently the cost of winter housing and so on (see Annexe V). The difficulty of obtaining this variety of information prompted the use in this study of proxy variables to estimate grassland productivity. The actual yield of grass, which is not measured by farmers, was estimated according to a number of more easily obtained variables, such as the site's soil type, drainage status, nitrogen application rate, etc. (see Annexe IV). Then the level of animal productivity was assessed from the estimated grass yield (see Annexe V).

The drainage studies also gave an insight into the extent to which benefits can be attributed to drainage where a number of other things have also changed. All post-war increases in productivity should be viewed against the underlying trend of yield increases due to the introduction of improved varieties, to increased fertilizer use and to a host of other factors (see Annexe VII).

The bulk of the drainage studies deals with the effects of waterlogging rather than those of flooding, which is comparatively poorly researched. This reflects the variability of damage from flooding according to its depth, duration, timing and other factors Section II.2 below explains the mechanisms by which poor drainage reduces agricultural productivity, following which the evidence for increased productivity following drainage is surveyed in section II.3.

II.2 THE IMPACT OF POOR DRAINAGE ON AGRICULTURE

II.2.1 Crop Growth

Water itself is not injurious to plants and most crops will survive in a water culture as long as sufficient oxygen is present. In waterlogged soils, however, the oxygen required by roots and soil organisms for respiration may be used more rapidly than it can be passed through the soil from the atmosphere. Conditions in the root zone consequently become anaerobic or, more specifically, anoxic.

Oxygen deficiency results in reduced root respiration, restricted uptake of water and nutrients by roots, slower rates of leaf expansion and accumulation of dry matter, depressed tillering, delayed maturation of plants and lighter grain yields (Belford, 1981). Prolonged waterlogging damages roots permanently and eventually results in the death of cells or roots. Oxygen starvation is exacerbated by the obstruction of gaseous diffusion in waterlogged soils, which allows a build-up of carbon dioxide around the roots.

Roots will not grow into saturated soil, so a high water table or waterlogged soil restricts root growth. Smaller root systems mean slower growth. The rice plant is an exception in this regard, having aerenchymous tissue in its roots which forms longitudinal channels down which air passes through the stem to the root tip. There is evidence that other cereals, such as wheat and barley, can also develop such channels but their capacity is small and only sufficient to permit survival, not to support vigorous growth. Even if the summer water table is low, a root system restricted by a high winter/spring water table to a shallow depth (eg. 30 cm) means reduced yields because the roots simply cannot take up sufficient water or nutrients from the volume of soil available to them. This is a common effect of the fluctuating water tables typical of low-lying areas of the U.K.

Wet soils have a lower specific heat and a greater thermal capacity than drier soils, so a greater amount of heat is required to raise their temperature. They therefore remain cold for longer during spring. This can seriously reduce the effective growing season of grass and autumn-sown crops and delay the germination of spring-sown crops, since crop growth rate is directly related to soil temperature. The problem is compounded because surface evaporation from saturated soils exerts a cooling effect on the soil.

There are some indirect effects of excess water on crop growth, besides the direct effects on plants described above. Excess water can have deleterious effects, not on the crop itself, but on its growing environment. Soil temperature affects growth rates indirectly because the level of micro-organism activity, making nutrients available to the crop, is also temperature-dependent, slowing dramatically below 9^{o}C. This activity is principally carried out by aerobic micro-organisms, so poor aeration also depresses the nutrient supply.

Quite apart from slowing the rate at which nutrients, particularly nitrogen, are made available in the soil, waterlogged conditions promote the actual loss of nutrients. Two processes are involved in the main. Firstly, soluble nutrients, including nitrogen, are leached from the soil as drainage water passes down through the soil profile. The greater the degree and duration of saturation, the likelier nutrients are to be leached. Annual losses of nitrogen by leaching have been estimated as being between 5 and 50 kg/ha on arable land in England. Soil type, particularly structure, affects leaching losses since water passing freely through large pores will not leach nitrates held in solution in fine pores. The second process is denitrification, in which successive reductions of nitrate produce nitrogen gas. This process is favoured by wet, anaerobic conditions but is slow as long as the temperature is low.

Wet, anaerobic conditions favour a number of diseases, both plant diseases such as "take-all" (Gacumannomyces graminis) and animal diseases such as liver fluke and Johne's disease. Some pathogens, particularly fungi, are favoured in their reproduction and pathogenesis by such conditions.

The slowing of biological activity in cold soils can be an advantage to crops in certain circumstances. It means that flooding or waterlogging in winter, when growth is negligible for most U.K. crops in the ground at that time, is less damaging than at other times of the year. Crops and aerobic micro-organisms use hardly any oxygen and so the anoxic conditions in the root zone which put the crop under stress, damage roots and ultimately kill plants develop slowly. Furthermore, the denitrifying micro-organisms will also be much less active. Waterlogging at times of rapid growth, when anoxic conditions develop quickly, is much more damaging.

The severity of the effect of excess water on final crop performance depends on a number of variables. Timing is important, not only for the climatic reasons described in the preceding paragraph, but also because crops are particularly sensitive to waterlogging at certain growth stages (eg. flowering, for many species) and relatively tolerant at others. There is great variation between species in this respect. Other sources of variation include the duration and frequency of waterlogging and the timing of nitrogen application. This large number of variables has posed difficulties for research into yield depression due to waterlogging (see section II.3.1).

II.2.2 Trafficability

The load bearing capacity of a soil depends on its shear strength, which decreases with increasing wetness (see Figure II.1). As soil dries from a saturated state it becomes more able to withstand the loads applied by animal hooves or by the wheels of tractors and machinery. For this reason poor drainage, by keeping the soil at a high moisture content, can delay either the turnout of animals or mechanical operations.

In the U.K. only a certain number of days are available for work during the critical seasons for cultivations, ie. spring (sowing, fertilizing, spraying) and autumn (harvesting, seedbed preparation, sowing of winter cereals). The loss of available work days through poor drainage results ultimately in reduced productivity. In the worst cases it might be impossible to sow in spring or, for root crops, to harvest in autumn and 100% loss of yield ensues. More typically yields may suffer because sprays or fertilizers cannot be applied at the right time.

As Figure II.2 illustrates, the timely execution of field operations is dependent upon a number of complex variables, only some of which are within the control of the farmer. However, in a mechanized agricultural system the primary determinant is the condition of the soil in terms of its ability to permit the use of farm machinery without causing an unacceptable degree of compaction or structural degradation.

FIGURE II.1

Relation of Soil Bearing Capacity to Soil Wetness

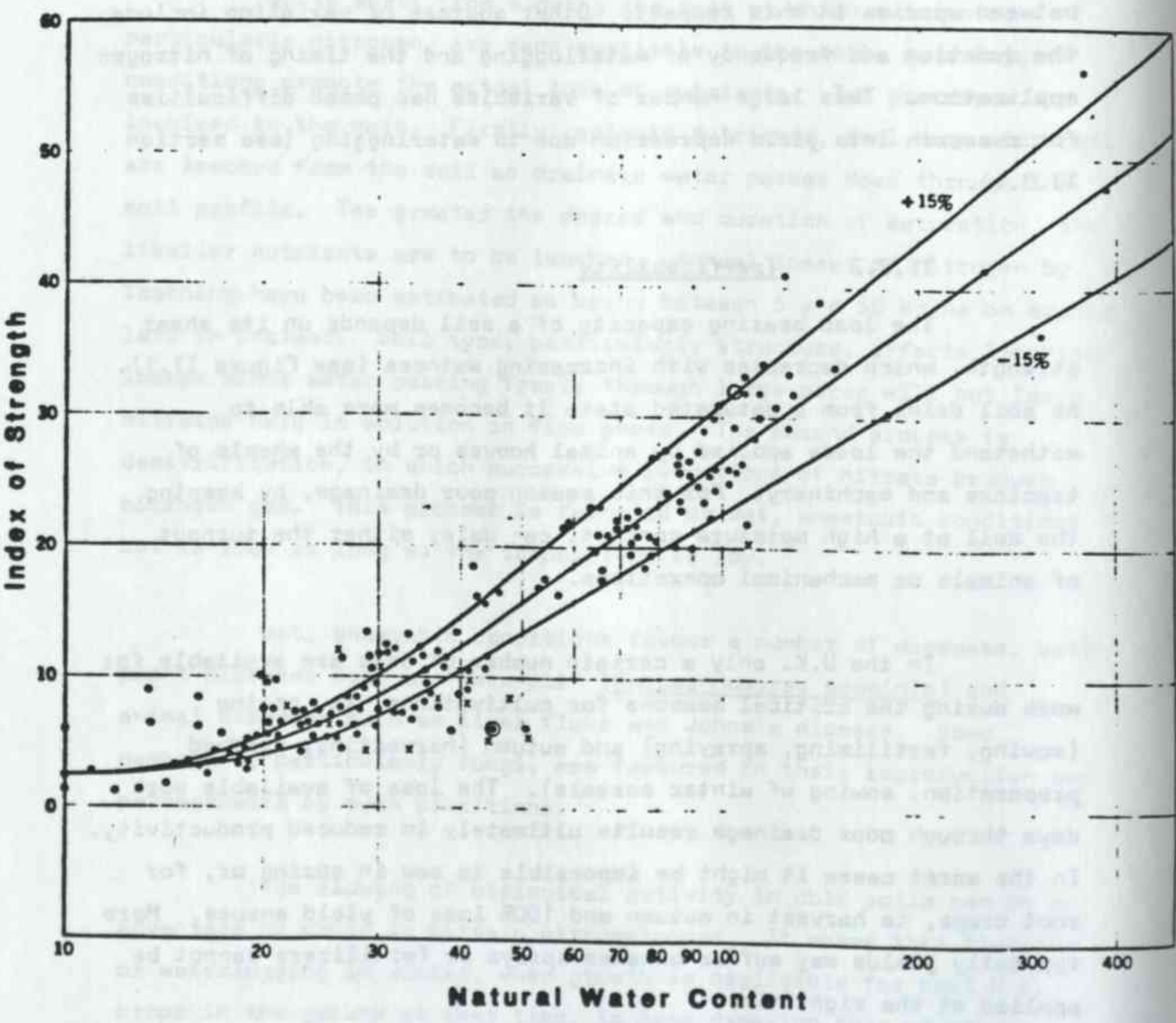
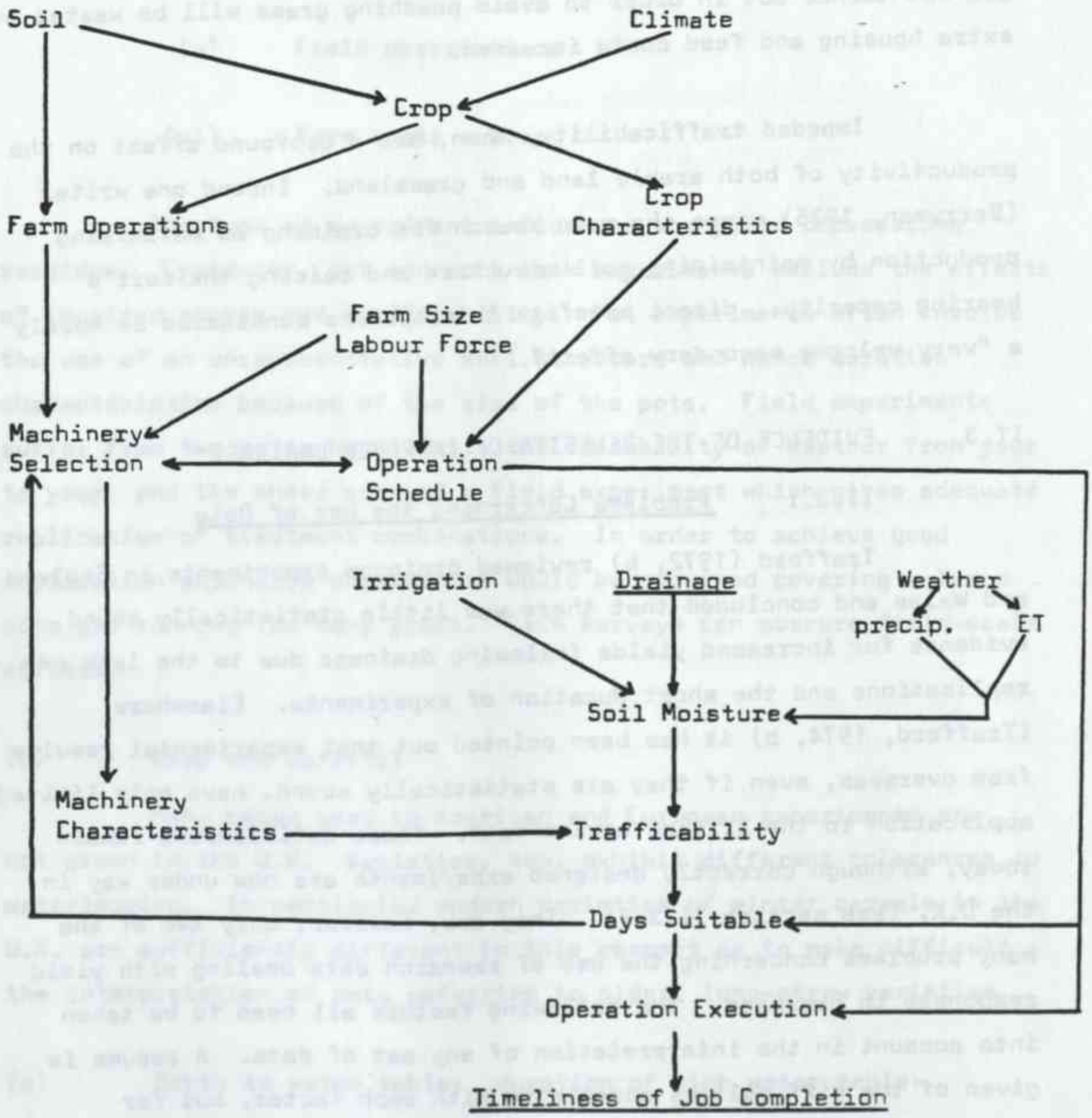


FIGURE II.2

Factors Influencing the Timeliness of Field Operations



Source: Reeve and Fausey (1977)

In the case of grassland, not only will the yield of grass suffer where access by machinery is impeded for such mechanical operations as the spring application of fertilizer, but productivity is further reduced where poaching is a risk (see Annexe IV). If cattle are turned out and poaching takes place the grass already grown will not be fully utilized by livestock because of contamination and treading. Furthermore, the future growth of grass will be affected by the damage inflicted on both sward and soil by poaching. If cattle are not turned out in order to avoid poaching grass will be wasted and extra housing and feed costs incurred.

Impeded trafficability, then, has a profound effect on the productivity of both arable land and grassland. Indeed one writer (Berryman, 1975) views the main reason for draining as maximising production by maintaining soil structure and raising the soil's bearing capacity; direct benefits to crops are considered as merely a "very welcome secondary effect".

II.3 EVIDENCE OF THE BENEFITS OF IMPROVED DRAINAGE

II.3.1 Problems Concerning the Use of Data

Trafford (1972, b) reviewed drainage experiments in England and Wales and concluded that there was little statistically sound evidence for increased yields following drainage due to the lack of replications and the short duration of experiments. Elsewhere (Trafford, 1974, b) it has been pointed out that experimental results from overseas, even if they are statistically sound, have only limited application to the British environment. These deficiencies remain today, although correctly designed experiments are now under way in the U.K. (see section II.3.2). They are, however, only two of the many problems concerning the use of research data dealing with yield responses to drainage. The following factors all need to be taken into account in the interpretation of any set of data. A resume is given of the difficulties associated with each factor, but for brevity's sake these are here discussed generally without reference to particular experiments.

(a) Type of experiment:

- (i) Lysimeter/pot
- (ii) Soil tank
- (iii) Experimental field with controlled water table

(iv) Experimental field with varying intensity/depth of drainage

(v) Field observations

(vi) Farm scale survey

The type of experiment influences the yield depressions recorded. Lysimeter, pot and soil tank experiments exclude the effects of impaired access and trafficability. Pot experiments often involve the use of an unrepresentative soil structure and hence aeration characteristics because of the size of the pots. Field experiments suffer from two major handicaps: the variability of weather from year to year, and the sheer size of a field experiment which gives adequate replication of treatment combinations. In order to achieve good replication expensive experiments would be required covering a large site and running for many years. Farm surveys can obscure field-scale effects.

(b) Crop and variety:

Many crops used in American and European experiments are not grown in the U.K. Varieties, too, exhibit different tolerances to waterlogging. In particular modern varieties of winter cereals in the U.K. are sufficiently different in this respect as to make difficult the interpretation of data referring to older, long-straw varieties.

(c) Depth to water table; duration of high water table:

The depth to the water table does not have an unequivocal relation to crop yield but it is the usual aeration/waterlogging parameter used, largely because of the supposed ease of controlling and measuring it. Account must also be taken of:

(i) The effect of water table behaviour on the availability of nutrients, particularly the nitrogen supply.

(ii) The soil type, insofar as its pore size distribution controls the moisture content in the unsaturated zone above the water table, the height of the capillary fringe and the oxygen diffusion rate (relevant in the case of a fluctuating water table).

(d) Static/fluctuating water table:

Experiments with static water tables fail to model typical U.K. water table behaviour, where a winter level high enough to restrict access to fields is followed by a summer level low enough in some cases to restrict growth. It is of little value to know the single optimum year-round water table which compromises between the demands of winter trafficability and summer evapotranspiration, since this is only going to be achieveable in areas of pumped drainage. Many experiments with static water tables are in any case concerned with irrigated areas and include yield depression due to salinity.

(e) Top/bottom watered:

Yield depressions recorded where no water is supplied to the soil surface and all water is taken up by capillary action tend to be rather greater than those recorded with surface watering. Again, they do not model U.K. conditions.

(f) Soil type and condition, including:

(i) Disturbed/undisturbed sample

(ii) Cultivations

The variability of soil is a familiar difficulty in comparing experimental results. Data from field experiments may be further complicated by lack of homogeneity on the site or the presence of conditions peculiar to the site which affect the lateral movement of water, eg. layers or patches of sand, perched water tables, etc.

Laboratory experiments often use disturbed samples which have a quite different pore size distribution than the soil in situ. They also do not include the effect of cultivations. In field experiments cultivations tend to be carried out to a wide range of standards from the surprisingly poor to the unrepresentatively excellent.

(g) Environmental conditions:

(i) Soil temperature		outdoor/indoor
(ii) Air temperature		outdoor/indoor
(iii) Rate of ET/respiration		outdoor/indoor
(iv) Solar energy input	covered/uncovered	outdoor/indoor
(v) Rainfall	covered/uncovered	outdoor/indoor

Differences in environmental conditions mean that much overseas work cannot safely be applied to the U.K., particularly where waterlogging occurs at high temperatures and respiration rates.

Some covered experiments in the U.K. have resulted in low radiation levels and air and soil temperatures which differ significantly from those prevailing outdoors.

There is a general problem with precipitation levels on covered experiments: does data issuing from an experiment with a certain level of simulated precipitation, whether it be the average rainfall or a selected frequency of heavy rainfall, really represent the mean effect of a number of years of actual, and extremely variable, U.K. precipitation?

(h) Correlation of imposition of treatments to growth stage:

In the majority of field experiments cultivations have been carried out simultaneously without correlation either to growth stage or the stage of drying of each drainage/water table treatment. Thus, for example, sowing of seeds or application of topdressings are inevitably carried out at the right time on only one drainage treatment and at the wrong time on all the others. Cultivation is usually left until the wettest treatment is just dry enough so that the benefit of extra spring growing days on the drier plots is lost. If, on the other hand, sowing is carried out at a different time on each plot as soon as it is ready, the ensuing weather will provide variations in inputs not correlated to growth stage. Thus, for example, a single storm might cause greater lodging, and hence loss of yield, where a cereal crop has grown taller on a drier and potentially higher yielding treatment than where it is lower on a wetter one. Without a number of years' data the vagaries of the U.K. weather can be expected to frustrate the field experimenter in such fashion and commonly result in footnotes explaining the results obtained.

Sensitivity to the imposition of a temporary high water table varies with growth stage and also with the respiration rate, and hence the weather, during that period.

(i) Yield parameter measured:

The yield parameter measured varies between crops. It seems to be generally agreed that for cereals the yield of dry matter is an adequate parameter. Sugar beet yield should include sugar content. Grass yield is more difficult to assess since palatability, digestibility and nutritional content all modify the value of grass production as measured in yield of dry matter. There are also difficulties associated with the different effects on the sward itself of removing grass by grazing and by mechanical harvesting. In general the yield of utilised metabolizable energy (UME) is used as the bottom line, and converted to a stocking rate by a more or less simple formula which seeks to add in additional nutritional requirements and management constraints on top of the simple ME production.

(j) Replication:

The problems of replication have already been mentioned in paragraphs (a) and (h) above. They apply mainly to field experiments; adequate replication ought to be achieved in any laboratory experiment.

(k) Inclusion of yield depression due to lost workdays as well as to excess soil water:

Lysimeter and pot studies, as previously mentioned, do not include yield depression due to lost workdays. Some field experiments, particularly those involving cut grass, also omit this factor.

(1) Soil fertility, including the correction of nutrient deficiencies:

Apart from the inherent variability in the fertility of different soils and the effects of antecedent cropping patterns and treatments on the fertility of experimental plots, there is a tendency for nutrient deficiency to be one of those things which do not come to light until an experiment is under way.

II.3.2 Crop Responses to Drainage

A number of data sources are briefly discussed below. Attention is paid both to the size of yield benefits accruing from drainage and to the drainage needs of crops, which can be used to set drainage design criteria. The results from the sources which are felt to be most applicable to the present study are tabulated at the end of this section (Tables II.6 and II.7). Further sources which do not receive any discussion below are given in the bibliography.

II.3.2.1 Arable Crops:

Trafford (1974a) reviewed experimental results concerned with the effects of short periods of high water level on crop yield. He concluded that the limited experimental data suggest wide differences between the tolerance of individual crops and between different dates and durations of flooding or waterlogging. It was found that waterlogging shortly before flowering can lead to the greatest depressions in final yield, particularly for potatoes and peas. Crops are generally sensitive to waterlogging during the germination phase.

Trafford (1974b) reported on a laboratory experiment to investigate the effects of short term waterlogging on the emergence of winter wheat. Samples were waterlogged immediately after planting for periods of 3 and 5 days at temperatures of 20^{o}C and 5^{o}C. His results suggest that any ill effects of waterlogging are reversible provided the duration is short; durations of less than 3 days appear to be unimportant. He noted that the effects of waterlogging were more severe in clay than sandy soils, (possibly reflecting the differences in the persistence of anaerobic conditions after the termination of the waterlogging treatment) and that a negative relationship existed between the final emergence and temperature during waterlogging.

A more extensive study of the response of winter wheat to waterlogging has been carried out by the Agricultural Research Council at Letcombe Laboratory. Winter wheat was grown in lysimeters containing undisturbed monoliths of sandy loam and clay soils, and subjected to treatments representing typically bad conditions likely to occur in the field in Britain (Cannell et al. 1980a). Winter wheat was shown to be most sensitive to waterlogging after germination but before emergence, when 16 days' waterlogging was enough to kill all the seedlings. Six days' waterlogging at this stage depressed plant populations to 12% (clay) and 38% (sandy loam), however vigorous compensatory growth by the surviving plants in the remainder of the season brought yields to about 82% of the control.

Waterlogging at any stage after emergence was shown to have no effect on plant populations although winter waterlogging usually depressed root numbers and, to a lesser extent, ear numbers at harvest. The waterlogged treatments also suffered an increase in the occurrence of the disease, 'take-all' (Gacumannomyces graminis) (Cannell et al, 1980b).

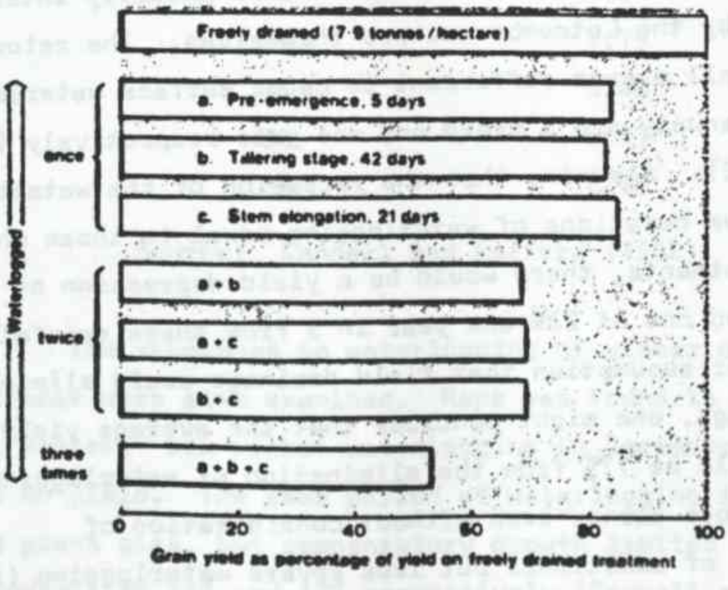
Waterlogging above or below the root apex did not affect the results and the evidence suggests that after emergence no single crop development stage is particularly sensitive to waterlogging (Belford, 1981). It was found, however, that the crop was sensitive to repeated waterlogging events. The crop was waterlogged to the surface during 3 growth stages, including a brief period before emergence, both separately and in combination. As Figure II.3 shows, yield depression was only about 15% for any single event, irrespective of growth stage, but increased to 23% for any combination of 2 and 46% where all 3 occurred. This is because the plant is capable of compensatory growth of one type or another where only one event occurs, even if it is waterlogged for 7 weeks in winter (treatment b).

If more than one event occurs it is less able to compensate. Results for winter barley were very similar in percentage terms.

The experiment is still running and Figure II.3 may not give the overall result of all the years' data taken together. These data should become available before long.

FIGURE II.3

Grain Yield of Maris Huntsman Winter Wheat in Response to Waterlogging Treatments on Evesham Clay in 1979-80



Source: A.R.C. Letcombe Laboratory

There are some difficulties in interpreting the Letcombe work, mainly because they do not include the effects of waterlogging in impeding trafficability and delaying cultivations. They have, however, started a parallel set of field experiments which include this important factor.

The research has been interpreted to give drainage design criteria. The main conclusion from the work is that watertables should be controlled below 50 cm, except for short durations (Cannell and Belford, 1982; Cannell, 1982). Drainage systems should be designed to remove excess water within 4 to 5 days for winter cereals, should the watertable rise to the surface. If waterlogging at the pre-emergence stage is unlikely on a particular site because of eg. river hydrology or because early sowing in autumn is guaranteed, a lower level of winter protection is acceptable because of cereals' comparative tolerance to winter waterlogging after emergence.

An estimation can be made of the size of the yield benefit from drainage, although the work has not been explicitly interpreted in this fashion by the Letcombe workers themselves. The return periods of rainfall events sufficient to cause surface waterlogging in October and January are 5 years and one year respectively (Cannell and Belford, 1982). Assuming that the recession of the watertable is such as to give durations of waterlogging equal to those chosen as experimental treatments, there would be a yield depression of at least 15% every year and one of 23% one year in 5 from these rainfall events. Making the further assumption that field drainage could eliminate these waterloggings, one might conclude that the average yield benefit from drainage would be 17% from the elimination of waterlogging during these periods alone, even without consideration of trafficability or of additional but less severe waterlogging (ie. not to the surface).

Another experiment at Letcombe Laboratory examined the effect of long periods of high watertables close to the surface but without necessarily any period of surface waterlogging. The treatments were chosen to model the soil water regime typical of many undrained clay soils in the U.K., where the winter watertable can fluctuate around 20 cm below the surface from December to April. The results (Table II.1) suggested that if the watertable was steady at a depth of 20 cm between December and March yields would be 9.1% lower than those with a watertable at 90 cm (Cannell and Belford, 1982). A watertable at 50 cm, representing the control given by mole drainage, gave almost as great an advantage (8.1%) as one at 90 cm. If the 'undrained' watertable was assumed to fluctuate between the surface and 20 cm yields were around 14% lower than those with a 90 cm deep watertable. In yet another, similar, experiment a late sown crop of winter wheat with a 20 cm watertable tillered less and gave 18% less grain than with a 50 cm watertable (ibid).

TABLE II.1

Effect of Different Depths of Winter Watertable from December to March in a Clay Soil on the Grain Yield of Winter Wheat

Depth of watertable (cm)	Grain Yield (t/ha at 85% DM)
0	7.18
10	7.04
20	7.79
50	8.48
90	8.57
LSD	0.68

Source: Cannell and Belford (1982)

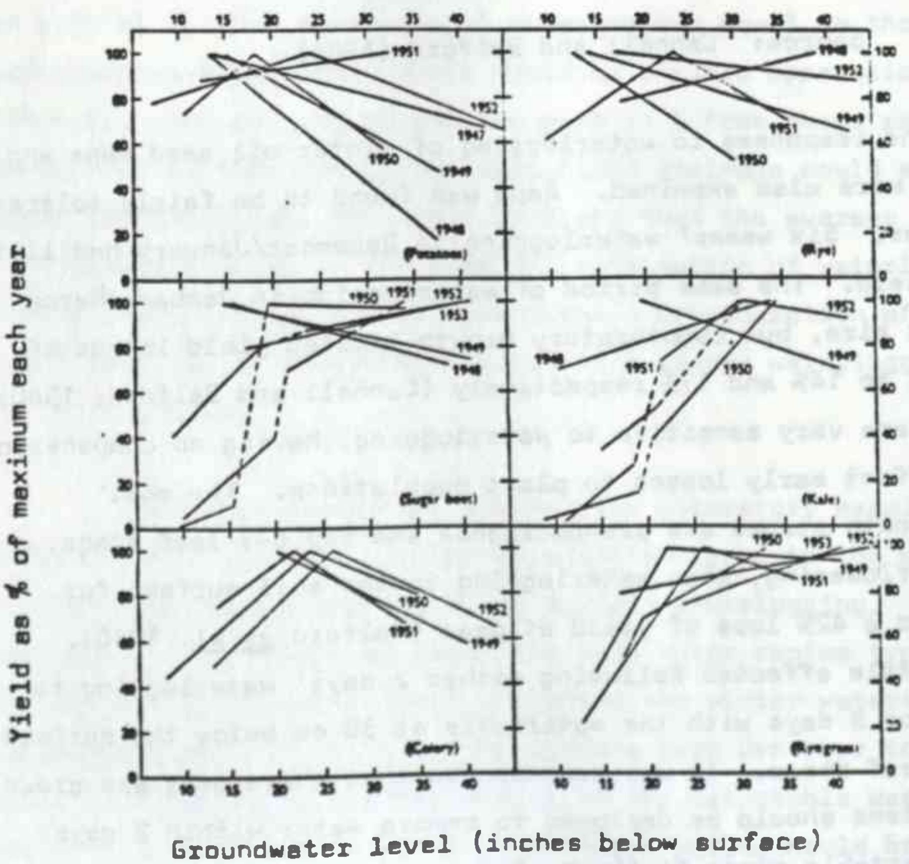
The responses to waterlogging of winter oil seed rape and spring peas were also examined. Rape was found to be fairly tolerant during winter. Six weeks' waterlogging in December/January had little effect on yield. The same period of waterlogging in January-March halved plant size, but compensatory growth limited yield losses of seed and oil to 14% and 17% respectively (Cannell and Belford, 1980). Spring peas are very sensitive to waterlogging, having no compensatory growth to offset early losses to plant populations. The most sensitive growth stages are pre-emergence and the 6-7 leaf stage, just before flowering, when waterlogging to the soil surface for 5 days caused a 42% loss of yield of peas (Belford et al. 1980). Yield was little affected following either 2 days' waterlogging to the surface or 5 days with the watertable at 50 cm below the surface at the 6-7 leaf stage. It was recommended that where peas are grown drainage systems should be designed to remove water within 2 days when the watertable rises to the surface.

These results are readily interpreted in terms of the crops' drainage requirements. Oil seed rape appears to have requirements similar to those of winter wheat while peas have more stringent requirements: water should be removed within 2 days following waterlogging to the surface. The yield benefit from drainage has not been estimated by the Letcombe workers themselves and information would be needed as to the return periods of the waterlogging events used as treatments before this can be done.

A series of experiments covering a variety of crops was carried out by H.H. Nicholson and others of Cambridge University from 1947 to 1953. These involved controlled groundwater levels on a fen peat site. The results are summarised in Figure II.4.

FIGURE II.4

Trends of Yields of Individual Crops



Source: Nicholson and Firth (1958)

While the results are not easy to relate to current yield levels because of the improvement of varieties since 1953 some interesting observations can be made from the relative yield trends shown above, mainly in terms of crop drainage requirements. Both potatoes and celery seem to have optimum watertable depths in this permeable light peat soil. Thus for potatoes in 1952, for example, yields were depressed with watertables below 60 cm because of water stress and depressed with watertables above 60 cm by waterlogging. The optimum level, however, varied markedly from year to year depending on the weather - in 1950 it was 45 cm. It was concluded that the evidence favoured the use of high water levels around 50-63 cm for potatoes in dry seasons if soil condition is good. Levels of 50-60 cm for celery are recommended in all years, which accords with Fenland practice for the latter crop, commonly grown with a raised water level.

In the case of sugar beet and kale marked failures occurred with watertables within 50 cm of the surface in wet years. The trends as a whole favoured groundwater levels of 75-88 cm for these crops. With one-year ryegrass leys the yield of dry matter increased with depth of the watertable and this trend was even more marked in the yield of crude protein. Sieving tests disclosed a very marked loss of tilth with watertables within 50 cm and a discernible loss even with watertables at 75 cm.

There are no reliable results for wheat from these experiments because at a late stage a copper deficiency was discovered to have been responsible for the very poor performance of this crop. Other crops are thought not to have been affected by the copper deficiency, either because they were less sensitive species, or, in the case of potatoes and celery, because they were sprayed or dusted with preparations containing copper. The occurrence of this defect is unfortunate in a field experiment whose quality of planning and execution seems to have been matched but rarely in post-War U.K. experiments.

The only other major set of U.K. data concerning cereals comes from work carried out in cooperation with the Field Drainage Experimental Unit (FDEU) on Experimental Husbandry Farms. Unfortunately the failure to overcome experimental difficulties, particularly in achieving adequate replication, precludes the confident use of these data to set levels of crop response to drainage. The results have, nevertheless, been examined by various authors (Trafford and Oliphant, 1977; Armstrong, 1977b, 1978). The results for winter wheat at Drayton E.H.F. have been summarised by Hunter and Trafford (1979). (Table II.2).

TABLE II.2

Yield of Winter Wheat Grown Under Varying Drainage Conditions at Drayton E.H.F. 1970-76 on a Heavy Clay of the Evesham Series

Mean control yield = 3.67 t/ha

	Drainage treatment	Yield gain over undrained control %	t/ha
1.	Pipes only	16	0.59
2.	Pipes at 15 m + subsoiling	26	0.96
3.	Pipes at 60 m + subsoiling	13	0.48
4.	Pipes at 60 m + moling	28	1.03

Source: Hunter and Trafford (1979)

Plainly these results indicate an advantage from drainage, but it is hard to say just how much advantage, particularly in view of the low yield levels - only 4.69 t/ha even on the highest yielding treatment. Commentators have accordingly been cautious in drawing firm conclusions. Bailey (1979), for example, concludes that the results show that in winters of above average rainfall yield increases of up to 1 t/ha can be achieved with drainage systems incorporating secondary treatments and 0.6 t/ha with close spaced pipes. This introduces caution on 3 counts, steering away from the average increase, from years of average weather, and from the percentage increases given in Table II.2 which may be misleading because of the low yields attained. This caution is doubtless well advised but it makes the conclusions much less useful. Another interpretation of the E.H.F. data suggests that where mole drainage of clayey soils has been used, grain yields up to about 20% greater than on undrained land have been found (Cannell and Belford, 1982).

A very interesting study has been made of the effects of land drainage on an area of the Stour Marshes in Kent, a large tract of silty clay alluvium (Lukehurst, 1981). In this area yield losses of winter wheat on undrained sites occurred as a result of both late and early planting, intermittent waterlogging in the growing season and submergence during winter. The penalty on this soil for a delay in sowing until early spring is very great due to puddling and capping of the bare soil over winter. The yield advantage from drainage was therefore considerable, a mean increase of 2.91 t/ha (see Table II.3). The drainage system used restricts the mid-drain watertable level to 80-90 cm below the surface.

TABLE II.3

Comparative Net Income from Wheat Production on Silty Clay Alluvium

	Without Tile Drains		Tile Drained	
	Per acre	Per ha	Per acre	Per ha
Average wheat yields (t)	1.63	4.02	2.78	6.93
Average gross income @ £103/t	167.89	414.06	286.34	713.79
Production cost	132.09	334.36	122.98	311.81
Net income	35.80	77.70	163.36	401.98
Variability of income: Upper	84.21	92.60	232.37	575.75
Lower	-54.84	-141.55	90.23	225.55

Source: Lukehurst (1981)

Closer examination of Table II.3 reveals a greater financial advantage from drainage than even this yield increase suggests, because it also reduces the cultivation requirements. Three processes on undrained land involve extra costs amounting to an increase of 13% over drained land. Ploughing is slower, 2-way harrowing is required for seedbed preparation and combine harvesting takes longer because the crop is slower to dry off. If sowing is delayed until spring, costs were found to be a further 8% higher. As a result incomes on undrained land were both low and variable, leading to some spectacular losses (see Table II.3).

The Dutch have been experimenting continuously since the 1940's, particularly in the assessment of crop response to groundwater levels in experimental fields on both clay and more permeable soils, including organic soils. There may be some difficulties in relating the formidable body of data produced to U.K. conditions: soils, rainfall, topography and microrelief are all arguably different. Nevertheless, Dutch conditions are more similar to those in the U.K. than conditions elsewhere in the world.

Hoogerkamp and Woldring (1968) reported that on a heavy clay soil yields of arable crops, especially cereals, increased with increasing depth of drainage. Drought damage due to deep drainage was rare for cereals on these soils. Decreased yields at high watertable levels were associated with a low supply of soil nitrogen. It was concluded that this would be better remedied by N fertilizing than by increasing the depth of drainage. Bearing in mind trafficability requirements, however, it was recommended that drainage should maintain the watertable at a depth of 65 cm.

These findings echo the earlier ones of van Hoorn (1958), also working on an experimental field with a heavy clay soil. It was found that crops tolerated a shallow watertable (40 cm) in winter with no detrimental effect on crop yields. Where constant watertables were maintained through the growing season, however, yields increased with increasing depth for all crops except potatoes, although the depth required to eliminate yield depression varied between crops (see Table II.4).

TABLE II.4

Relative Yields at Groundwater Levels from 40-150 cm Below the Surface on Clay Soil for the Years 1946-1955

The maximum yield is taken as 100%.

Crop	No. of Years	Grain, roots, tubers					Yield of Level 100% in kg/ha
		40	60	90	120	150	
Cereals							
Wheat	6	58%	77%	89%	95%	100%	4600
Barley	5	58	80	89	95	100	4100
Oats	3	49	74	85	99	100	5000
Pulses							
Peas	4	50	90	100	100	100	2750
Beans	3	79	84	90	94	100	3100
Other crops							
Caraway	3	80	96	98	100	100	1700
Rape seed	2	79	95	95	98	100	2500
Sugar beet seed	1	75	82	90	96	100	4250
Sugar beet	2	74	84	92	97	100	40500
Potatoes	1	90	100	95	92	96	26000

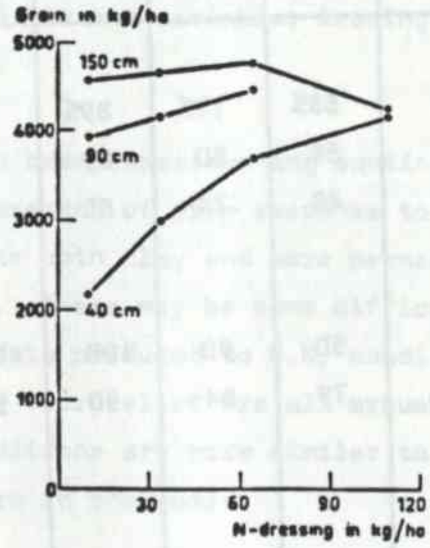
Source: van Hoorn (1958)

Potatoes show signs of an optimum watertable depth at 60 cm. No other crop suffered from moisture shortage on this soil, irrespective of the depth of the watertable.

It was found that yield depression due to a shallow watertable could be largely eliminated by increasing the nitrogen dressing (Figure II.5). The inference is made that with deeper watertables more soil N is supplied to crops and that this can be compensated for where watertables are shallow by increasing N fertilizer. The amount of soil N supplied at different watertable depths was inferred by combining Figure II.5 with a general curve of the response of cereals to nitrogen (Figure II.6) to give the extrapolations shown in Figure II.7.

FIGURE II.5

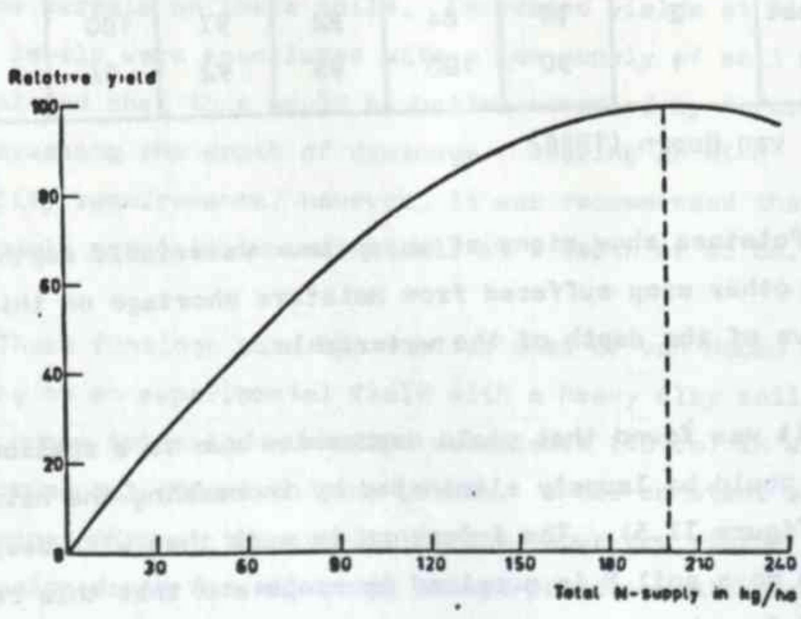
Influence of Nitrogen Dressing on Yield of Cereals at Various Depths of Watertable



Source: van Hoorn (1958)

FIGURE II.6

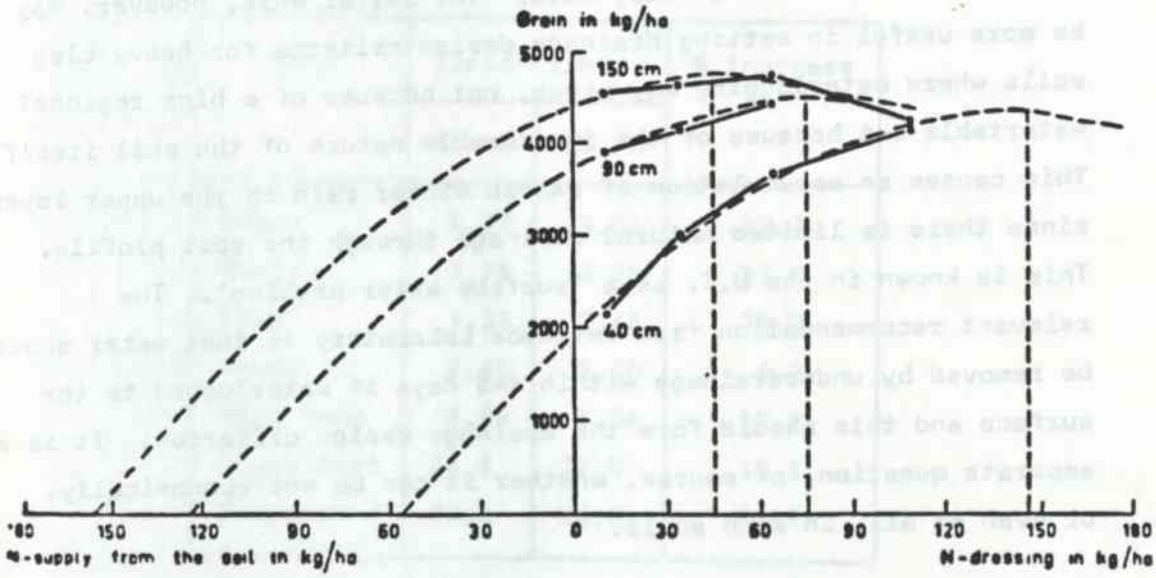
Influence on Yield of Cereals of Total Amount of Nitrogen Supplied by Soil and Fertilizer



Source: van Hoorn (1958)

FIGURE II.7

Influence of Depth of Watertable on Nitrogen Supplied by the Soil



Source: van Hoorn (1958)

In later work van Hoorn (1982) reports that, on the same experimental field, a constant watertable at 30 cm depth from November to February had no detrimental effects on the growth of winter cereals. Adverse effects were found with watertables shallower than 30 cm on another experimental field.

In the Dutch work described above on heavy clay soils 2 general conclusions were drawn:

(i) Under Dutch conditions arable crops (except potatoes) grown on these soils with deep watertables could overcome the summer soil moisture deficit, even in dry years when it exceeds 150 mm. Since a deep watertable has a positive effect on aeration and nitrogen production, a watertable depth of 1 m is favourable for arable crops grown on heavy clay soils. (NB: a different conclusion was drawn for grass: see section II.3.3.2)

(ii) Control of the watertable in winter was only necessary to a depth of 30-40 cm.

These conclusions broadly support the work of Letcombe Laboratory on an Evesham clay soil. The latter work, however, may be more useful in setting drainage design criteria for heavy clay soils where waterlogging may occur, not because of a high regional watertable but because of the impermeable nature of the soil itself. This causes an accumulation of excess winter rain in the upper layers since there is limited natural drainage through the soil profile. This is known in the U.K. as a 'surface water problem'. The relevant recommendation from Letcombe Laboratory is that water should be removed by underdrainage within 4-5 days if waterlogged to the surface and this should form the drainage design criterion. It is a separate question, of course, whether it can be met economically, or even at all, in such soils.

The use of constant watertable levels through the growing season makes it difficult to interpret the data as far as yield benefits from drainage are concerned. In areas with no high regional watertable the excess of evapotranspiration over rainfall in summer normally largely dries out the soil to a considerable depth (eg. 80 cm). It may be useful, however, to consider the yield increase resulting from a lowering of the watertable from 40 cm to 60 cm as might occur if field drainage is installed following the removal of an arterial restriction which had imposed a constant high watertable (Table II.5).

TABLE II.5

Yield Increases Resulting from a Lowering of the Watertable from 40 cm to 60 cm

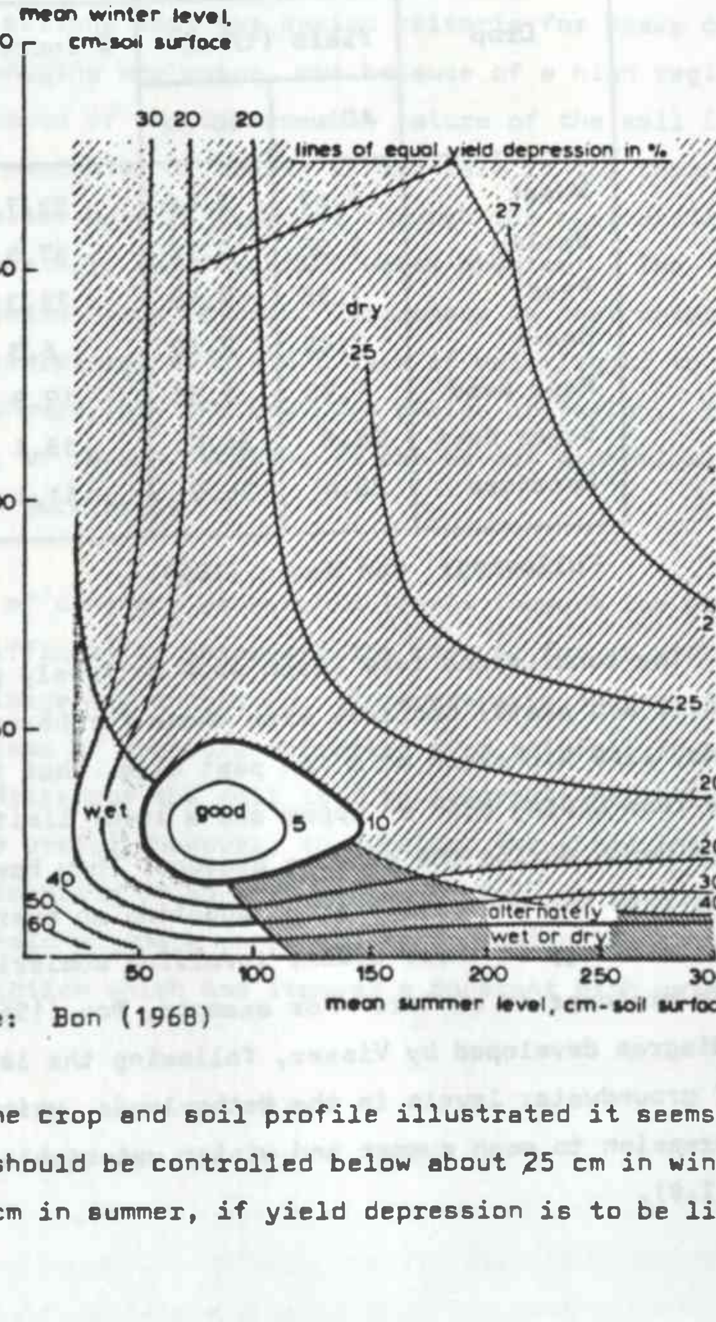
Crop	Yield (t/ha)		% Increase
	40 cm	60 cm	
Wheat	2.67	3.54	32.7
Barley	2.38	3.28	37.8
Peas	1.38	2.48	79.3
Beans	2.45	2.60	6.3
Rape seed	1.98	2.38	19.9
Sugar beet	28.8	34.0	18.1
Potatoes	23.4	26.0	11.1

Following: van Hoorn (1958)

The conclusions from Dutch work on freely permeable soils (sandy soils and peats) contrast with those for heavy clay soils. They found, like Nicholson on a fen peat site, that there could be an advantage from giving both an upper and a lower limit to the watertable depth during the growing season. They have subsequently researched into the possibilities of adopting an overall water management strategy on these soils, involving subirrigation in summer and drainage in winter. For example, Bon (1968) employs a type of diagram developed by Visser, following the latter's massive survey of groundwater levels in the Netherlands, which related yield depression to mean summer and winter watertable depths (Figure II.8).

FIGURE II.8

Example of a Yield Depression Diagram, Divided into Sectors of Soil Humidity, in Relation to the Mean Groundwater Table in Both Summer and Winter



Source: Bon (1968)

For the crop and soil profile illustrated it seems that the watertable should be controlled below about 25 cm in winter and above about 90 cm in summer, if yield depression is to be limited to 5%.

The weight of opinion, both in the U.K. and the Netherlands, is that it is of limited value to know the optimum mean (or constant) watertable depth, since damage to crops typically occurs because of temporarily high watertables following rain, when waterlogging occurs in the normally unsaturated uppermost layers.

Plainly the mean watertable depth and the soil type influence the frequency, severity and duration of such events, since together they determine the volume of storage for excess water in the zone above the watertable which is normally unsaturated. But the rainfall pattern itself is also of the utmost importance. Variations in rainfall largely account for the differences in optimum watertable depth from year to year found by Nicholson in the U.K. and by workers in the Netherlands. Thus a general objection to field experiments relating yields to mean or constant watertable depths is that, given the variability of rainfall, many years' data have to be examined before an average value for the optimum mean watertable depth can confidently be offered.

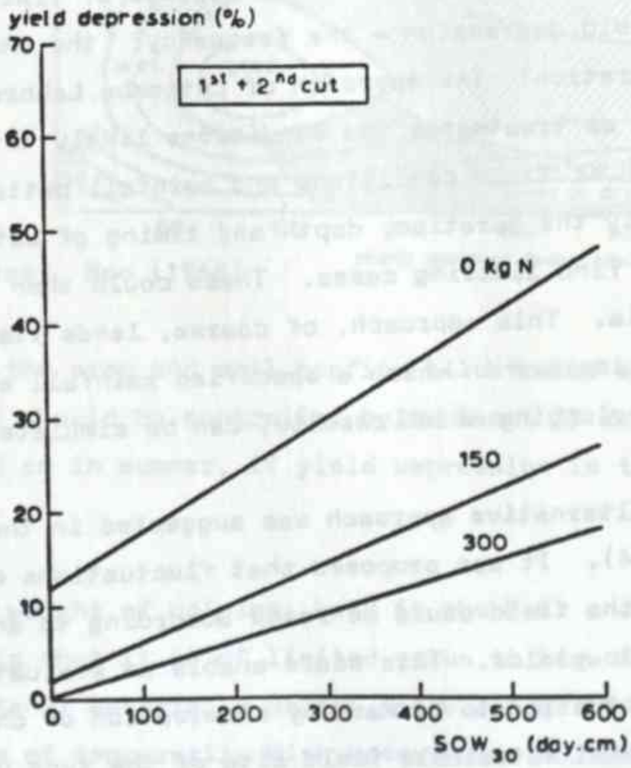
A more fundamental criticism is that the decisive influence of severe rainfall events and the fluctuating watertables which follow rain should find expression in experimentation, either as an independent variable or as a treatment. In other words the yield depression by waterlogging should be related to fluctuating watertable depth and not to a mean or constant depth. This, however, introduces a new complication: what aspects of fluctuation should be related to yield depression - the frequency? the shallowest level attained? duration? The approach of Letcombe Laboratory to this was to impose as treatments the conditions likely to occur in extreme cases, given U.K. field conditions and rainfall patterns. They then varied slightly the duration, depth and timing of waterlogging in an attempt to find limiting cases. These could then form drainage design criteria. This approach, of course, lends itself to the use of covered lysimeters in which a specified rainfall event, and the transient waterlogging which results, can be simulated.

An alternative approach was suggested in the Netherlands by Sieben (1964). It was proposed that fluctuations of the watertable in the field could be rated according to an index and the index related to yields. This would enable an evaluation of watertable fluctuation to be made by observation of changing levels on an experimental watertable field site of the type used by Nicholson, van Hoorn and others for experiments using mean or constant levels. The index Sieben proposed is known as SEW (or SOW, depending on translation). SEW is the number of cm-days by which the watertable encroaches above a certain depth during the winter. Thus if the watertable stays below the specified depth except for 2 days when it is 10 cm above that depth, the SEW index would be 20 cm-days. Sieben suggested that 30 cm was the critical depth and the index is usually known as SEW_{30}. It was claimed that SEW_{30} is related in a linear fashion to crop yield (Figure II.9). The index ingeniously combines reference to both the height and the duration of temporary waterlogging but is not correlated to growth stage. Unfortunately, there seems to be a lack of actual published data relating SEW_{30} to yields.

FIGURE II.9

Yield Depression of the First and Second Cut of Grass on Peat Soil in Relation to the Height of the Groundwater Table Above the 30 cm Level (SOW_{30}) at Three N Levels

The yield at 300 kg N and SOW_{30} = 0 is taken as 100%.



Source: Feddes and van Wijk (1976)

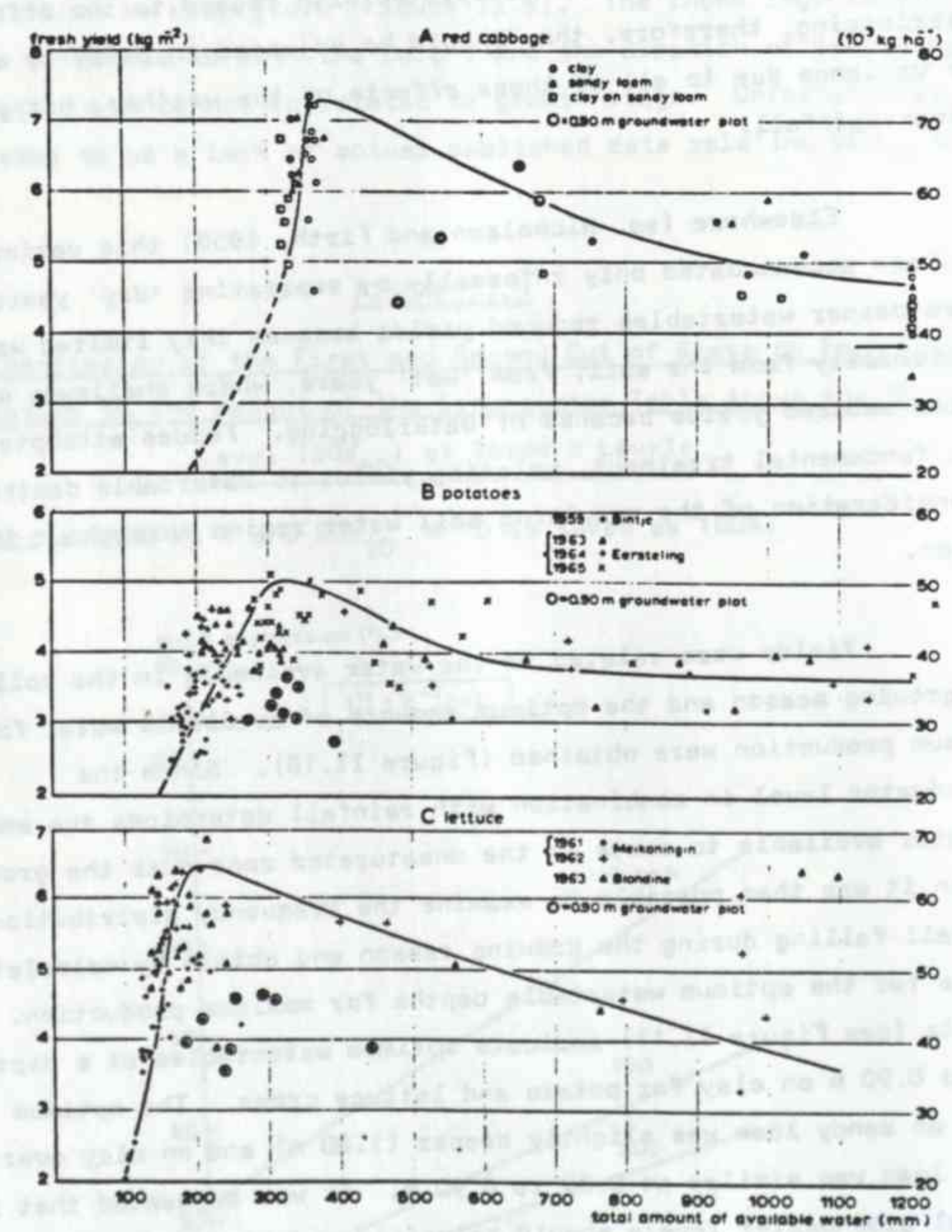
Feddes (1971) also drew attention to the fact that because of changes in weather conditions the relationship between yield and watertable depth differs from year to year. Rainfall distribution affects not only the incidence of waterlogging but also water availability for evapotranspiration in the growing season. Furthermore the solar radiation and accumulated evapotranspiration in a particular year also affect final yield, and they too vary considerably. Before experimental yields can be interpreted with regard to the effects of waterlogging, therefore, they should be adjusted in order to allow for variance due to all of these effects of the weather, not just to winter rainfall.

Elsewhere (eg. Nicholson and Firth, 1958) this variance had been accommodated only informally by separating 'dry' years, where deeper watertables reduced yields because they limited water availability from the soil, from 'wet' years, where shallower water-tables reduced yields because of waterlogging. Feddes attempted a more fundamental treatment, relating yields to watertable depths by a consideration of the resulting soil water regime throughout the season.

Yields were related to the water available in the soil over the growing season and the optimum amounts of available water for maximum production were obtained (Figure II.10). Since the groundwater level in combination with rainfall determines the amount of water available to roots in the unsaturated zone over the growing season it was then possible to examine the frequency distributions of rainfall falling during the growing season and obtain by calculation values for the optimum watertable depths for maximum production. The results (see Figure II.11) indicate optimum watertables at a depth of around 0.90 m on clay for potato and lettuce crops. The optimum depth on sandy loam was slightly deeper (1.00 m) and on clay over sandy loam was similar at 0.80 to 0.90 m. It was suggested that in general groundwater levels should be maintained at levels somewhat lower than the calculated optimum depth, although the depths calculated by Feddes are already somewhat lower than most results from straightforward field experiments using controlled watertables, both in the Netherlands and elsewhere.

FIGURE II.10

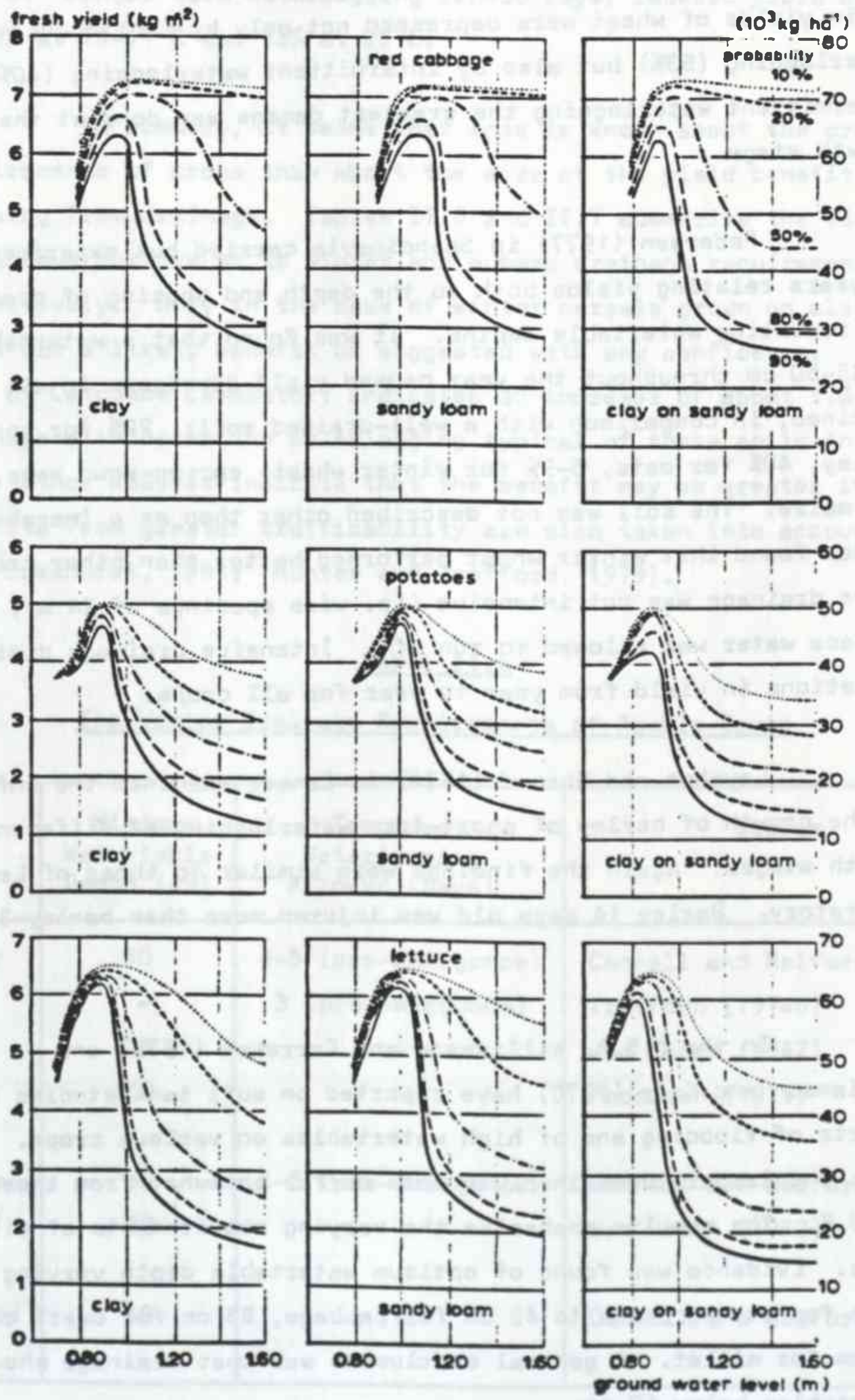
Dependence of Fresh Yield of Red Cabbage, Potatoes and Lettuce, as Measured on the Three Profiles of all Groundwater Plots, on Total Amount of Available Water



Source: Feddes (1971)

FIGURE II.11

Dependence of Fresh Yield of Red Cabbage, Potatoes and Lettuce Grown on Clay, Sandy Loam and Clay on Sandy Loam Respectively, on Groundwater Table Depth Over the Growing Season at Five Probability Levels of Exceedance



Feddes (1971)

Other overseas work provides further background data, although many of these experiments are not capable of interpretation for U.K. conditions.

Watson *et al* (1976) in Australia carried out a glasshouse pot experiment with various waterlogging treatments on cereal crops. The results were broadly similar to those of Letcombe Laboratory. Grain yields of wheat were depressed not only by continuous waterlogging (53%) but also by intermittent waterlogging (40%). With intermittent waterlogging the greatest damage was done at the earliest growth stage.

Pedersen (1977) in Scandinavia carried out experiments over 17 years relating yields both to the depth and spacing of drains and the resulting watertable depths. It was found that a watertable depth of 45-50 cm throughout the year caused yield decreases in all crops examined, in comparison with a well-drained soil: 20% for spring barley, 40% for oats, 5-9% for winter wheat, spring-sown rape, beet and maize. The soil was not described other than as a 'marsh soil'. It was found that winter wheat performed better than other crops where drainage was not intensive (ie. wide spacings of 24 m), provided surface water was allowed to run off. Intensive drainage diminished variations in yield from year to year for all crops.

Leyshon and Sheard (1974) in Canada examined the influence on the growth of barley of short-term waterlogging at different growth stages. Again the findings were similar to those of Letcombe Laboratory. Barley 14 days old was injured more than barley 35 days old.

In the U.S.A. Williamson and Carreker (1970) and Williamson and Kriz (1970) have reported on soil tank studies of the effects of flooding and of high watertables on various crops. The crops and temperatures involved both differ somewhat from those in the U.K. The results emphasise the varying requirements of different crops. Evidence was found of optimum watertable depth varying from 30 cm for string beans to 45 cm for cabbage, 85 cm for dwarf corn and 100 cm for millet. A general conclusion was that drainage should keep watertables below 60 cm.

Luxmoore <u>et al</u> (1973) in Mexico paid particular attention to waterlogging of wheat at different soil temperatures. With treatments imposed at 50% anthesis, which occurred at 72 days after sowing in the glasshouse and after 91 days in the field, no yield reduction was found from short-term waterlogging (10-15 days) at a soil temperature of 15-17°C nor for longer term waterlogging (30 days) at 5°C. Longer term waterlogging (20-30 days) reduced yield by 15-23% at 15-17°C and 73% at 25°C.

In summary, it seems that more is known about the drainage requirements of crops than about the size of the yield benefit accruing from drainage. Tables II.6 and II.7 summarize the findings of various authors as to winter and summer drainage requirements respectively. Only in the case of winter cereals grown on clayey soils can a likely benefit be suggested with any confidence. The work of Letcombe Laboratory indicates an increase of about 17% if drainage eliminates the waterlogging typical of these soils in the U.K. Other sources indicate that the benefit may be greater if benefits from greater trafficability are also taken into account (eg. Lukehurst, 1981; Hunter and Trafford, 1979).

TABLE II.6

The Winter Drainage Requirements of Arable Crops

Crop	Minimum Watertable Depth (cm)	Temporary Waterlogging Allowed (Days)	Source
Winter Wheat	50	4-5 (pre-emergence)	Cannell and Belford (1982)
	-	3 (pre-emergence)	Trafford (1974b)
	30	-	van Hoorn (1982)
	50	-	Pedersen (1977)
Winter Barley	50	4-5 (pre-emergence)	Cannell and Belford (1982)
	30	-	van Hoorn (1982)
Oilseed Rape	50	-	Cannell and Belford (1982)

TABLE II.7

The Spring/Summer Drainage Requirements of Arable Crops

Crop	Minimum Watertable Depth (cm)	Temporary Waterlogging Allowed (Days)	Source
Winter Wheat/Barley	50	21 (during stem elongation)	Cannell and Belford (198
	100	–	van Hoorn (1958)
	50	–	Pedersen (1977)
Wheat		15 (at 50% anthesis)	Luxmoore *et al* (1973)
Oilseed rape	50	–	Cannell and Belford (198
	50	–	Pedersen (1977)
	60	–	van Hoorn (1958)
Potatoes	55*	–	Nicholson and Firth (195
	60*	–	van Hoorn (1958)
	90*	–	Feddes (1971)
Sugar beet	80	–	Nicholson and Firth (195
	90	–	van Hoorn (1958)
Peas	50	2 (at 6-7 leaf stage)	Cannell and Belford (195
	60	–	van Hoorn (1958)
Beans	90	–	van Hoorn (1958)
Kale	80	–	Nicholson and Firth (1958
All crops	60	–	Williamson and Carreker (
	65	–	Hoogerkamp and Woldring (

* For potatoes the watertable should be controlled at this depth.

II.3.2.2 Grass:

A large body of data exists due mainly to the efforts of the Grassland Research Institute (GRI) relating grass yields to a wide range of factors, both in experimental contexts and on the farm. Sadly, the relations of grass yield to drainage are not among those which have been comprehensively researched. A major field experiment has, however, recently begun at the GRI Permanent Pasture Group headquarters at North Wyke in Devon. When results become available they should form a solid basis for estimating yield benefits from improved drainage.

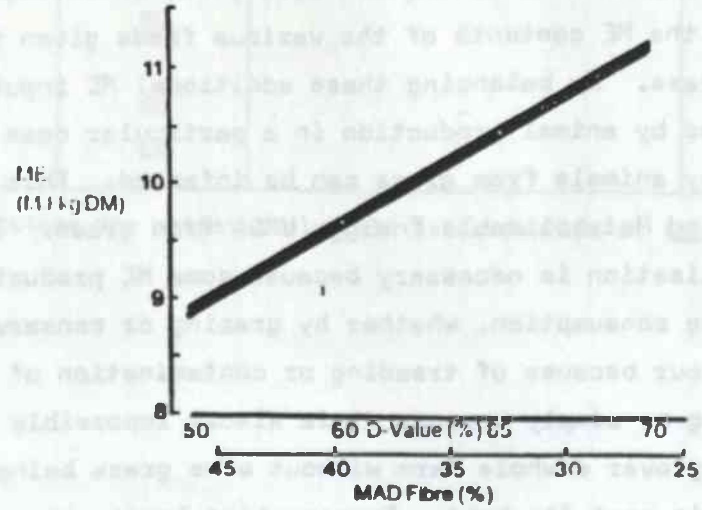
Selection of the yield parameter poses a particular difficulty in the assessment of grassland productivity. In experimentation the grass is cut and the dry matter (DM) yield measured. At farm level the DM yield is not known since productivity is assessed in terms of liveweight gain or milk yield. This difficulty is resolved by using the yield of Metabolisable Energy (ME) as the parameter of productivity. Metabolisable Energy is that part of the energy contained in grass which can be converted by ruminants. Other aspects of grass food value are important besides the ME value, notably its protein content. This, however, is difficult to evaluate (see Thomas and Young, 1982, pp 32 f). The use of ME as the parameter of grassland yield, then, forges a link between the production of grass in the field and the production of milk or meat.

The ME represented by a given milk yield or liveweight gain is known, as are the ME contents of the various feeds given to animals in addition to grass. By balancing these additional ME inputs against the ME represented by animal production in a particular case the ME actually gained by animals from grass can be inferred. This is termed the Utilised Metabolisable Energy (UME) from grass. The reference to utilisation is necessary because some ME production is always lost during consumption, whether by grazing or conservation. Grazing losses occur because of treading or contamination of grass, damage by poaching or simply because it is almost impossible to manage the grazing over a whole farm without some grass being consumed when it is past its best. Conservation losses occur during both harvest and storage (see Annexe IV). At farm level, then, UME is calculated retrospectively in this way; it is the energy represented by animal production which is not due to the additional feeds (see MAFF Technical Bulletin 33, 1979). Following recent usage by MAFF the total ME production, including the portion lost during consumption, will be referred to in this Annexe as the farm ME yield.

The DM yield found during experimentation can be converted into the ME yield by direct measurement of the ME value of the harvested grass per unit DM. ME yield can also be estimated from DM production provided the type of sward and growth stage at harvest are known. The ME value of grass declines as it matures in the field. Stemming growth is more fibrous and less digestible than younger, leafy growth. It has a lower ME value per unit DM. On the other hand, there is a gain in DM bulk as the grass matures. Overall ME yield therefore reaches a peak before the grass becomes over-mature and any remaining gains in bulk fail to compensate for a declining ME/DM ratio. The broad relationship between ME value, fibrous content and D-value, which is the standard measure of digestibility is given in Figure II.12.

FIGURE II.12

The Relationship Between Metabolisable Energy Value of Silage (ME, MJ/kg DM), D-Value and MAD-Fibre



Source: Thomas and Young (1982)

The D-value of early, leafy growth is about 70D, but this declines to 67D during stem elongation and 64D by the time flowering heads emerge, falling to 61D for the mature crop. If a D-value for grass can be estimated by reference to its age at cutting, the ME yield can quickly be computed from the DM yield.

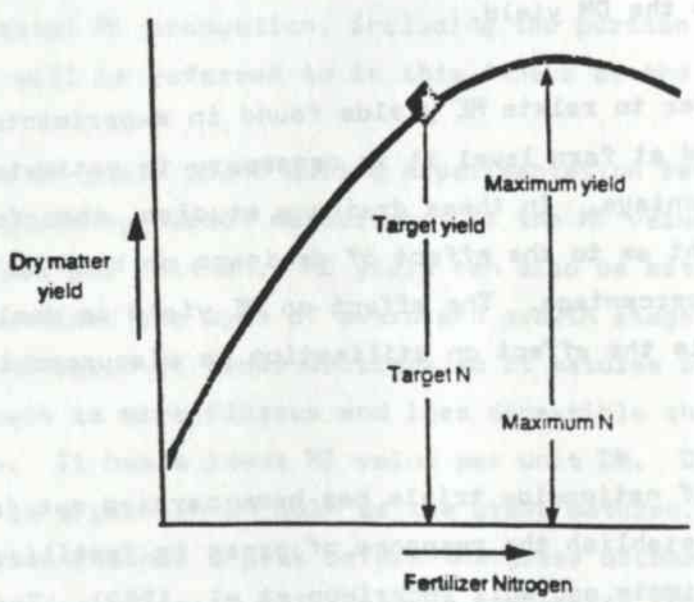
In order to relate ME yields found in experimentation to UME yields discovered at farm level it is necessary to estimate the utilisation percentage. In these drainage studies, therefore, evidence is sought as to the effect of drainage on both ME yield and the utilisation percentage. The effect on ME yield is dealt with in this section while the effect on utilisation is discussed in section II.3.3.2 below.

A set of nationwide trials has been carried out jointly by GRI and ADAS to establish the response of grass to fertilizer nitrogen in relation to climate and soil (Morrison et al, 1980). This experiment, known as GM-20, has established levels of grass yield which can reliably be used to predict grassland productivity. The data have been so used by MAFF (eg. MAFF, 1982) and by I.C.I. (Thomas and Young, 1982), and are so used in this study (see Annexe IV). The experiment identifies fertilizer nitrogen (N) application and water availability as the main influences on the yield of a perennial ryegrass sward.

The general response to fertilizer N is shown in Figure II.13. It is more or less linear up to a fairly high value (about 300 kg N/ha), whereafter the response declines until a maximum yield is reached at about 600 kg N/ha. In this illustration a target application is shown, representing a putative point of diminishing returns (in fact the point where response falls below 10 kg DM per kg N applied). Ninety percent of the maximum yield can be achieved with 60% of the nitrogen needed to give the maximum yield.

FIGURE II.13

General Form of a Response of Grass to Fertilizer Nitrogen



Source: Thomas and Young (1982)

Water availability is controlled by 2 factors: summer rainfall and the water holding capacity of the soil. Summer rainfall varies according to region (see Figure II.14) and altitude. Water holding capacity depends on soil type. Clays and loams hold greater amounts than sandy, stony or shallow soils (see Annexe IV). By classifying according to summer rainfall and soil type, 5 site classes for water availability were generated (Table II.8). Their relation to grass yield is shown in Figure II.15.

FIGURE II.14

Average Rainfall Summer Half-Year (April-September)

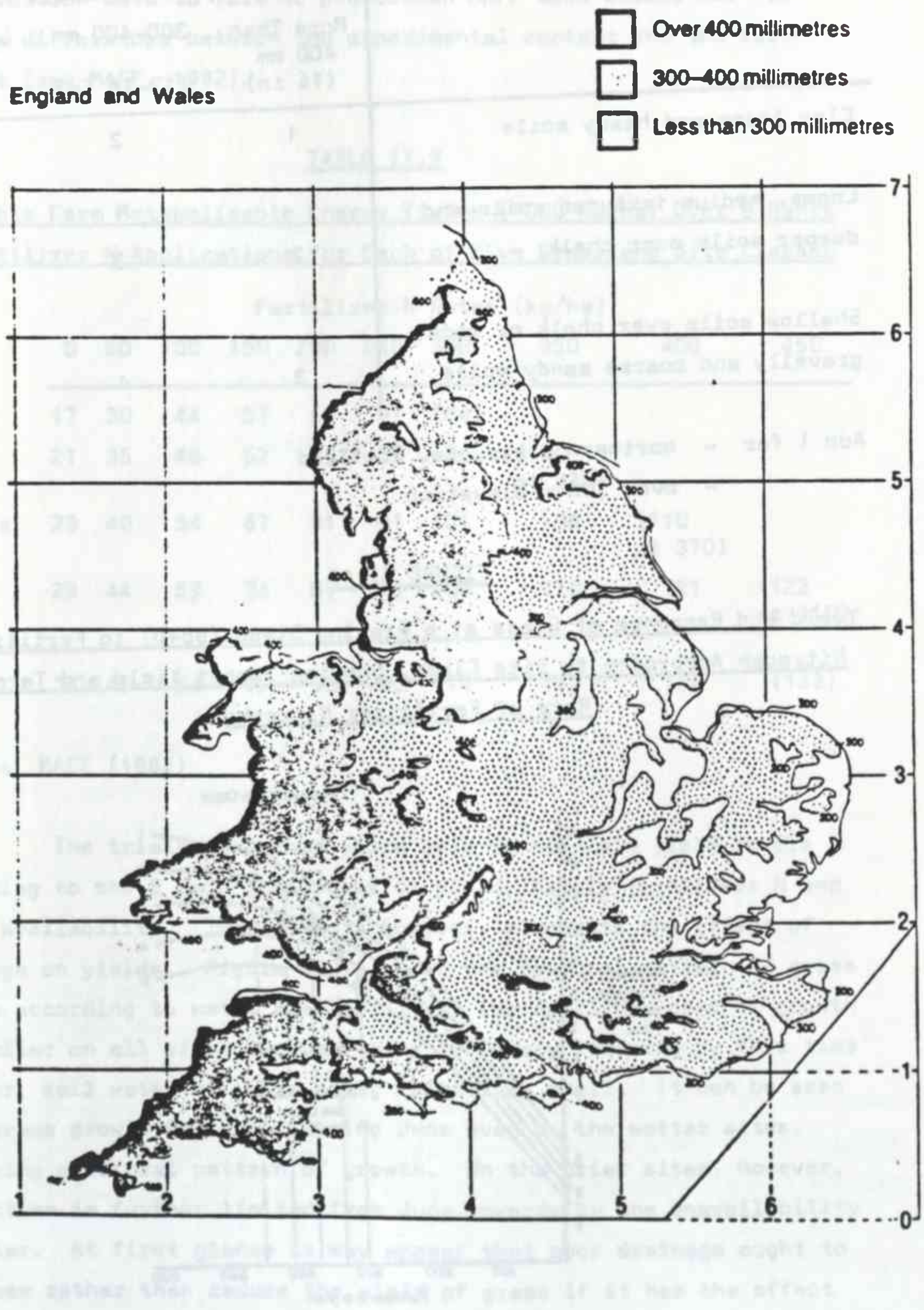


TABLE II.8

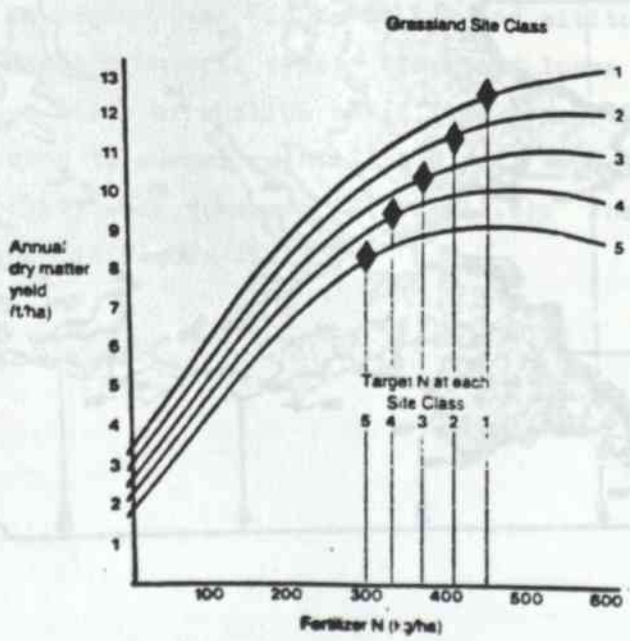
Site Classes

Soil Texture	Average April-September Rainfall: More Than 400 mm (16 in)	300-400 mm (12-16 in)	Less Than 300 mm (12 in)
Clay loams and heavy soils	1	2	3
Loams, medium textured soils and deeper soils over chalk	2	3	4
Shallow soils over chalk or rock, gravelly and coarse sandy soils	3	4	5

Add 1 for - northern areas, ie. Scotland
- over 300 m elevation

FIGURE II.15

Yield and Response of Grass at a Grazing Stage (6B+D) to Fertilizer Nitrogen According to Site Class, Showing Target Yield and Target Rate of Fertilizer Nitrogen



Source: Thomas and Young (1982)

MAFF have interpreted these data to give estimates of farm ME production according to N fertilizer application and site class for water availability (Table II.9). In converting the experimental DM production data to farm ME production MAFF made allowances for various differences between the experimental context and the farm context (see MAFF, 1982).

TABLE II.9

Probable Farm Metabolisable Energy Yields ('000 MJ/ha) Over a Range of Fertilizer N Applications for Each of Five Grassland Site Classes

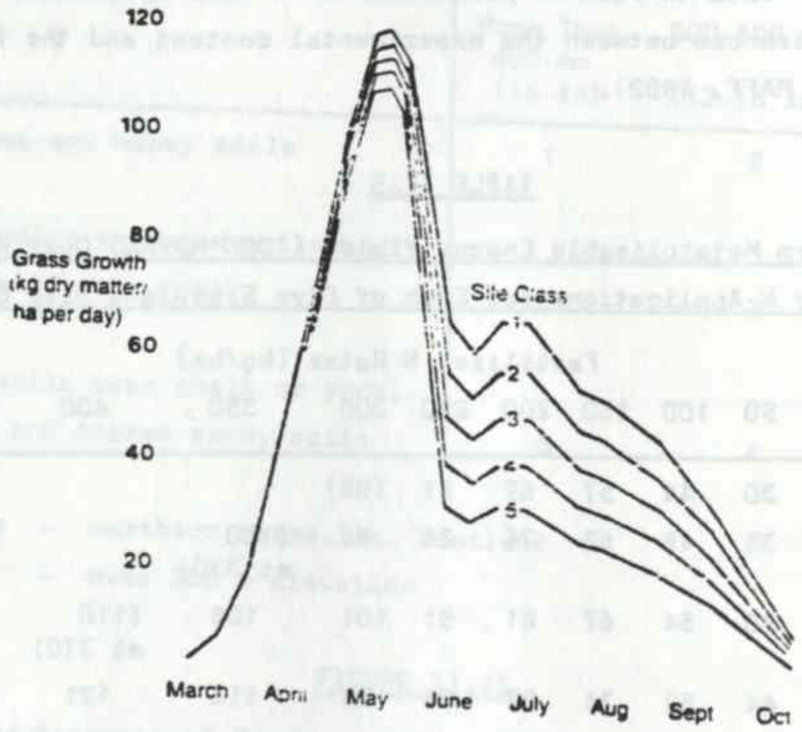
	Fertilizer N Rates (kg/ha)									
	0	50	100	150	200	250	300	350	400	450
Poor	17	30	44	57	69	81	(88)			
Fair	21	35	48	62	76	86	96	(100 at 330)		
Average	25	40	54	67	81	91	101	108	(110 at 370)	
Good	29	44	59	74	87	99	108	116	121	(122 at 410)
Very Good	34	49	64	79	93	105	114	122	128	(133)

Source: MAFF (1982)

The trials described above help to set farm yield levels according to the 2 main influences on yield, namely fertilizer N and water availability. They do not, however, elucidate the effect of drainage on yields. Figure II.16 shows the seasonal pattern of grass growth according to water availability. The April/May peak of growth is similar on all sites because water is rarely limiting by this time of year, soil water deficits being relatively small. It can be seen that grass growth falls off during June even on the wetter sites, following a natural pattern of growth. On the drier sites, however, production is further limited from June onwards by the unavailability of water. At first glance it may appear that poor drainage ought to increase rather than reduce the yield of grass if it has the effect of increasing water availability in summer.

FIGURE II.16

Seasonal Pattern of Dry Matter Production from a Perennial Ryegrass Sward at Five Site Classes

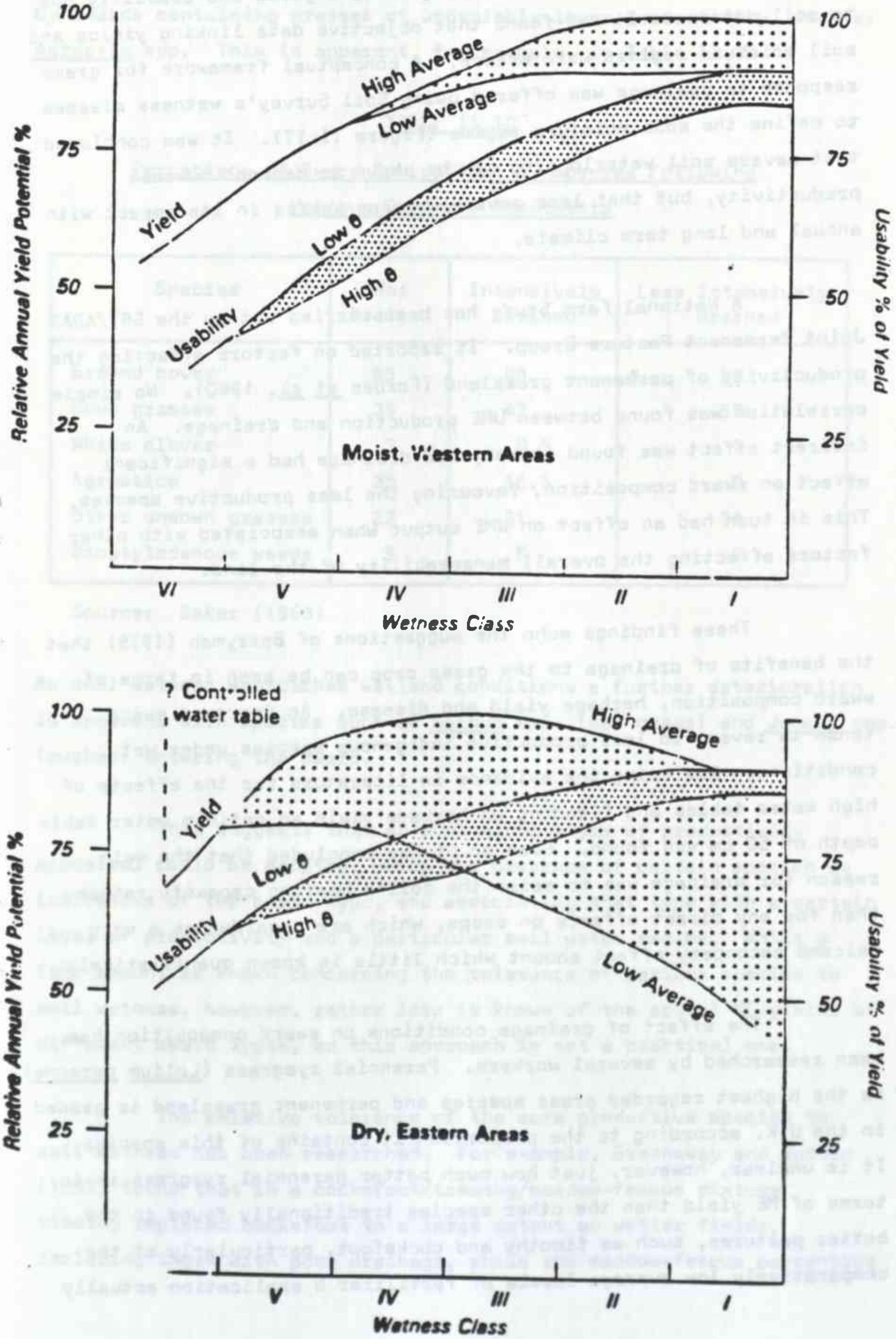


Source: Thomas and Young (1982)

This may well be the case in dry years on some sites. Van Hoorn (1982), with over 30 years' experience of drainage experimentation in Dutch conditions, concluded that grass production is favoured by deep water tables in wet years and shallow water tables in dry years and that these effects roughly balance in the long term, as far as DM production is concerned, for a variety of constant and variable water table depths. The evidence reviewed below, however, suggests that on many sites in the U.K. the advantage of wet soil in dry years does not outweigh the disadvantage in wet years. Nevertheless on many sites there may well be a case for a genuinely managed water table rather than straightforward drainage, if yields are not to be depressed in dry summers (see also Thomasson, 1979).

FIGURE II.17

Schematic Model of Relationships Between Soil Wetness Class, Yield, Usability, Plant Available Water (A_v) and Retained Water Capacity at 50 mb. suction (θ) in 'Moist' and 'Dry' Climatic Zones



Thomasson (1979) surveyed the evidence in the British and Irish literature on differences in grassland yield and usability due to soil wetness. It was found that objective data linking yields and soil moisture regimes were scarce. A conceptual framework for grass response to drainage was offered using Soil Survey's wetness classes to define the soil moisture regime (Figure II.17). It was concluded that severe soil waterlogging can be shown to depress overall productivity, but that less severe wetness varies in its impact with annual and long term climate.

A National Farm Study has been carried out by the GRI/ADAS Joint Permanent Pasture Group. It reported on factors affecting the productivity of permanent grassland (Forbes et al. 1980). No simple correlation was found between UME production and drainage. An indirect effect was found whereby bad drainage had a significant effect on sward composition, favouring the less productive species. This in turn had an effect on UME output when associated with other factors affecting the overall manageability of the land.

These findings echo the suggestions of Berryman (1975) that the benefits of drainage to the grass crop can be seen in terms of sward composition, herbage yield and disease. An improved sward tends to revert to less productive indigenous species under wet conditions. Reviewing the evidence in literature for the effects of high water tables and flooding on herbage yield an optimum water table depth of 50 cm was found. Even so it was concluded that the main reason for drainage was to raise the soil's bearing capacity rather than for any direct effects on crops, which are regarded as a very welcome secondary effect abount which little is known quantitatively.

The effect of drainage conditions on sward composition has been researched by several workers. Perennial ryegrass (*Lolium perenne*) is the highest regarded grass species and permanent grassland is graded in the U.K. according to the proportion it contains of this species. It is unclear, however, just how much better perennial ryegrass is in terms of ME yield than the other species traditionally found in the better pastures, such as timothy and cocksfoot, particularly at the comparatively low average levels of fertilizer N application actually used in farming practice. It is clear, however, that at a certain level of wetness these favoured lowland pasture grasses are replaced by swards containing grasses of undeniably lower productivity, such as Agrostis spp. This is apparent, for example, in Table II.10.

TABLE II.10

Percentage of Sward Composition by Species Following Various Drainage Treatments

Species	Not Drained	Intensively Drained	Less Intensively Drained
Ground cover	85	88	88
Sown grasses	35	47	55
White clover	3	0.5	1
Agrostics	35	16.5	9
Other unsown grasses	22	31	34
Dicotyledenous weeds	5	5	1

Source: Baker (1963)

As soil wetness approaches wetland conditions a further deterioration is apparent with species such as Nardus spp. (mat grass) and Juncus spp. (rushes) entering the sward.

This suggests that an ecological style of productivity appraisal could be adopted, using the presence of certain species as indicators of the sward type, and associating that type with a certain level of productivity and a particular soil water regime. While a fair amount is known concerning the tolerance of various species to soil wetness, however, rather less is known of the actual ME yields of different sward types, so this approach is not a practical one.

The relative tolerance of the more productive species to soil wetness has been researched. For example, Greenaway and Budden (1959) found that in a cocksfoot/timothy/meadow-fescue mixture timothy replaced cocksfoot to a large extent on wetter fields, including those with poor drainage, while the meadow-fescue percentage changed little. The tolerances of all the better grasses are describe qualitatively in the MAFF booklet on grasses and grassland. There seems to be little quantitative data differentiating the ME production of the more productive species from that of perennial ryegrass. Perhaps it is safest to assume that the productivity of permanent grassland approaches closely to that of a pure perennial ryegrass sward provided it consists mainly of the other favoured species such as timothy, etc. This is the approach taken by MAFF in adapting the GM-20 trials data, which are based on pure perennial ryegrass swards, to estimate the farm ME yield of mixed swards.

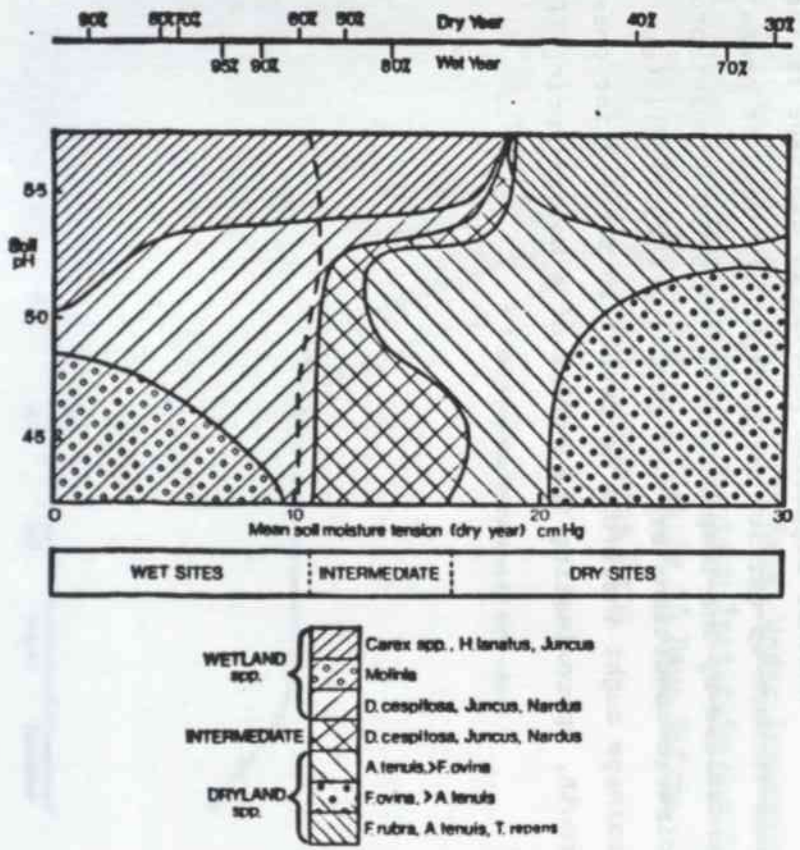
Klages and Asleson (1959) in the U.S.A. examined the response to N fertilizer application and water table level of a wet meadow sward, ie. one composed of species less productive than those favoured grasses which can be aligned with perennial ryegrass. The wet meadow species, naturally, are tolerant of a fairly high water table. It was found that species composition changed greatly over a 3 year period and this change accounted for much of the effect of the treatments on yield. High water tables favouring sedges and forbs (herbs) gave low yields while water tables below 30 cm and high N application (112 kg N/ha) favoured grasses and produced high yields.

Hoogerkamp and Woldring (1967) found on a heavy river clay in the Netherlands that botanical composition gradually changed under the influence of the water table level, but no true indicators of wetness (or drought) were found.

Work carried out by the Hill Farm Research Station in the Southern Uplands of Scotland suggests that Juncus spp. (rushes) can be used as an indicator (Rogers et al, 1974). Evidence was found that Juncus spp. invade at a certain level of soil wetness (see Figure II.18) and that DM production of the sward was significantly depressed at that level of wetness. It was concluded that the standard of drainage required on wet sites is that which would prevent invasion by Juncus spp. Sites were classified as wet, dry or intermediate and the relations between oxygen percentage, relative DM yield and soil moisture tension (as the measure of soil wetness) were examined (Figure II.19). It was found that in a wet year dry sites gave 50%

FIGURE 11.18

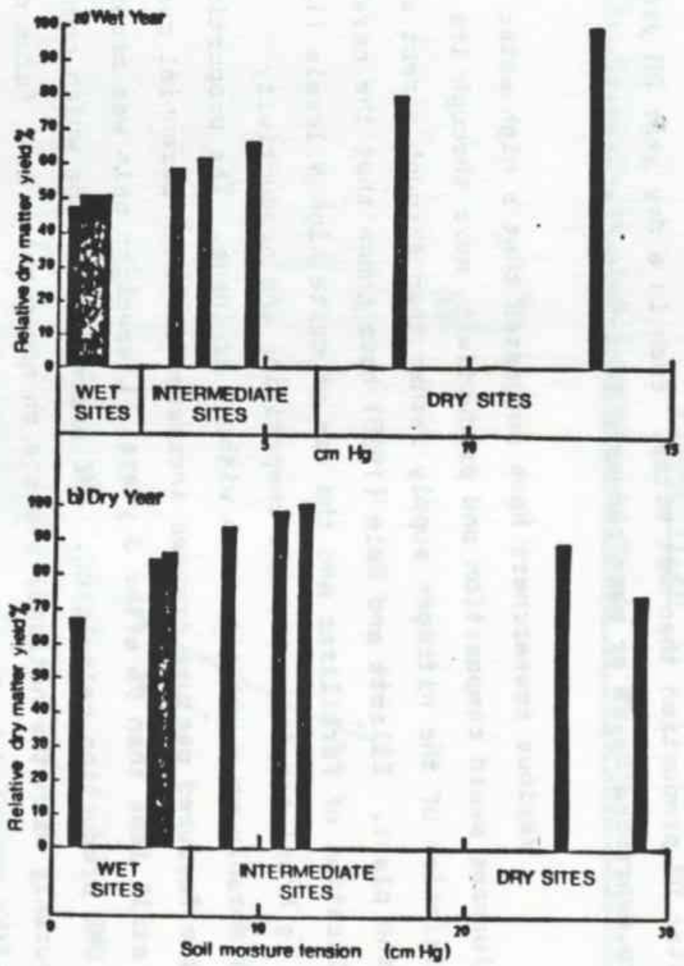
The Distribution of Indigenous Vegetation Types in Relation to Soil Acidity and Soil Moisture Tension. The Broken Line Represents the Moisture Tension Below Which Juncus spp. Might be Expected to Invade Improved Pastures. The Scale at the Top Shows the Percentage of Time in Two Growing Seasons, One Wet and One Dry, During Which the Soil Remained Wetter than Field Capacity



Source: Rogers et al (1974)

FIGURE 11.19

The Relative Annual Dry Matter Yield of Perennial Ryegrass at Eight Sites of Differing Mean Moisture Tension in (a) a Wet Year, and (b) a Dry Year



Source: Rogers et al (1974)

better DM production than wet sites. Even in a dry year DM yields were depressed by 8% or more compared to intermediate sites.

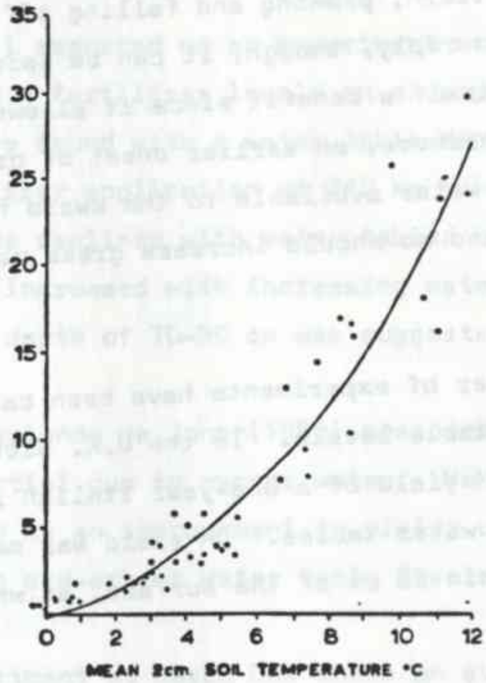
Various researchers have suggested that a high water table influences sward composition and productivity more through its restriction of the nitrogen supply rather than through direct effects on the plant. Elliott and Dale (1980) have shown that the careful application of fertilizer and the use of quite high N levels (140-190 kg N/ha) can improve sward composition and productivity considerably on a wet site even without drainage. The proportions of the favoured pasture grasses increased although perennial ryegrass was still less than 9% after 3 years. Liveweight gain was recorded and UME production calculated. UME averaged 66 GJ/ha which compares favourably with the national average on non-suckler beef farms of 40 GJ/ha reported by Forbes _et al_ (1980).

It seems from the foregoing that the improvement of sward composition is a benefit of drainage but that this effect is difficult to quantify given current knowledge of the ME yield from different types of sward.

Another suggested benefit of drainage is that it allows the soil to warm up earlier in spring. The rate of grass growth is controlled by the temperature at the growing point provided soil moisture conditions are not limiting (Roy, 1981) (see Figure II.20). Drainage ought therefore to result in the earlier onset of rapid growth, approximating the effect of a warmer spring (Figure II.21).

FIGURE II.20

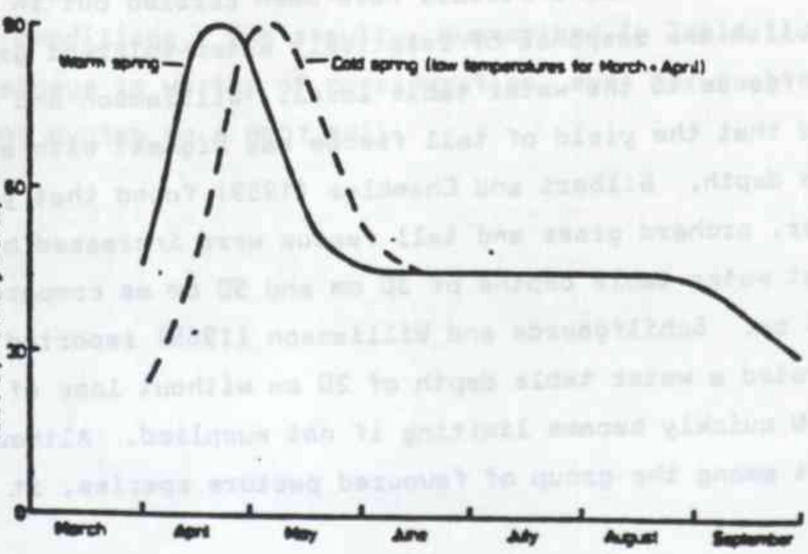
The Relation of Leaf Extension of Grass to Mean Soil Temperature



Source: Roy and Peacock (1972)

FIGURE II.21

Simplified Curve for Potential Grass Growth Rates Under Irrigation Based on Plot Trial Results at Grassland Research Institute for S.24 Perennial Ryegrass. Date of Spring Peak is 10 Days Before Calculated Mean Ear Emergence Date



Source: Roy (1981)

There is a lack of conclusive experimental evidence to support this theory and a possible objection to it is that the overall yield of grass may not be increased, rather growth will simply follow its seasonal pattern, peaking and falling off again, a little earlier in the year. In reply, though, it can be said that earlier grass production is itself a benefit since it allows cattle to spend longer at grass. Furthermore, an earlier onset of growth increases the total amount of water available to the sward from rainfall during the growing season and so should increase grass production, other things being equal.

A number of experiments have been carried out relating grass yields to water table levels. In the U.K. Nicholson and Firth (1958) found that the DM yield of a one-year Italian ryegrass ley was favoured by deep water tables. DM yield was markedly limited with water tables within 60 cm of the surface, as was the crude protein yield.

Hoogerkamp and Woldring (1967, 1968) in the Netherlands found that on heavy clay soils water tables had a clear but variable effect on yields. In spring and in wet periods deep water tables gave the highest yields. In dry periods, however, water supply was limiting and the reverse was found. The decreased yields at high water table levels were associated with a low N supply and it was suggested that they were better remedied by N fertilizing than by drainage.

A number of trials have been carried out in the U.S.A. to establish the response of relatively water-tolerant grasses such as tall fescue to the water table level. Williamson and Willey (1964) found that the yield of tall fescue was highest with a 40 cm water table depth. Gilbert and Chamblee (1959) found that yields of ladino clover, orchard grass and tall fescue were increased by an average 46% at water table depths of 30 cm and 50 cm as compared with a depth of 15 cm. Schilfgaarde and Williamson (1965) reported that fescue tolerated a water table depth of 20 cm without loss of yield except that N quickly became limiting if not supplied. Although tall fescue is not among the group of favoured pasture species, it is a useful grass and its tolerance to quite a high water table offers the possibility of gains in DM yield with minimal drainage improvement, although the question of trafficability remains.

Boeker (1974) reported on an experiment using a variety of water table depths and N fertilizer levels on a very light sand. The best DM yields were found with a water table depth of 70 cm although with a fertilizer application of 240 kg N/ha a depth of 50 cm was best. Yields declined with water tables below 90 cm. Crude protein content increased with increasing water table depth, so an overall optimum depth of 70-90 cm was suggested.

In the Netherlands de Jong (1982) measured the yield depression below potential due to excess water. He found that underdrainage resulted in an improvement in yields up to a maximum of 14-20% depending on pre-scheme water table levels and soil type.

A MAFF experiment at Hayes Oak shows an average DM yield which appears 13% higher on conventionally drained than undrained plots. This is a preliminary result from 3 years' data.

The Langabeare Experiment (Trafford, 1971) attempted to assess the benefit of drainage of grassland in terms of the liveweight gain of bullocks. Three treatments, combining drainage, fertilizing and re-seeding, were tested against an undrained control on Culm Measure Clay of the Tedburn Series. The results show a positive response to fertilizer in all cases, but drainage considerably improved ground conditions. The results, summarized in Table II.11, suggest that drainage is worthy of consideration, even for such an extensive farming system on a poor soil.

TABLE II.11

Results From Langabeare, 1962-1964

Treatment	Liveweight Gain (kg/ha)	Yield (% of control)
Undrained	242.3	100
Undrained but fertilized	303.4	121
Drained and fertilized	437.9	180
Drained, reseeded and fertilized	419.0	173

Source: Berryman (1975)

Rhoades (1964, 1967) examined the flood tolerance of a number of native American grasses. Wide differences were found between species and it is difficult to relate the behaviour of these species in American weather conditions to the U.K. context. In general, though, flood damage was found to increase with both depth and duration of flooding. Timing was of particular importance, there being little or no damage during the period of dormancy and greater damage with increased growth activity. Repeated flooding had an additive effect on damage.

In summary, the evidence suggests that yield benefits from drainage can be expected on grassland but the size of the benefit in terms of ME yield is uncertain. It seems that a partial improvement of very wet sites is possible with a minimal drainage improvement, enabling the less favoured of the pasture grasses to replace wetland species. The drainage requirements of the more favoured pasture grasses are stricter. A water table depth of at least 50 cm would seem to be required. The application of N fertilizer can largely alleviate the effect of high water tables on the growth of grass.

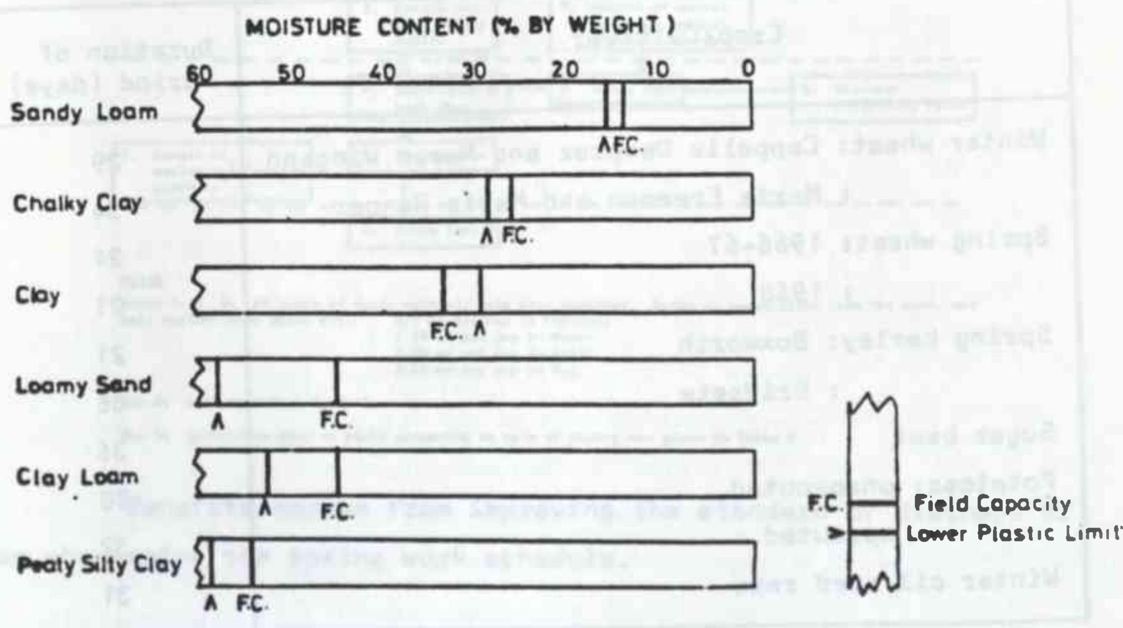
II.3.3 Trafficability Response to Drainage

Trafficability is a function of both soil and machinery, so different operations are limited by different maximum moisture contents. In attempting to define these moisture contents the approach of the U.S. Army Engineers has been to provide an empirical rating index for both soils and vehicles, using a cone-penetrometer (Reeve and Fausey, 1974). This approach has also been applied to agricultural equipment (eg. Aldabagh and Beer, 1975). However, in the absence of such data, the lower plastic limit of the soil is frequently accepted as being the upper limit for working soils in agriculture (Godwin and Spoor, 1977).

As Figure II.22 shows, the relationship between the lower plastic limit and field capacity varies between soil types according to the clay content. In heavy clay soils drainage alone is insufficient to lower soil moisture content to the plastic limit and some moisture must be removed through evapotranspiration at the surface.

FIGURE II.22

Relation Between the Lower Plastic Limit and Field Capacity



Source: Unpublished Silsoe College data.

Steinhardt and Trafford (1974) carried out field experiments to investigate the direct and indirect effect on soil structure of subsurface piped drainage in ploughed and unploughed soil. In a ploughed soil, subsurface drainage was found to be effective in reducing wheel sinkage and lateral compaction, and they concluded that it was advisable to maintain water tables deeper than 50-60 cm.

Van Hoorn (1958) found that a water table depth of 40 cm on a clay soil affected structure enough to obstruct tillage.

II.3.3.1 Arable Crops:

Jarvis (1977) has reviewed the evidence for the effects of timeliness of soil-engaging operations on crop yields. He quotes figures from various sources that indicate the effects of delayed sowing and suggests trafficability requirements for the sowing of some crops (Table II.12).

TABLE II.12

Sowing Periods Giving 95% or More of Maximum Yield

Crop/Cultivar	Duration of Period (days)
Winter wheat: Cappelle Desprez and Maris Widgeon	29
: Maris Freeman and Maris Ranger	34
Spring wheat: 1966-67	24
: 1968	21
Spring barley: Boxworth	21
: Bridgets	38
Sugar beet	36
Potatoes: unsprouted	28
: sprouted	32
Winter oil seed rape	31

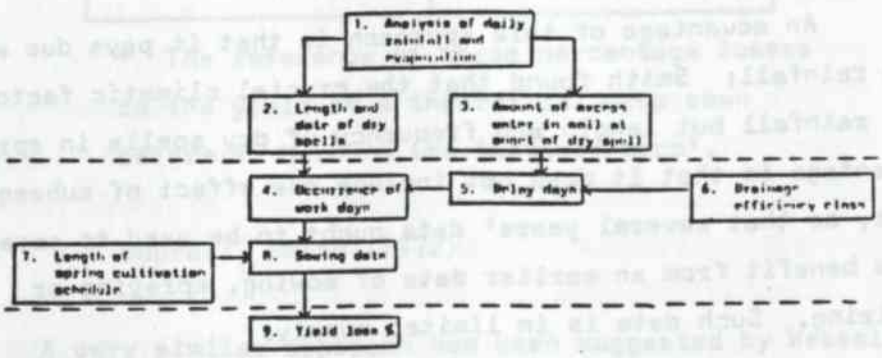
A straightforward survey of available work days in spring and autumn at 60 experimental sites, with and without drainage, has been carried out by Armstrong (1977).

The results display a wide range of scatter, suggesting large variations in the degree of benefit, with mean values of 25 extra days in autumn and 27 in spring when the soil is workable on the drained sites. There is an indication that secondary treatments (subsoiling or moling) give increased benefits.

It remains to evaluate this gain in work days in terms of increased productivity. This has been attempted with some success by Smith (1972) for spring barley, using the simple and appealing model for spring sown crops shown in Figure II.23. Here the number of extra work days is estimated according to the standard of drainage (Table II.13).

FIGURE II.23

Model of Barley Production: Due to Smith (1972)



Notes

Boxes 1, 2, 3: 20 years of daily rainfall data were examined. Rates of evaporation from the bare, wet soil surface were taken as:- 0.5 mm per day in February
1.25 mm per day in March
2.00 mm per day in April
2.50 mm per day in May

Box 5: calculate from Table 3.

Box 9: percentage loss of yield according to date of sowing was given in Table 4.

Benefits accrue from improving the standard of drainage or from shortening the spring work schedule.

In order to adapt this approach for winter cereals it would be necessary to consider both the date of spring cultivations and the 'window' for sowing in autumn between the time when conditions become suitable for sowing, which is itself affected by drainage in some cases, and the time when they become too wet.

TABLE II.13

Drainage Efficiency

	Delay Days			
	A (good)	B (moderate)	C (poor)	D (bad)
Excess water:				
Little or none	1	1	2	2
Under 1 inch (25 mm)	1	2	3	4
1-2 inches (25-50 mm)	2	3	4	5
Over 2 inches (50 mm)	2	4	5	6

Source: Smith (1972)

An advantage of this approach is that it pays due attention to the rainfall; Smith found that the crucial climatic factor was not annual rainfall but length and frequency of dry spells in spring. A disadvantage is that it does not include the effect of subsequent weather, so that several years' data ought to be used to assess the average benefit from an earlier date of sowing, spraying or fertilizing. Such data is in limited supply.

Smith's model uses only 4 classes of drainage efficiency according to the number of delay days resulting from given amounts of excess water (ie. precipitation minus evaporation) by which the drying time needed for a soil to become workable is lengthened (Table II.14). It is therefore fairly insensitive to drainage improvement since a change of one class is the only adjustment which can be made in practice. Smith suggests, though, that an analysis of sensitivity to drainage improvement can be carried out by plotting yield loss against the 4 classes on a unit scale.

TABLE II.14

Percentage Loss of Barley Yield* According to Date of Spring Cultivations Immediately Prior to Sowing

Work Days	Loss of Yield (%)
Before 15 March	nil
15 - 21 March	5
22 - 28 March	10
29 March - 4 April	15
5 - 11 April	22½
12 - 18 April	30
19 - 25 April	37½
26 April - 2 May	47½
3 - 9 May	57½
10 - 16 May	67½
After 16 May	100

* The reference of these percentage losses is the yield of a theoretical crop sown before 15 March - the 'optimum crop'.

Source: Smith (1972)

A very similar approach has been suggested by Wesseling, cited by Berryman (1975) who reproduces a table relating the number of drying days required by various soils to water table depths and evaporation rates (Table II.15).

TABLE II.15

The Number of Drying Days Required Before Cultivations are Possible, for Various Constant Water Table Depths and Evaporation Rates

	Evaporation mm/day	Depth of Water Table (cm)						
		160	140	120	100	80	60	40	20
Clay	1	3	4	5	6	8	10	17	25
Silt	2	3	4	6	9	14	33	54	69
Loam	2	1	1	2	2	2	3	4	7

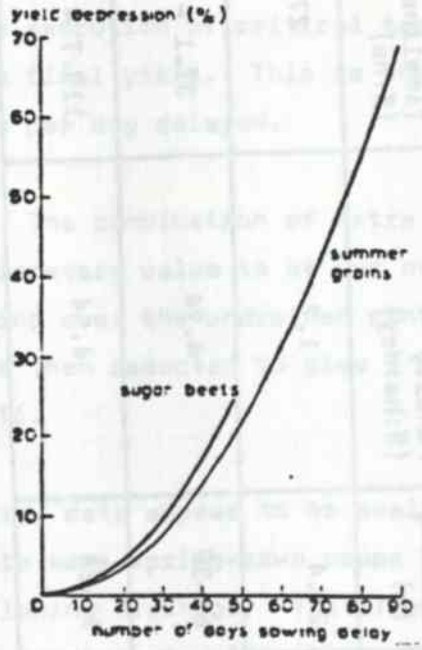
Source: Wesseling (1968)

In the Netherlands both numerical and hydraulic analogue models of the soil water profile have been used to calculate the number of work days in spring and the first day of workability (Wind, 1976). The operation of the hydraulic analogue is described and it was run for 25 years' meteorological data and checked against the subjective data of a farmer who, fortuitously, had kept a diary over that time containing his judgement of spring working conditions. The advantages of the hydraulic analogue are that the criterion of workability can be a soil water parameter and that the effect of the actual weather is modelled. The criterion used in this case is a limit of workability on the wet side of h = 300 cm in the top 5 cm of soil, where h is soil water suction. Wind found that drainage depth had a pronounced effect on spring workability and drainage intensity very little effect. He attributed this to the decisive importance of depth of water table at the beginning of a dry period. Some data is given for Dutch conditions relating drain depth, planting date, drought damage and yield reduction. Figure II.24 shows the effect on yields of sowing delay in spring.

Another simulation model predicting available spring work days and the earliest planting date has been developed in the U.S.A. (Wendte, et al, 1978). This model uses a water budget in 2 layers of the soil with a specified water table height. Evapotranspiration and runoff are estimated and subtracted from rainfall. The criteria for the planting date are varied according to the level of management.

FIGURE II.24

Yield Depression for Summer Grains and Sugar Beets as a Result of a Delay in Sowing



Source: Wind (1960)

Attempts have been made, using this approach, to assign a monetary value to the timeliness benefit of field drainage. The approach adopted by Wendte, Drablos and Lembke (1977, 1978) and Aldabagh and Beer (1975) can be summarized as follows:

(i) A model is used to compute daily soil moisture values in the upper layers of the soil for a number of soil types with a variety of drainage intensities.

(ii) An empirical relationship is established between soil moisture content and soil strength to determine the trafficability of the soil.

TABLE II.16

The Timeliness Benefit of Drainage in Relation to the Spring Planting of Corn in Three U.S. Soils

Date Source	Date	Soil Type	Drain Spacing (m)	Average Timeliness Penalty (Ø:ha:day)	Average Annual Timeliness Benefit (Ø:ha)
Aldabagh & Beer	1975	Webster (Silt Clay Loam)	24.4	1.7	27.17
Wendte, Drablos & Lembke	1978	Drummer (Silt Clay Loam)	61-30	4.94	37.1 - 155.9
"	"	Elliott (Silt Loam)	37-24	4.94	110.7 - 153.0

(iii) From the above, the number of days on which the soil is workable is calculated for critical months in spring for the various drainage intensities. A benefit in terms of extra work days can be calculated as the difference between the drained and undrained states.

(iv) A timeliness penalty function is established to relate delay in the execution of critical tasks, eg. spring sowing, to the reduction in final yield. This is then costed to give a loss in terms of dollars per day delayed.

(v) The combination of extra work days and the penalty function allows a monetary value to be put on the timeliness benefit of each drainage spacing over the undrained control. The average annual cost of drainage is then deducted to give a net benefit per hectare as shown in Table II.16.

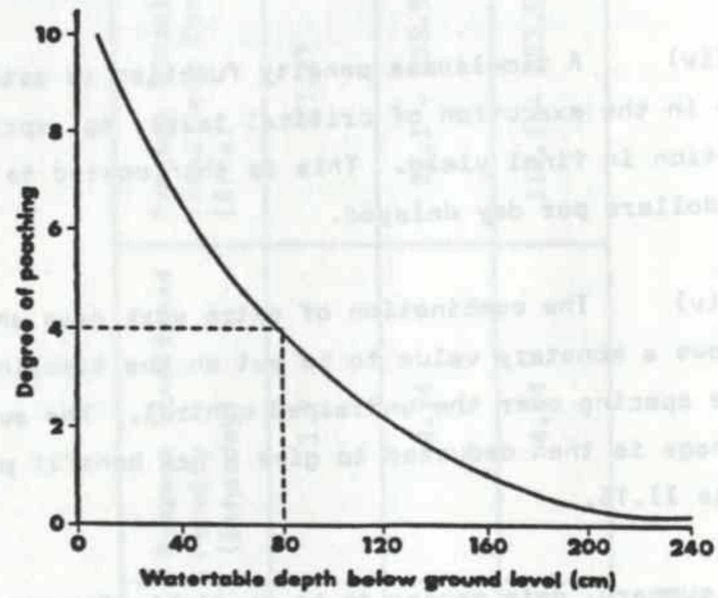
In summary, data appear to be available for the prediction of yield benefits to some spring-sown crops due to increased trafficability following drainage. The effect on autumn-sown crops is less clear. It seems that water tables should be restricted to at least 50 cm depth.

II.3.3.2 Grassland:

The relationship between poaching and soil moisture has been investigated by Kunze (1967) (cited by Massey et al, 1974). He found that the tendency to poaching increased as the organic matter in the top soil increased and as the water table rose. His results, shown in Figure II.25, indicate that the optimum water table level to overcome poaching is about 80 cm. This is in accordance with findings of Massey et al (1974) who investigated the occurrence of poaching of 2 surface water gley soils in Lancashire. They concluded that a water table of at least 50 cm below ground level during the design storm is needed to minimize poaching with levels of 100 cm at other times.

FIGURE II 25

The Effects of Water Table Position on Poaching of Grassland



Source: Kunze (1967)

Van Hoorn (1982) suggests that, while water tables up to 30 cm for short periods in winter do little or no harm, they should be at least below 1 m at the beginning of March, for both arable crops and grassland. The relation of soil bearing strength to water table depth for a heavy clay soil is given (Table II.17)

TABLE II.17

Bearing Strength of Grassland in kg/cm^2 in Spring and Autumn

Constant groundwater level	25 cm	40 cm	65 cm	95 cm	140 cm
Bearing strength	7	8	11	12	12

Hoogerkamp and Woldring (1967, 1968) found that a water table depth of 65 cm was needed to prevent poaching on a heavy river clay. Berryman (1975) reports a variety of depths recommended by other workers, ranging from a 50 cm depth found necessary by Rycroft in the U.K. to depths of 80-100 cm found by German and Dutch workers. Hope (1982) reports that trials in Northern Ireland on a silty clay soil showed that poaching was reduced if the water table was below 30 cm and eliminated at a depth of 45 cm.

There is a limited amount of data relating the utilisation efficiency of grass to soil wetness.

Utilisation efficiency was estimated at 69.5% overall for the purposes of evaluating land drainage benefits for a scheme in Ireland (Walsh and Lee, 1983). There are some indications that utilisation is higher in general in moister areas, where grass growth is more reliable and therefore management easier (Wolton and Brockman, 1979). Since the figure of 69.5% applies to an area of high rainfall as compared to Southern England, it may be considered a 'high average'. Recent work concerning farms in Buckinghamshire (Peel, 1982) gives a calculated utilisation (for one year only) of 70% on the best-drained farm, which was on chalk, going down to 44% on the worst-drained farm, which was on Oxford clay. Similar work in Devon gave a range from 72% to 58% according to the standard of drainage and soil type. Poor utilisation was due, not simply to poaching itself, but to understocking, which prevented poaching but wasted grass.

Harrod (1979) offers a system of grassland classification which defines objective grassland soil suitability classes with reference to both yield potential and trafficability. In predicting the trafficability class the influences of the soil, climate and slope are all taken into account. It remains to set levels of productivity for each class (see Annexe IV).

In summary, it is clear that trafficability and poaching risk have a profound effect on the productivity of grassland. Utilisation efficiency in the worst cases is little more than half that of the best sites. The relation of utilisation to drainage, however, is unknown. It is impossible to estimate confidently either the likely improvement on a particular site or soil after drainage or the standard of drainage required.

II.4 MODELS OF THE IMPACT OF POOR DRAINAGE

An obvious advantage of modelling yield response to drainage is to enable predictions to be made of the likely benefits from drainage. A more immediate advantage in research is that models offer a solution to one of the main experimental difficulties, namely the variability of weather from year to year. Meteorological data are actually abundant and this can be turned to advantage if they can be used to model the resulting soil water regimes season by season. Provided that the fundamental relations of crop growth and trafficability to soil moisture are known the response of a given crop to a given drainage condition can be calculated for all the years of weather data available.

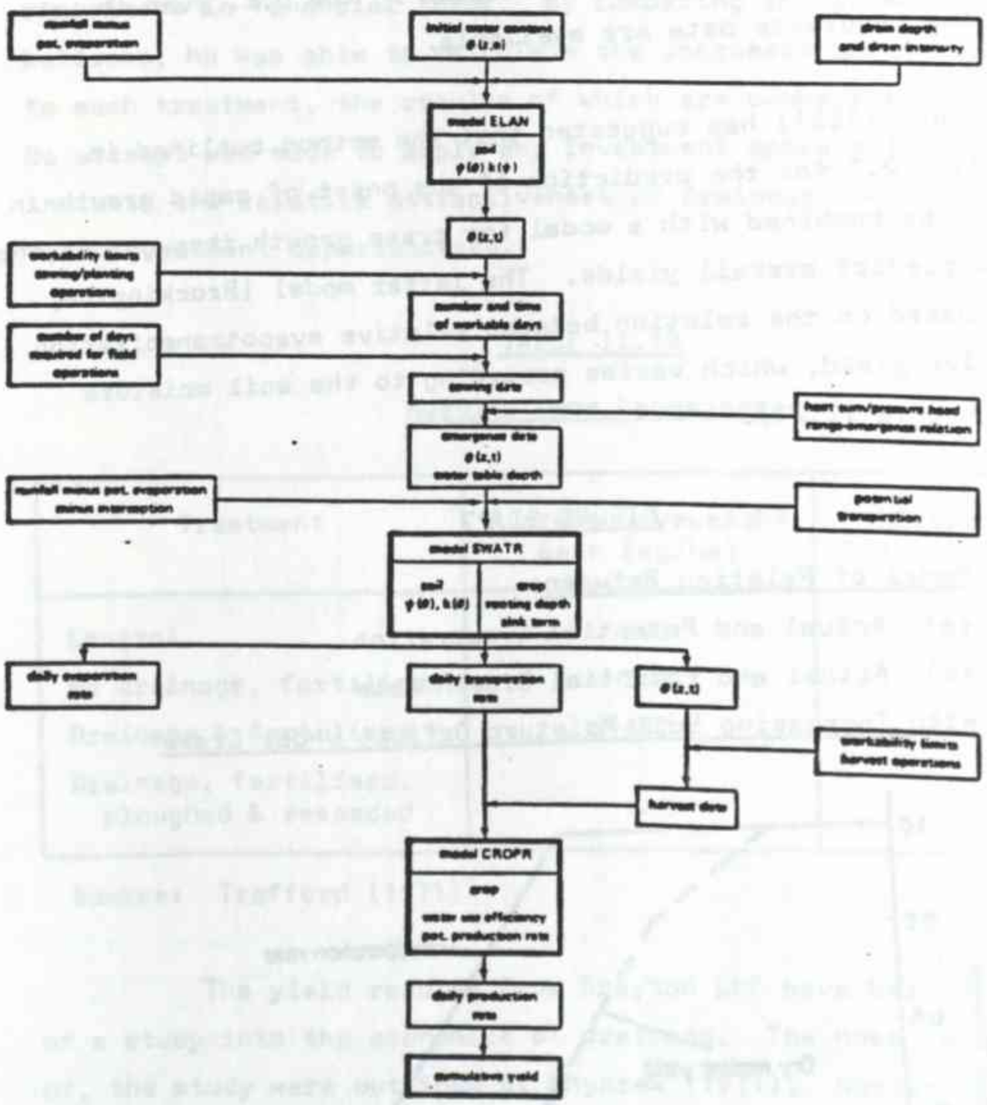
A model has been developed in the Netherlands which draws on various of the research sources mentioned above in section II.3 to combine all of the factors affecting crop response to drainage either directly or through their effect on trafficability. This integrated model is summarised in Figure II.26. It has 3 sub-models. The first sub-model, ELAN, keeps a daily soil water balance according to meteorological data and drainage characteristics. Workability limits are applied to the resulting soil water profile to predict available work days and hence the crop's sowing date. Soil temperature is also predicted from the soil water profile and this enables the emergence date to be estimated. The second sub-model, SWATR, uses the soil water profile, meteorological data and crop growth stage from emergence onwards to predict daily crop water use. A third sub-model, CROPR, interprets crop water use in terms of daily herbage production accumulating into the eventual crop yield.

A model, DRAINMOD, has been developed in the U.S.A. which also predicts water table behaviour from meteorological data for a given drainage condition (Skaggs, 1982). DRAINMOD has been used in combination with the concept of a Stress Day Index (SDI), as advanced by Hiler (1969), to investigate crop responses to drainage. SDI was identified with Sieben's SEW_{30} index (Ravelo *et al*, 1982) and the relations of SDI to yield explored (Hardjoamidjojo *et al*, 1982; Skaggs *et al*, 1982).

FIGURE II.2.6

Integrated model of crop yield, taking into account standard of drainage.

Source: **van Wijk and Feddes (1982).**



Other American workers have claimed that while DRAINMOD offers a good means of assessing the effect of installing drainage in a particular situation, and hence is useful for drainage design, simple regression models are preferable for predicting yields on a broad soil/crop/management condition (Lembke, et al, 1981).

An integrated model which takes account of both direct crop response to soil wetness, and the effects on yields of impeded trafficability has not yet been developed in the U.K. even though many of the requisite data are available.

Roy (1981) has suggested that the method outlined in section II.3.2.2 for the prediction of the onset of rapid growth in spring can be combined with a model for grass growth throughtout the season to predict overall yields. The latter model (Brockington, 1970) is based on the relation between relative evapotranspiration and relative yield, which varies according to the soil moisture deficit (Figure II.27).

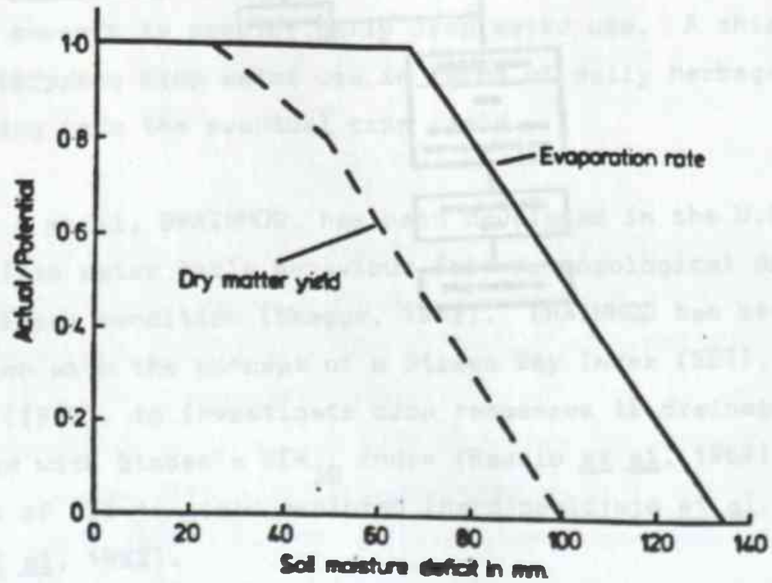
FIGURE II.27

Model of Relation Between:

(a) Actual and Potential Evaporation

(b) Actual and Potential Growth Rate

With Increasing Soil Moisture Deficit Under Grass



Source: Roy (1981)

It is apparent that even if the relations suggested by Figure II.27 are well founded trafficability limits still need to be applied in order to estimate overall productivity and the relation between soil moisture deficit and drainage reamins to be explored.

II.5 THE FINANCIAL EVALUATION OF FIELD DRAINAGE

II.5.1 Using Experimental Results

Trafford (1971) assessed the results of the Langabeare experiment in financial terms. By comparing the liveweight gain of bullocks, he was able to calculate the increased margins attributable to each treatment, the results of which are summarised in Table II.18. No attempt was made to apply any investment appraisal techniques to indicate the relative attractiveness of drainage compared to other farm investment opportunities.

TABLE II.18

Results from Langabeare

Treatment	Average Liveweight Gain (kg/ha)	Extra Margin Over Control (£/ha)
Control	245	0.00
No drainage, fertilized	307	0.65
Drainage & fertilized	442	3.28
Drainage, fertilised, ploughed & reseeded	442	1.54

Source: Trafford (1971)

The yield results from Drayton EHF have been used as a basis of a study into the economics of drainage. The need for, and objectives of, the study were outlined by Whybrew (1971). Hunter and Trafford (1979) compared the drainage treatments against an undrained control upon the basis of the Payback period. They used the actual data from the 4 years of winter wheat and extrapolated these over the 6 year period, 1970-76. To allow for changes in prices 3 budgets were produced using current prices, 1970 constant prices and 1976 constant prices (see Table II.19). The results show all systems to be

Table II.19 : Results from Drayton EHF based upon a mean control of 3.67 t/ha

Treatment	Net cost (£)		Yield Gain (t/ha)	Annual Value of increased yield (£)		
	1970	1976		1970 Budget	Actual	1976 Budget
Pipes only	78	154	0.59	15.64	34.81	48.97
Pipes @ 15m & subsoiling	84	164	0.96	25.44	56.64	79.68
Pipes @ 60m & subsoiling	56	103	0.48	12.72	28.32	39.84
Pipes @ 60m & Moling	56	103	1.03	27.30	60.77	85.49

Source: Hunter and Trafford (1979)

Table II.20 : Results from Drayton EHF

Treatment	Yield (% of control)		Total Cost (£/ha)	Mean annual return increase over 8 yr. (£/ha)	Cost-Benefit Ratio	Payback Period (yr)
	Sp. Barley (3 yr. mean)	W. Wheat (5 yr. mean)				
Pipes & Moling	112	124	405	67	1:2.33	4
Pipes only	110	112	430	38	1:1.36	13

Source: Bailey (1979)

economically justifiable with the actual return being greater than would have been predicted in 1970 due to relative price changes. The payback period ranged from 9 years to 1½ years but it was pointed out that this would have been more than doubled had 50% grant aid not been payable.

In his analysis of the Drayton data, Bailey (1979) included the results for spring barley yield. As no account was taken in the experiment of the possibility of earlier planting, the Smith (1972) model was used to estimate the yield increase of spring barley on drained over undrained plots. The project was appraised firslty in terms of the national investment - using a test discount rate of 5%, a working life of 30 years and assuming that average benefits accrued annually, to calculate a cost-benefit ratio - and secondly in terms of the farmer's investment - considering costs net of grant aid and using a fixed borrowing rate of 14.5% to calculate a payback period. Both assessments were based upon 1979 commodity prices. The results given in Table II.20 show that on the clay soil in question the cheapest system, namely moling over wide spaced drains, was superior in financial terms although both systems were justifiable.

Bornstein and Fife (1973) investigated the response of alfalfa and hay yields to drainage on Cabot silt loam in Vermont (U.S.A.). Yields from drained plots were generally higher, as were percentages of alfalfa in the hay. Financial analysis showed drainage to be a worthwhile investment for hay, both for on-farm use and for sale. Sixty metre spaced drains were to be preferred to 30 m drains and gave a rate of return on investment of 16.5-18.4% within a payback period of 5-6 years.

Crop yield data for Southern Ontario (see Bolton, Dirks and Hore, 1980) were used by Colwell and Bolton (1979) to evaluate 5 alternative investments relating to drain spacing reductions for grain corn and soybean production. A computerised discounted cash flow model was used incorporating 4 sets of input data:

(i) Capital investment variables; such as cost, project, duration, loan repayments.

(ii) Performance variables; such as crop yield increases, prices.

(iii) Land value variables; land price differential due to drainage and land price inflation rate.

(iv) Miscellaneous variables; such as grant, area involved, marginal tax rate, estimated income.

No advantage was taken of potential timeliness benefits and increased yields were assumed over the 40 year expected life of the drain. Only the costs and benefits relating to the improved drainage were considered.

All investments considered gave internal rates of return in excess of 10%, however it was shown to be more profitable to accept sub-optimal yields rather than install drains at very close spacing. (It should be noted here that no secondary treatments were considered therefore perfect drainage of the clay soils would require very close drain spacing.) Increased land values had a relatively minor influence on drainage profitability although returns were shown to be sensitive to changes in crop price, crop yield, taxation, and the cost of drainage.

II.5.2 Using Farm Results

The approach adopted by the Huntingdon Division of ADAS (Smith, 1976) was to define yields and cropping patterns on the 3 basic soil types of the division for 3 yield situations, namely normal (100%), low (70-80%) and breakdown (50-60%). One hundred hectare farm models were constructed, based upon cropping patterns, production levels and gross margins estimated as being typical of the soil/yield category by local advisory staff. For each category, an assumed increase in production following drainage was calculated as the increase in returns to be expected from moving from breakdown to low, or low to normal yield situations.

With the cost of drainage being expressed in terms of an annaul cost to the farmer for a variety of interest rates and recoupment periods, the worthwhileness of the investment was evaluated by 4 methods:

(i) Assuming capital was borrowed at the existing market rates.

(ii) Considering the field drainage system as part of the fixed equipment of the holding.

(iii) Comparing investments in drainage with other working capital employed in the farm business.

(iv) Considering drainage as a marginal investment.

The results indicate that for the Huntingdon Division the worthwhileness of drainage was 'beyond dispute' where normal production was restored from low or breakdown yield situations. On each of the soil types the cost of drainage was low in comparison with the losses due to inadequate drainage, the cost being covered at least within 2 years, often in one.

Calvert and Morris (1974) (see also Morris and Calvert, 1976) based their study of the financial benefits and costs of field drainage in Eastern England upon data from 3 selected farms for which field records had been kept before and after drainage. A fourth hypothetical case study was generated from ADAS data from the Huntingdon Division.

Financial analysis was based upon a comparison of net improvements in gross margin performance arising from the drainage investment. The return was evaluated by 5 methods:

(i) Payback period.

(ii) The rate of return on gross and average investment.

(iii) The sinking fund method.

(iv) The Net Present Value (N.P.V.)

(v) Internal Rate of Return (I.R.R.)

In each case it was assumed that drainage involved only a marginal change in the farm business. Their results, summarized in Table II.21 below, suggest that drainage was undoubtedly worthwhile. The lowest I.R.R. shown was 27½% where drainage was for increased yields which failed to materialize in the first 3 years. At the time this represented a high rate of return for a farm investment.

II.5.3 Economic Models of Drainage Development

Work at the University of Manitoba (Rigaux and Singh, 1977; Singh, 1979) has been concerned with the development of a model to assess the economic impact of alternative levels of drainage development. The model estimates the costs and optimum design capacities for the drainage system in addition to the land use adjustments which are neceesary to facilitate optimum development.

A computer model was used by Colwell (1978) to assess the economic feasibility of increasing the productivity of 5 major crops in S.E. Canada by drainage. It was estimated that the average yield increases would be sufficient to make drainage investment a profitable proposition for grain corn, soybeans and wheat.

II.5.4 Evaluation Techniques for Field Drainage

Trafford et al (1977) reviewed the place of field drainage in the economy of the farm business and recommended the use of discounted breakeven budgeting techniques to evaluate drainage projects. Using information on the size and timing of capital outlay, the economic life and the cost of capital, the average annual cost of the project can be calculated from amortization tables and equated with annual breakeven benefits. This technique has been used by Molyneux (1981) to assess the average crop and livestock responses required to break even in relation to the cost of drainage.

Table II.21 : The Results of Calvert and Morris

Case	Payback	R.R. on av. investment	S.F.	N.P.V. @ 10%	N.P.V. @ 15%	N.P.V. @ 25%	D.C.F. to nearest 1%
				per £100 net investment			
1	Year 1	188%	£6.48	£531.62	-	-	92%
2	Year 5	100%	£2.90	£197.47	-	-	28%
3	Year 1	186%	£5.22	£775.06	-	-	113%
4.1	Year 3	98%	£6.39	£258.07	£183.49	£ 89.62	46%
4.2	Year 1	98%	£6.39	£302.64	£238.89	£155.71	91%

Source: Calvert and Morris (1974)

Table II.22 : Crop and livestock responses required to break even in relation to the cost of drainage.

Net capital cost of scheme £/ha	200	300	400	500	600	700
Capital cost amortised over 10 yrs @ 15% (£/ha)	40	60	80	100	120	140
Increase in yields required:						
Cereal @ £110/tonne (Kg/ha)	377	502	753	879	1130	1255
Potatoes @ £45/tonne (Kg/ha)	879	1381	1757	2259	2635	3138
Sugar Beet @ £25/tonne (Kg/ha)	1632	2385	3263	4016	4769	5647
Milk production @ 13p/litre (litres/cow)						
Stock rate 0.4 ha/cow	123	184	246	308	369	430
0.5 ha/cow	147	221	295	369	443	517
0.6 ha/cow	185	276	369	462	554	645

Source: Molyneux (1981)

His results, shown in Table II.22, are based on an interest rate of 15% with capital repaid over 10 years. Taxation and periodic expenditure were excluded.

Calvert and Morris (1974) reviewed the 5 techniques of investment appraisal used by them. They concluded that Discounted Cash Flow methods represent the best method of financial appraisal, taking into account the timing of cash flows. The percentage return can be compared with that of alternative investments and the technique can be used to show the effect of ancillary investments. Helme (1973) also preferred the use of D.C.F. techniques, critisising the breakeven approach for using average yields when generally the land will be farmed in rotation.

The Payback method has the advantage of being easily calculated and understood by the farmer. It emphasises the attractiveness of a low risk venture with a quick return. Calvert and Morris (op cit) recommended the payback period for general use.

II.6 PRE-INVESTMENT EVALUATION OF LAND DRAINAGE SCHEMES

II.6.1 Techniques Employed

Over the years, a number of techniques have been employed to evaluate land drainage schemes in economic or financial terms in order to justify the expenditure upon time. For many agricultural schemes in the 1950's and 1960's the benefits appeared so obvious that a simple statement of the area of benefit, or cost per acre of benefit, sufficed to vindicate the scheme. However, in the last decade evaluation has become increasingly rigorous and cost-benefit analysis has become the basis of decision-making. Costs are more easily estimated, being comprised of measurable quantities of materials and labour. However, the main problematic and controversial area involves the assessment of the benefits to agriculture (Parker and Penning-Rowsell, 1980). Several techniques have been applied to the problem, some of which are summarized below.

Changes in the value of agricultural land following land drainage improvements have been used as indicators of net agricultural benefit. Struyk (1971) investigated the usefulness of land values as a measure of flood damage on agricultural land and observed a significant difference in values between flood prone and flood free areas which was attributable to flood risk. The evaluation of an improvement scheme on the River Soar in Leicestershire (John German and Son, 1963) was based upon the increase in the vacant possession value of the land. The present and likely future conditions of the land were evaluated. The combined costs of river improvement and ancillary drainage works were then subtracted from the capital improvement value to derive a net capital improvement.

Menz (1964) working in the U.S.A. presented a methodology for the economic evaluation of a drainage project based upon cost-benefit analysis. The technique was intended for use in irrigated areas suffering from inadequate drainage (with no problem of surface flooding) but elements of the approach could be adapted to the U.K. situation. The area under consideration was divided into selected depth-to-water table categories and land use types and the percentage of the total area in each land use/water table class was assessed. A function was derived for each land use type to relate yield to depth of water table and financial budgets were drawn up for each crop type. Yield estimates for each land use/water table class were budgeted to provide an estimate of existing net income per acre. Alternative water table levels were considered on an incremental basis according to alternative engineering options. The new yield data were then evaluated and compared with the cost of works. Cost-benefit ratios were calculated, with the difference between with- and without-project net incomes representing the 'enhancement' value.

The technique assumes constant, controlled water table levels and that benefits are entirely attributable to increased yield from existing land uses. These benefits are realized immediately on completion of the scheme therefore no phasing of benefits is necessary. No allowance is made for changing land use in response to lower water tables.

Morris and Spoor (1976) in a pre-investment appraisal of an arterial drainage improvement scheme in Yorkshire, considered that the major benefit would arise from changes in cropping and livestock patterns rather than from increased yields from existing production systems. Existing land uses were identified and winter/spring steady state water tables were defined for the 2 potential improved land uses, namely, good quality grassland and cereal production. Local (parish) data were used to provide yield estimates gross margins, and fixed costs for existing cereal and livestock activities in the area. The area of potentially improveable land was defined and likely changes in production estimated for 2 alternative water table levels. The average expected increases in net returns (gross margins minus fixed costs) were estimated and compared with drainage costs using discounted cash flow techniques to evaluate the worthwhileness of the improvement scheme. Local enquiry suggested that the expected installation of field drains by farmers following the scheme would account for no more than 25% of the potential benefit area, and for those who intended to drain there was likely to be an average delay of 5 years. The net return increases were moderated accordingly.

Similar techniques have been applied to land drainage schemes where the major predicted benefits relate to flood alleviation. Laurence Gould Consultants Ltd. (1980) based their financial appraisal of works on the River Severn upon a comparison of projected patterns of agricultural production for the future with and without the river improvement works. Forecasts were based upon trends revealed in parish statistics, a farmer interview survey, personal knowledge of the area and consultations with MAFF. Gross margin data were accumulated from information derived from the survey and local experience for low, medium and moderately high levels of performance.

No allowance was made in the 'future-with' project case for increased yields (arising from the river improvement works) as it was considered that flood alleviation would result in improved rotations and farm systems. It was assumed that all land that was currently under crops or grass, that was not already drained or unploughable, would be underdrained following improvement works. An 'S'-curve was assumed for the rate of uptake of field drainage and improved farming practices commencing in the year following completion of engineering works, reaching 85% in year 10 and 100% by year 19.

Improvements in the future-without project situation were expected to occur in a linear fashion in line with earlier trends in the area.

The project was appraised using discounted cash flow techniques for 'future with-' and 'future without-' project conditions. The area of benefit was assumed to be coincident with, and confined to the Medway Line. Additional capital investment and maintenance costs were taken into account, including the cost of underdrainage. Grants were excluded and no allowance was made for incremental taxation.

A similar approach was used in the River Soar study (Laurence Gould Consultants Ltd., 1981). However, separate uptake curves for the adoption of improved agricultural practices were used for each reach, based upon the results of the farmer survey.

An approach to scheme evaluation, where the benefits are likely to be in the form of increased productivity of grassland, has been developed in Ireland, (Walsh and Lee, 1983), and was used on the River Maigue scheme (Ireland Office of Public Works, 1976). A farm survey was carried out to assess pre-scheme stocking rates for each soil type within the benefit area and post-scheme potential stocking rates were calculated from experimental site data. The aggregate increase in stocking rate therefore represented the maximum benefit. The existing regional stocking rate was expressed as a percentage of potential to provide a measure of efficiency which was used to moderate the post-scheme potential stocking rate, and provide an estimate of likely uptake. The benefits of the scheme were therefore expressed as the difference between the pre- and post-scheme stocking rates.

II.6.2 The Middlesex Polytechnic Method

The Middlesex Polytechnic Flood Hazard Research Project team have produced a manual for the assessment of benefits arising from flood protection works (Penning-Rowsell and Chatterton, 1977). Their approach to the evaluation of agricultural benefits is based upon the 'enhancement' of land receiving flood alleviation. Enhancement can result from an increase in returns from an existing land use or a change to a more profitable use. The benefits from reduced crop damage are not considered to be substantial, but can be incorporated in the assessment technique if necessary.

The Middlesex Polytechnic method is based upon a farm questionnaire survey to identify present land use of each field on the farm and expected future use for each alternative level of flood protection. This forms part of the input to a computer model. The second major input consists of details of gross margin data for each land use. This is generally obtained from uptodate published sources. However, as published data refer to 'upland' (ie. non-flood plain) siutations, the 'standardised' figures are moderated upon the basis of local knowledge and experience to reflect the appropriate conditions. It is suggested that an average 'reduction factor' of the order of 10% could be applied where necessary. Future (ie. post-scheme) gross margin levels are assumed to be equivalent to 'upland' figures.

As an alternative to the questionnaire, likely future land uses can be estimated by local agricultural experts and ADAS officers, to provide a maximum theoretical enhancement. The combination of land use and gross margins data allows an enhancement value to be calculated as the difference between present and future gross margins.

As potential benefits will not be immediately realized, some estimate needs to be made of the likely uptake rate. It is suggested that information on likely rates of change can be obtained from local sources but if only the total number of years before full benefits are achieved can be estimated the application of observed 'S'-curves from schemes elsewhere may be feasible. Allowance can be made for the reduction in damage to buildings and equipment by applying standardized depth/damage curves to the frequency of flood events of various magnitudes. The phased benefits are then discounted to arrive at a present value of the benefits which can be compared with the present value of costs to derive a net present value.

A short critique of the Middlesex Polytechnic method has been compiled by the Local Government Operational Research Unit (L.G.O.R.U., 1978). The technique relies very heavily on the assumption that farmers can accurately predict their responses to hypothetical situations, such as alternative flood return periods, and that the responses are unbiased. It should be remembered that the flood protection works will cost the farmer nothing and, if he is in favour of the scheme, his replies may be exaggerated to ensure the works are carried out. His response may also be biased by recent severe flooding events, (or lack of them!).

Inevitably, some assumptions have to be made and the choice of 'reduction-factor' and particularly phasing-in period, will have an important influence on net present benefits when discounting techniques are used. The method has the advantage, however, of allowing local experience to be incorporated into the schedule.

The Local Government Operational Research Unit (L.G.O.R.U., 1978) suggest an adaption of the Middlesex Polytechnic method for situations where drainage improvements, without flood alleviation, are expected to lead to changes in land use. In place of flood return period, alternative standards of drainage are defined in terms of anticipated durations and frequencies of waterlogging each with their own respective benefit assessment. However, LGORU maintain that in a drainage improvement situation increased returns from existing land uses are likely to be more important than in flood alleviation schemes. A modified approach is therefore proposed (LGORU op cit) in which the benefits of improved drainage are the removal of the yield constraints, imposed by waterlogging. A relationship is derived between rainfall and the severity of waterlogging in 'existing' and 'improved' situations. When this is combined with a model relating waterlogging to crop damage, it is possible to estimate the expected frequency of individual yield. Expected benefits can then be phased and discounted over the life of the project and compared with costs to derive a net present value.

II.6.3 <u>Section 24(5) Surveys</u>

Average annual benefits for agricultural areas for the Section 24(5) surveys (STWA, 1980) have been assessed by the Ministry of Agriculture Fisheries and Food (MAFF). Assessment has been based upon the land potential and changes in gross margins that would result from improved drainage. The cost of field drainage was included where appropriate, but no attempt was made to account for the phasing of benefits at this stage.

The test discount rate of 5% was used for the assessment of the net present value of costs and benefits over a life of 50 years. Schemes were then ranked upon the basis of their cost/benefit ratio. No account was taken of intangible costs and benefits.

II.6.4 A Critique of Pre-Investment Evaluation of Land Drainage Schemes

The majority of pre-investment appraisals of land drainage schemes in the U.K. have been conducted as a joint exercise between Water Authorities and MAFF for the purpose of obtaining MAFF grant aid. In the main, MAFF have provided the assessment of agricultural benefits which the Water Authority has then incorporated within a cost/benefit analysis at the Government's designated 5%[1] discount rate for public works. The estimate of benefits has been arrived at by predicting the increases in net farm income per hectare for specified enterprise improvements facilitated by the scheme, and grossing these up according to the area of benefit. In some cases, assumptions have been made about the time it takes to achieve full benefit. In the past, this approach has proved acceptable to most parties. More recently, however, it has come under close scrutiny by those with non-agricultural, mainly conservationist interest, who argue that present evaluation methods do not give a reliable estimate of the real value of land drainage improvement schemes. In December 1981 MAFF reduced their involvement in benefit assessment studies to that of providing a data base for use by Water Authorities and their representatives. Today STWA receive no assistance from MAFF.

The main criticisms that can be aimed at the bulk of pre-investment drainage evaluation studies relates to the bases for identifying potential benefits (and costs), estimating the rate of uptake of these benefits, and valuing net agricultural benefits. In addition there are criticisms of the discounted cost-benefit technique itself.

II.6.4.1 The Nature and Rate of Uptake:

A major criticism of many pre-investment drainage evaluations is the method used to identify the nature and rate of uptake of agricultural benefits attributable to a given scheme. Whilst the process of defining net agricultural benefits in general terms (increased gross margins less extra fixed costs and field drainage costs) is satisfactory, the prediction of the type and extent of net benefits that can reasonably be expected to follow

1. Since October 1978.

drainage improvement is sometimes open to criticism. For instance, there has been a tendency to generalise (usually optimistically) potential benefits when sub-areas within a given scheme exhibit very different potential benefit characteristics. More seriously, estimates of potential benefit have often been made on purely technical grounds without due attention to farm/farmer characteristics. For example, benefit assessments have on occasion assumed a move from grass to cereals, and the necessary installation of field drains, when local farmers are clearly committed to livestock production. Where pre-scheme benefit assessments have been based on farmer interview or local advisory views, these sources, as potential direct or indirect beneficiaries of the scheme, may understandably be subject to optimistic bias; for instance yield estimates are often high, and rotational requirements (required to protect soil structure on soils unsuited to cereal monocropping) are sometimes overlooked.

The predicted rate of uptake of benefits, defined in terms of the area of particular benefit types coming on stream each year, is critical to the evaluation of the improvement scheme, particularly where discounting criteria are used. It is often assumed that land drainage is the main constraint and that once this is overcome, benefits flow automatically. As reported earlier, assumptions regarding uptake rate have varied, but are characterised by their general arbitrariness and/or optimism. The evidence suggests that there are great variations in actual farmer response to opportunities provided by improved drainage within and between schemes, but as yet no attempt has been made to identify factors which determine uptake rate. Where actual uptake has been monitored, it has usually been insufficiently defined in terms of field drainage installation; benefits are much more diverse than this.

II.6.4.2 Financial versus Economic Prices:

With a few notable exceptions, the majority of pre-investment drainage evaluation studies have used prevailing 'financial', market prices to value agricultural benefits. Whilst this is acceptable for assessing the profitability of a scheme to the individual farmer beneficiary, MAFF and the Water Authorities are charged with considering the worthwhileness of resources committed to drainage improvements in terms of their contribution to the national economy, and for this purpose 'economic' prices (which reflect the real, opportunity cost value of extra goods and services to the community) should be used. Where financial and economic prices are significantly different, basing cost-benefit analysis on the former, may not lead to the efficient selection or ranking of drainage improvement schemes.

For the purpose of economic analysis, financial farm gate prices of inputs and outputs associated with the land drainage scheme need to be adjusted to their economic values by removing the effect of grants, subsidies and taxation (which are merely transfers between Government and producers, consumers and taxpayers, and do not represent any real change in the value of inputs or outputs) and adjusting for the effects of import tariffs, levies and intervention buying practices which maintain commodity prices at artificially high levels. It has been suggested that the overall effect of using financial prices for farm inputs and output is to overstate the real net value of extra production by between 2 and 4 times (Black and Bowers, 1981); in some cases, particularly for produce in surplus such as dairy, the net benefit of expanded output can be negative; the extra costs being greater than the extra benefits.

The justification for using financial prices has been that economic pricing is complicated and requires many assumptions, that financial prices reflect the import saving role of agriculture, and that the majority of subsidies are paid by our EEC colleagues. However, the net effect of economic pricing, it is agreed, would be to reduce the attractiveness of capital projects which improve farming productivity at the margin of cultivation. Most agricultural land drainage schemes fall into this category, and their economic feasibility could be prejudiced accordingly.

II.6.4.3 Unquantifiable Environmental Impact:

Other criticisms relating to the use of financial cost benefit for drainage evaluation analysis have concerned the failure to identify indirect, largely unquantifiable, non-priced factors, particularly concerning environmental impact. This has been linked to a fundamental criticism of the use of cost-benefit analysis in situations where natural (wetland) resources are either protected and preserved, or exploited and irreversibly lost. The LGORU Report (1978) discusses these issues in some detail, and the ways of recognising environmental benefits and costs without measuring them, although does not prescribe how these methods would apply in practice.

II.6.4.4 Features of the Discounting Technique:

A continuing issue of debate is the appropriateness of the discounting method for land drainage projects. Apart from the identification and measurement of costs and benefits themselves, assumptions relating to the timing of cost/benefit streams, inflation, project life, residual value, and the choice of discount rate have an important bearing on the outcome of the analysis. The often arbitary assumptions about the rate of benefit uptake are critical to the timing of benefit streams. The use of constant prices assumes that inputs and outputs will inflat equally, when much of the evidence suggests that rising costs and reduced farm margins is likely to remain a permanent feature. Definitions of project life and residual value (more critical at lower discount rates) often appear arbitary and variable, usually in favour of the scheme. Land drainage projects profitable at the 5% Government discount rate for public works are deemed appropriate for grant aid. Proponents of land drainage argue that it is fitting that long term infrastructural investments of this kind should be treated favourably. Antagonists, suggest that the effect of optimistic benefit assessment is further magnified by the low discount rate, such that resources are directed to land drainage which could have been better used elsewhere, either within or without, the farming sector. Those arguing in favour of environmental conservation and against land drainage schemes point out that lower discount rates give weight to long term environmental costs, but simultaneously encourage a higher level of investment and a more rapid depletion of natural resources. One way round this dilemma may be to discount preservation and development components at different rates (LGORU, 1978).

An important feature of any feasibility study is the sensitivity of the recommendations to likely changes in critical parameters and assumptions. In the majority of cases this does not appear to have been done. The more detailed comprehensive and economically rational pre-investment studies have usually been undertaken where serious conservation issues are raised by the proposed development (eg. Somerset Levels, Middle Arun, Gedney Drove).

II.7 NON-AGRICULTURAL IMPACTS OF LAND DRAINAGE

Figure II.28 shows in diagramatic form the various impacts of land drainage works. The agricultural impacts have been considered in some detail elsewhere in this report and a cursory investigation into the non-agricultural impacts can be made here.

II.7.1 Environmental Impacts

(i) Natural Vegetation:

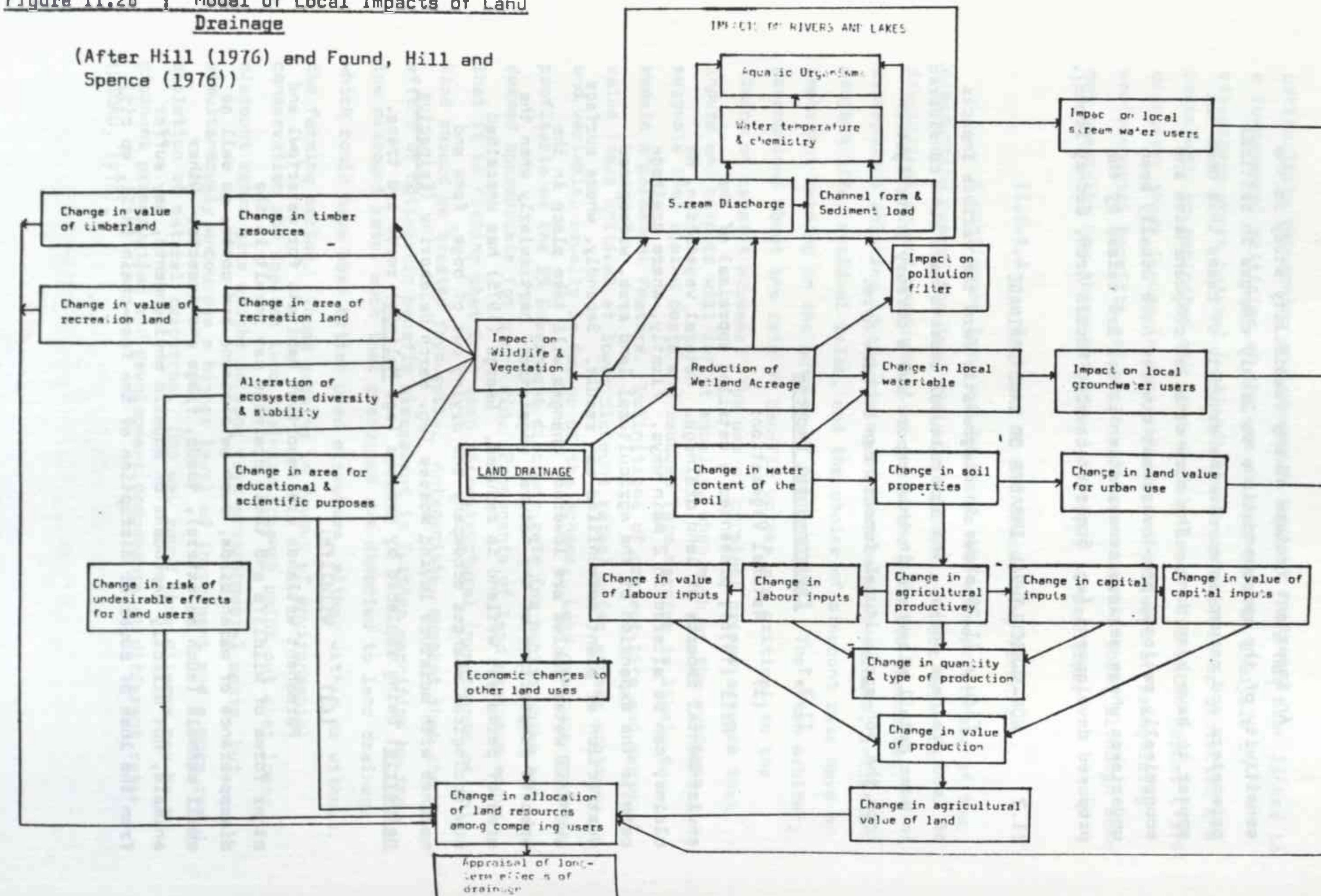
Hill (1976), presented a detailed appraisal of the environmental impacts of land drainage. Natural vegetation, he claims, can be altered in 2 main ways. Firstly, where drainage permits the expansion of the agricultural land area, widespread destruction of plant communities can result. Secondly, where surface and soil water tables are lowered, changes will take place in the species composition of the natural vegetation, particularly when the area of permanent wetland is reduced. George (1975) has described how ecological changes accompany the drying out of bogs, fens and marshes with moisture loving mosses (eg. March Heleborine (Epipactus palustris) being replaced by grasses (eg. Molinia) reeds and trees.

(ii) Wildlife:

Permanent wetlands are important habitats for waterfowl and other forms of wildlife and their drainage can result in the disappearance of marsh birds, such as bitterns and coots, as well as small mammals (such as otters), toads, frogs and insects. Other animals, not directly dependant on aquatic environments, may suffer from the loss of cover or disruption of the food-chain (Hill, op cit).

Figure II.28 : Model of Local Impacts of Land Drainage

(After Hill (1976) and Found, Hill and Spence (1976))



(iii) Water Table:

Under certain edaphic and geological conditions, land drainage may, by diverting excess water into rivers, lead to a lowering of ground water levels, particularly where for example, flood plain inundation is important for the recharge of aquifers. The effect will depend largely upon local topographic and hydrogeologic conditions. The lowering of water tables may have a variety of consequences, including the drying up of shallow wells and farm ponds and reductions in summer stream flows (Hill, op cit). Thomasson (1975) however believes that in the U.K. situation lowering of ground water tables is unlikely to be a problem. The lowering of water tables on peat land however, is likely to have severe effects. The oxidization of the peat causes a rapid lowering of the soil surface that can only be abated by the maintenance of high water tables.

(iv) Hydrology:

Any change in the soil-water regime of an area is likely to lead to some change in river flow and hydrology. As Thomasson (1975) pointed out, such a change may result from an alteration of the vegetal cover of a catchment due to land use change, and this can have a significant effect on rates of interception, evapotranspiration, infiltration, and, because of the effects on soil structure, through-flow. However, the most significant modification of the hydrological cycle results from field and arterial drainage.

By lowering the water table, field drainage systems tend to increase the storage capacity of the upper soil layers and therefore reduce runoff after heavy storms. The rapid evacuation of water after the storm renews the storage capacity and reduces the probability of rain falling on saturated soils. There is field experimental evidence to show that underdrainage does not lead to increased river flood flows (eg. Bailey and Bree, 1981; Rycroft and Massey, 1975) and that flood frequency can be reduced (Green, 1979). For example, in a study of 2 small catchments in the Upper Severn, Newson and Robinson (1983) found that peak discharges fell after field drainage had been installed and there was no apparent increase in flood risk.

Arterial drainage improvements, however, have the effect of reducing the time it takes for soil water to reach the main channel resulting in earlier flood peaks. Bailey and Bree (op cit) found that arterial channel improvements could increase the value of the 3 year flood by up to 60% whilst reducing the time it takes to reach the flood peak. The drainage of peat soils by open ditches was shown to have a similar effect (Newson and Robinson, 1983).

River improvements and channelization may seriously disrupt the hydrological and biological balance of the river. Toms (1975) has described the effects upon fish populations and other aquatic life. Land drainage works, and regular maintenance can lead to alterations in the sediment load, water temperature and nutrient status of a watercourse (Hill, op cit).

II.7.2 Impacts on Other Land Uses

The alteration of the landscape and ecology of an area can have a profound impact upon its use particularly for recreation and amenity purposes. Angling can be disrupted by the alteration of the river flow characteristics, causing a change in the aquatic species, and the drainage of permanent wetlands can drive away the waterfowl species sought after by bird watchers. The destruction of cover can also have important effects upon the value of an area for hunting and shooting, not only of waterfowl, such as ducks, but also of mammals.

Any change in the flow of a river or its water chemistry can have severe effects upon riparian land uses downstream. The drying up of small streams in summer, for example, or an increase in levels of toxic elements in the water, would severely restrict the possibilities of river abstraction for irrigation.

II.7.3 Land Drainage and Environmental Conflict

In recent years the environmental impacts of land drainage have come under close scrutiny from those with conservation interests, and in particular cases, these conflicts have bcome issues of national public interest. The controversy over the proposals for the Yare Barrier, for example, has been well documented (O'Riordan, 1980;

Caufield, 1981) and has featured in the national press and on national television.

Concern for the impacts of land drainage on the environment in U.K. focuses on 2 levels; firstly, for the permanent loss of wetland habitats and secondly for the subsiduary effects of agricultural change. Newbold (1977) had commented upon the value of wetlands and shown how the effects of land drainage can lead to permanent losses of plant and animal species. The effects of agricultural change are more complex; lowland grassland supports a unique ecosystem that is dependant upon a continual balanced management by the farmer (Brotherton, 1977). Changes from indiginous permanent pasture to a sown sward or to arable use upset this balance producing far ranging effects upon the local flora and fauna as well as to the landscape value (Shoard, 1980).

In response to public demand, those with responsibilities for land drainage have concerned themselves with ways and means of reconciling the conflict between demand for improved drainage and flood protection and the need to preserve the wildlife and landscape value of the countryside.

Miers (1975) presented a guide for land drainage engineers for the incorporation of conservation, amenity and recreation interests in the design of land drainage works. He argues that the effects of land drainage have frequently been to enhance amenity, recreation and conservation values. He suggests that compensatory works should be carried out where land drainage work causes unavoidable damage.

In 1976, the Water Space Amenity Commission (WSAC) set up a working party to devise a set of guidelines to (a) reconcile where possible the execution of land drainage works with the interests of conservation, amenity, landscape, fisheries and recreation, and (b) to indicate where these interests could be furthered in connection with land drainage works (Drummond, 1977). These guidelines were published in 1980 (WSAC, 1980).

II.7.4 The Wildlife and Countryside Act (1981)

Under the Countryside Act 1968 (Section 11) and the Water Act 1973 (Section 22) the Water Authorities are required to take account of the effects of land drainage works on wildlife and amenity. This responsibility has been furthered by the Wildlife and Countryside Act 1981 (Section 18) that requires Authorities to exercise their functions so as to conserve or enhance the natural beauty, flora, fauna, geological or physiographical features of special interest. Where proposals for works relate to notified sites of Special Scientific Interest prior consultation with the Nature Conservancy Council is required, except in cases of emergency.

II.8 FARMER UPTAKE OF DRAINAGE BENEFITS

The agricultural benefits of land drainage can be divided into 2 classes; those that are realized automatically upon completion of an improvement scheme, such as the reduction of flood damage, and those that require a subsequent investment or change of practice on behalf of the farmer. The opportunity to increase livestock stocking density or change from spring to winter cereal production as a result of an improvement scheme, must be viewed as 'potential' benefits that may or may not be realized over a number of years.

It is apparent from the above discussion of evaluation techniques that no satisfactory method of predicting the uptake of potential benefits has, as yet, been found. In some instances estimates of the nature and rate of uptake have been based on local knowledge (eg. Morris and Spoor, 1976), in others farmer questionnaire surveys have been used (eg. Laurence Gould Consultants Ltd., 1981). The LGDRU (1978) suggest using observed information on uptake from similar schemes already in operation and this approach has been used by Penning-Rowsell and Chatterton (1977, p. 130) in their case study from Sussex. All of these approaches have their shortcomings; local knowledge is often vague and subjective, and questionnaire interpretation is based on the assumptions that farmers will act as indicated on the day of the interview and that responses are unbiased. The application of results from other areas appears to offer the most useful solution, but extreme caution is required in allowing for differing socio-economic or environmental conditions, and until now, adequate information has been lacking.

II.B.1 Earlier Studies of Uptake

(i) The United States Department of Agriculture (USDA) carried out a series of field investigations over the period 1959-72 to identify whether or not land use change resulted from flood protection in rural areas (discussed in full by McDonald, 1974). The findings were inconclusive, but McDonald (op cit) has suggested a number of shortcomings in their approach, that invalidate the results, particularly that too short a period of investigation was taken.

(ii) McDonald (1974, 1975) compared land use changes in a flood protected and an unprotected area in S.W. Scotland. Pre-scheme land uses were derived from 1935 land use inventories for an unprotected control and a protected area that were considered to be environmentally similar. These were each compared with the results of a post-scheme field survey. Land uses were divided into 4 categories, (namely: permanent pasture, temporary pasture, roots and cereals) that formed a progression in flood susceptibility from low to high. The change in land use was calculated as a shift in 'flood susceptibility' towards more tolerant or more prone production systems, and analysed using 'chi-squared' methods. The results showed that a significant difference in land use was associated with flood alleviation and indicated the total level of uptake of improved practices on the flood protected land. The approach made no attempt to quantify the benefits or to assess the rate of uptake over time.

(iii) Recently ADAS have been attempting to collate data on field drainage installation following land drainage improvement works (J. Kemp - personal communication). Records of the timing and areas of drainage have been analysed to produce a series of uptake curves for individual schemes, eg. a curve was produced for the Bushley scheme on the River Severn in Worcestershire, by ADAS - Wolverhampton A. McAuliffe - personal communication). These curves, although providing useful information upon the rate of adoption of improved practices make no attempt to explain or quantify the nature of land use following draining, nor do they consider improvements that have not involved the installation of field drainage.

II.8.2 Theoretical Aspects of the Uptake of Potential Benefits

The uptake of potential benefits has generally been viewed as a single function and has been expressed as a unique curve showing percentage of total uptake against time. Thus the assumption is made that at any given time, for a given plot of land, the farmer either has, or has not, responded to the benefit potential. Clearly this binomial approach is unsatisfactory as there are often alternative responses to the opportunities presented by a land drainage scheme. A number of potential benefits may be available, some of which may be mutually exclusive (eg. improved grazing and arable production) others complementary (eg. increased grazing and increased silage production). In order to evaluate the uptake of benefits for a given improvement scheme, it is necessary to identify both the likely <u>nature</u> and <u>rate</u> of uptake

II.8.2.1 The Nature of Uptake:

For each potential benefit, a portion of the benefit area, designated by the Medway Line, can be excluded from the total uptake area if it is unsuitable for improvement. This must include sites preserved for their conservation or amenity value, areas that are physically unsuitable, and areas, such as common land, that are unlikely to be improved due to land tenure characteristics. Of the remaining area it must be assumed that the choice of whether or not to take advantage of the potential benefits lies primarily with the farmer concerned.

The way in which the farmer responds to the new opportunity offered by a land drainage scheme may be studied from a behavioural point of view. It must be assumed that each action performed by the farmer is carried out in order to contribute towards the achievement of some goal (Petit, 1976). The classical economic motive of profit maximization rarely prevails and the goals and aspirations of farmers are generally complex. Farmers, for example, have been shown to place great value upon 'the way of life', independance and the successful performance of tasks (Gasson, 1973). Attitude to risk has an important influence on farmer investment behaviour. Farmers are not only interested in the expected average return from an investment but also the likely variation in return (riskiness) year to year. Utility analysis argues that, rather than trying to maximise profits, individuals will strive to maximise utilisty, which is a function of both expected profits and anticipated risks.

The nature of the farmer's response to the improvement opportunity will be influenced by an interaction of: farm and farmer characteristics, the physical capability of the land, and exogenous influences, such as the general economic climate and the availability of information. The relationship between these factors is shown in Figure II.29.

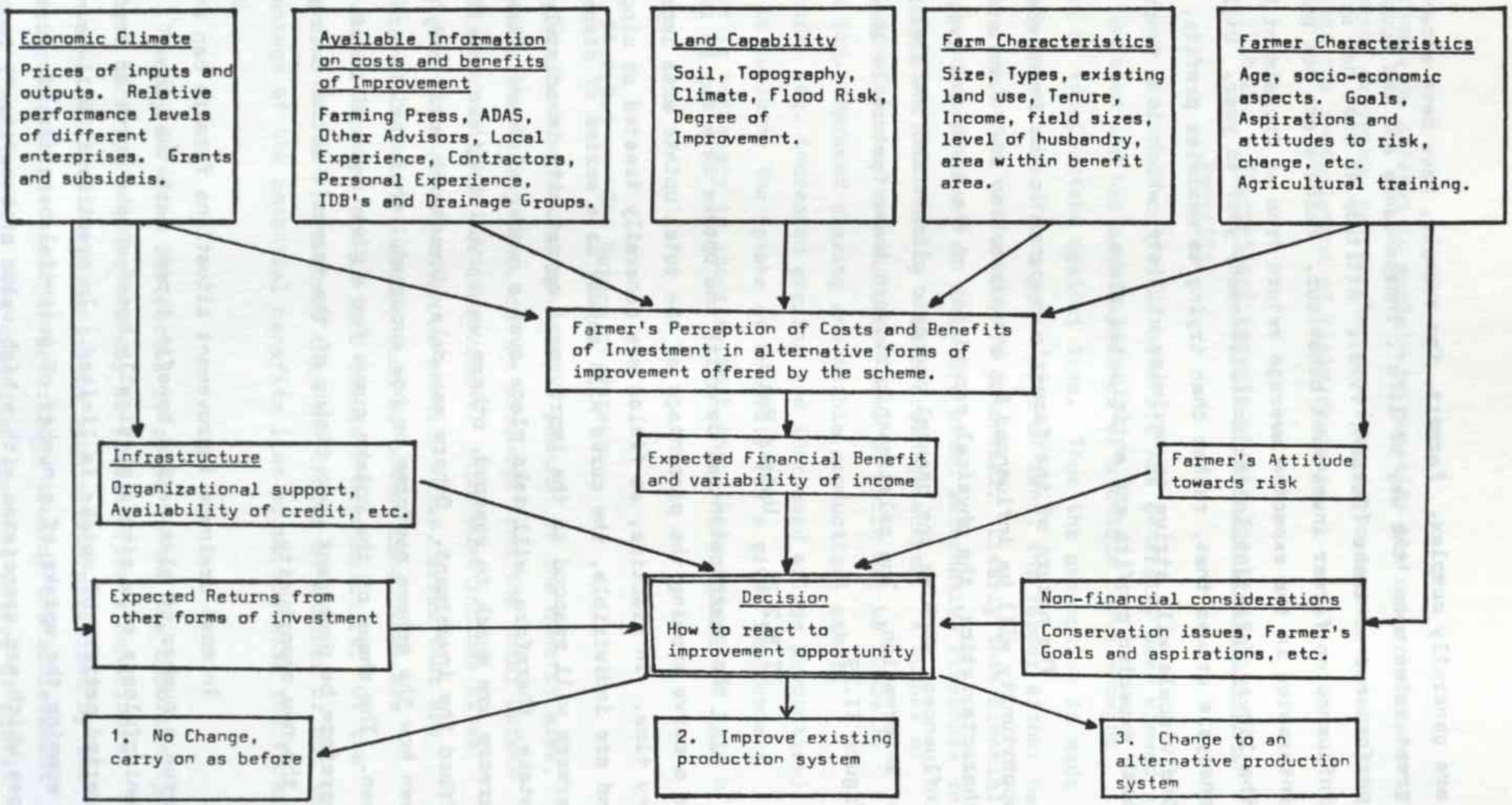
II.8.2.2 Uptake Rate:

For each potential benefit, the uptake rate may be expressed as a curve showing the percentage of the total uptake area improved at any time. In practice, as fields are generally treated as single units and are indivisible, the curve will appear as a series of steps. Few farmers will respond to the improvement opportunity immediately and uptake, therefore, will take place over a number of years. Some farmers are quick to respond, others wait until they are able to afford the investment. Others may delay investment until they have seen how the scheme performs or how successful their neighbours have been. The shape of the uptake curve for a given type of benefit will therefore be dependant upon timing of the farmer's action in response to the new opportunity.

In most drainage improvement situations farmers can and do pursue a number of alternative benefit types, such that the meaningfulness of a single physically based uptake curve to describe a varied pattern of uptake is limited. In practice it will be necessary to examine the uptake of a number of potential benefits, in particular those which are associated with a high value of benefit.

FIGURE II.29

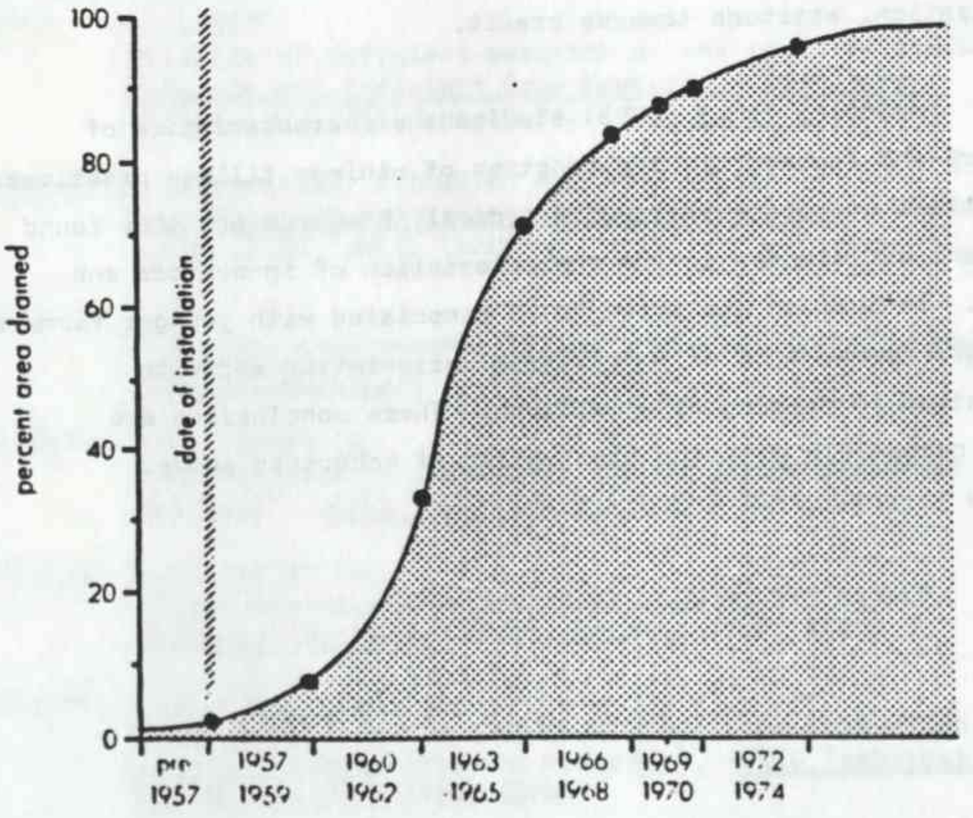
Factors Likely to Affect the Nature of Uptake of Potential Benefits Following River Improvement Works



Diffusion theory has often been used by rural sociologists to account for the rate of adoption of improved practices (eg. Ryan, 1948). The theory predicts that the rate of adoption (or uptake rate) follows the pattern of a normal distribution. When expressed in a cumulative form, it describes the classic 'S'-curve. The limited studies of the rate of uptake of land drainage benefits, particularly the installation of field drainage systems, have suggested 'S'-curves to be typical (Figure II.30). For example, MAFF figures for the rate of installation of field drains following the improvement of flood protection on the River Stour in Kent, showed a typical 'S'-curve over a 20 year period (see Penning-Rowsell and Chatterton, 1977, p. 130).

FIGURE II.30

'S'-Curve of Uptake of Field Drainage Installation



Attempts have been made to divide the 'S'-curve into 'adopter categories' ranging from innovators (first to adopt) to laggards (last to adopt) and to investigate the characteristics of the members of these classes. Several factors have been correlated with 'innovativeness' in farming, and these have been summarized by Robertson (1971) as follows:

(a) Demographic factors: eg. education, social status.

(b) Communication behaviour: eg. exposure to sources of information, extension services and mass media.

(c) Social interaction factors: eg. social participation, opinion leadership, cosmopolitanism.

(d) Attitudinal and personality factors; eg. 'venturesomeness'.

(e) Value factors: (little conclusive evidence).

(f) Farm management factors: eg. size of farm operation, specialization, attitude towards credit.

Korsching <u>et al</u> (1983) studied the characteristics of innovators and laggards in the adoption of minimum tillage practices. Their pattern of uptake followed a typical 'S'-curve and they found significant differences in the characteristics of innovators and laggards. Innovation was shown to be associated with younger farmers with larger farms, more of a 'business' orientation and with participation in farming organizations. These conclusions are entirely compatible with the observation of Robertson above.

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ANNEXE III

METHODS AND SOURCES

ANNEXE III

METHODS AND SOURCES

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List of Abbreviations

ADAS	Agricultural Development and Advisory Service
CLA	Country Landowners Association
FDEU	Field Drainage Experimental Unit
IDB	Internal Drainage Board
MAFF	Ministry of Agriculture, Fisheries and Food
NFU	National Farmers Union
SMD	Standard Man Day
SPSS	Statistical Package for the Social Sciences
SSSI	Site of Special Scientific Interest
STWA	Severn-Trent Water Authority
TFA	Tenant Farmer's Association

ANNEXE III

METHODS AND SOURCES

Stage II of the study comprised the main field study during which a detailed evaluation of selected STWA drainage improvement projects was made. Stage II involved data collection from a variety of sources, including a survey of farmers, followed by detailed analysis with a view to meeting the objectives specified in Annexe I.

III.1 SELECTION OF SCHEMES FOR EVALUATION

In consultation with STWA, a set of criteria were defined for the selection of land drainage improvement schemes for detailed evaluation. These were that:

(i) The areas benefiting from the schemes should be primarily agricultural.

(ii) The schemes should have been completed long enough ago for a substantial and realistic uptake of benefits to have occurred, but not so long to have faded from memory. The period 1965-75 satisfies this requirement. However, some schemes completed outside of this bracket will be included.

(iii) The total of schemes selected should represent an even spatial distribution throughout the STWA catchments.

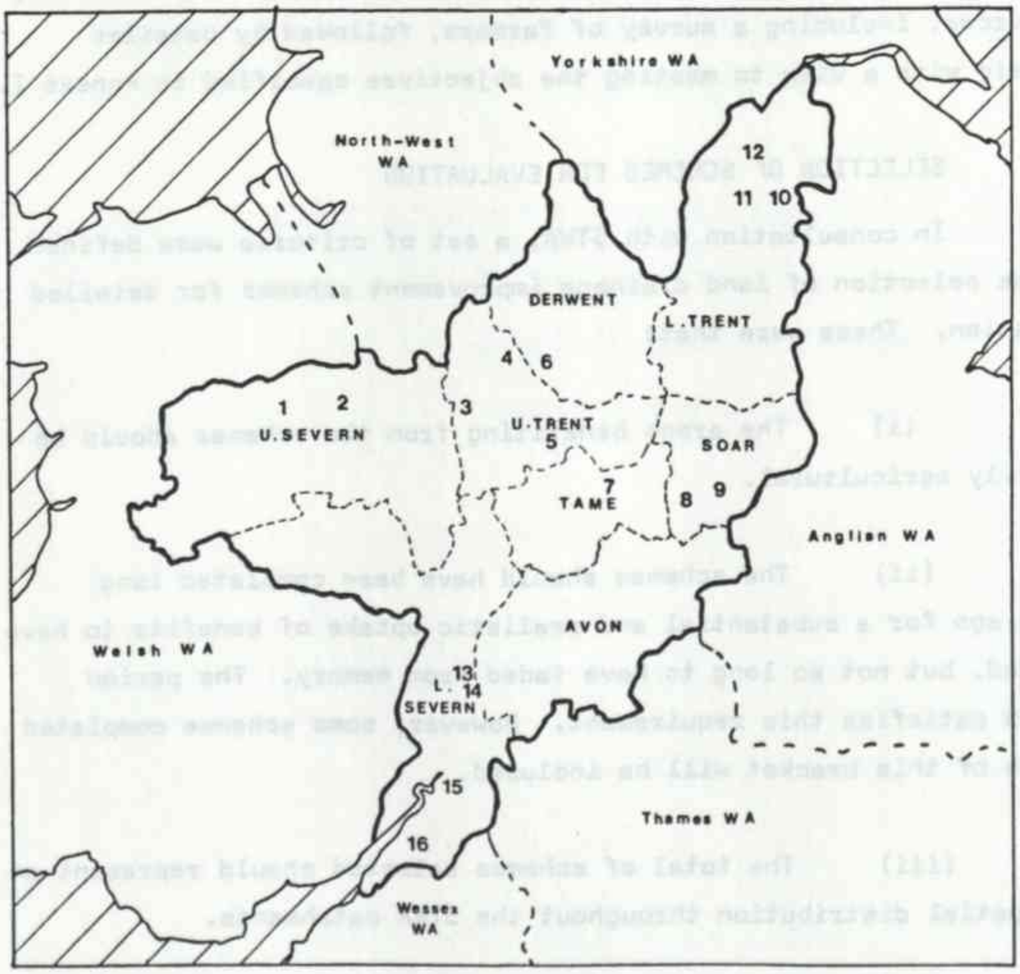
(iv) The schemes should cover a variety of topographical and agricultural situations.

(v) There should be no bias towards 'successful' or 'unsuccessful' schemes.

(vi) Each scheme should have presented a definable 'improvement opportunity' for which an 'uptake' (which may be zero) can be observed. Schemes carried out to prevent future deterioration of the land drainage system, but presenting no improvement

FIGURE III.1

SEVERN-TRENT WATER AUTHORITY:
Land Drainage Divisions & Selected Schemes



U. SEVERN DIVISION

1. R. Morda
2. Sleap Brook

U. TRENT DIVISION

3. Doley Brook
4. R. Blithe
5. R. Trent (Alrewas)

DERWENT DIVISION

6. R. Tean

TAME DIVISION

7. R. Sence (Temple Mill)

SOAR DIVISION

8. R. Soar (Sharnford)
9. R. Sence (Kilby Bridge)

L. TRENT DIVISION

10. R. Trent (Beckingham Marsh)
11. R. Idle (Mattersey)
12. R. Idle (Misson)

L. SEVERN DIVISION

13. R. Severn (Ripple)
14. R. Severn (Bushley)
15. Epney Rhine
16. Oldbury

opportunity, (eg. schemes that have been carried out to prevent an increase in flood frequency following anticipated urban development upstream), cannot be evaluated in terms of uptake.

Sixteen schemes were selected (see Figure III.1), viz. (by Division):

Lower Severn Division:	River Severn - Saxon's Lode to Mythe Hook (Ripple)
	River Severn - Bushley to Upper Lode
	South Gloucs. IDB - Epney
	South Gloucs. IDB - Oldbury
Upper Severn Division:	River Morda - Morton Bridge to Vyrnwy Confluence
	Sleap Brook - Fiddler's Bridge to Roden Confluence
Lower Trent Division:	River Trent - Beckingham Marshes
	River Idle - Idle Stop to Bawtry
	River Idle - Bawtry to Mattersey
Upper Trent Division:	Doley Brook - Ruele Pools to Hell Hole Wood
	River Trent - Alrewas to Yoxall Bridge
	River Blithe - Blythe Bridge to Cresswell
Soar Division:	River Soar - Sharnford to Croft
	River Sence - Kilby Bridge to Wistow
Tame Division:	River Sence - Temple Mill
Derwent Division:	River Tean - Stramshall Mill to Dove Confluence

No suitable schemes could be found in Avon Division as most work carried out in that area during the relevant time period was either of a maintenance nature or was carried out primarily for urban benefit. Nonetheless it was felt that the 16 schemes provided suitable coverage of the conditions found throughout the STWA region, and 5 schemes in IDB's were included.

III.2 DATA COLLECTION : REQUIREMENTS, SOURCES AND METHODS

The pre-occupation of Stage II was the identification and explanation for the selected STWA schemes of:

- the nature and rate of uptake of drainage benefits,
- the factors which have influenced uptake,
- the overall actual performance of individual schemes against predicted or potential performance using a variety of criteria.

The data requirements for this purpose are extensive and varied, both in terms of source and level of detail. Data requirements for evaluating uptake vary from the micro-level particulars of the individual field to the macro-level statistics that describe the general economic climate facing the farming sector. Figure III.2 summarizes the data requirements at various levels of aggregation.

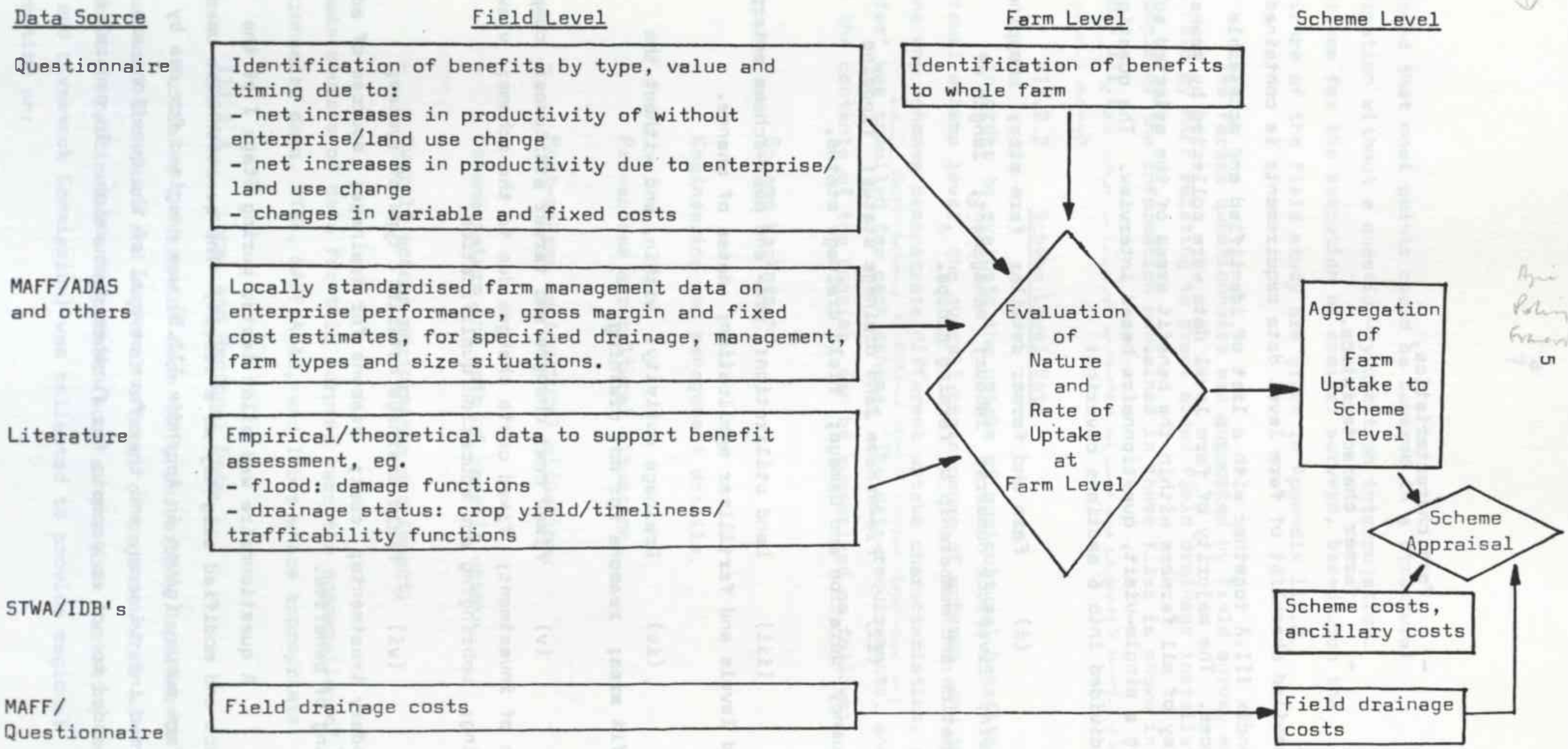
III.2.1 Field/Farm Level Data

The most detailed data requirements relate to the assessment and explanation of benefit uptake at individual field level. The type of data needed can be summarized as follows:

- pre-scheme drainage status,
- post-scheme drainage status,
- actual nature and rate of benefit uptake (including field drainage details),

FIGURE III.2

Data Sources for the Evaluation of Uptake and Scheme Appraisal



- farm characteristics,

- farmer characteristics.

A detailed checklist of farm level data requirements is contained in Appendix III.A together with a list of identified and accessible sources. The majority of farm level data were collected by means of a survey of all farmers within the benefit areas of the selected schemes using a single-visit, questionnaire-based interview. The questionnaire was divided into 6 sections covering:

(i) Farm and farmer details: farm size; cropping pattern; livestock numbers; labour; management; length of occupation and membership of farming groups.

(ii) Pre-scheme land drainage status: flooding frequency, duration and damage; field drainage status.

(iii) Land utilization: pre- and post-scheme enterprises; yield levels and fertilizer application; dates of change.

(iv) Drainage activity: within, and without the benefit area; reasons for not draining.

(v) Fixed cost changes and farmer attitudes: competing areas of investment; fixed costs changes due to the scheme; view of farming; upbringing and education/qualification.

(vi) Field drainage details: type of system; secondary treatments; cost; reasons for drainage; sources of advice; ranking of benefits.

A questionnaire was pilot tested during Stage I of the project and modified slightly as a result. The questionnaire used in the farm survey (given in Appendix III.B) was desgined for use by informed interviewers, and therefore several of the questions are open-ended to act as prompts for further discussion. In general it was found that most points could be covered in a structural conversation without a question-by-question interrogation. Guidelines for the execution of similar surveys, based upon the experience of the field study are given in Appendix III.D.

The farmer questionnaire was supported by field survey and files held by MAFF relating to grant aided field drainage installations. An example of the information contained in these files is shown in Appendix III.C.

III.2.2 Scheme Level Data

In order to evaluate the uptake of agricultural benefits at individual scheme level, the overall performance of schemes, and the reasons why schemes demonstrate different uptake characteristics, a 'dossier' was compiled for each scheme. The data requirements, and hence the contents of the dossier, can be summarized as follows:

- Scheme background,
- Engineering and management details,
- Pre-scheme agricultural situation,
- Post-scheme agricultural situation,
- Scheme nature and rate of benefit uptake,
- Overall scheme performance and impact.

The main sources of data for this purpose were the aggregation of farm questionnaire data, STWA, MAFF/ADAS, and IDB's where appropriate.

III.2.3 Local and Regional Data

Published information from MAFF, University Departments of Agricultural Economics and regional offices of organisations with interests in particular enterprises (such as the Milk Marketing Board, Meat and Livestock Commission) was collected to provide regional information on:

- Farming structure: farm size, type, tenure, land use,
- Farming performance: enterprise gross margins, fixed costs, net farm income,

and the changes in these over a period relevant to the life of drainage improvement schemes. An overview of farming in the area of the STWA is given in Annexe VII.

Information was also collected from individuals and organisations relevant to drainage improvement, in particular IDB's, local farmers drainage groups and land drainage contractors.

III.2.4 Empirical/Theoretical Data

A detailed study was made of the research into the effects of flooding and waterlogging on crop yields, and trafficability. The results of this study are given in Annexe II. This information was used to substantiate farmers' observations and to provide a basis for estimation where more detailed information was not available.

III.3 DATA LOGGING AND ANALYSIS

A computer based system of data logging and retrieval was devised to suit the study's requirements using the Statistical Package for Social Scientists (SPSS).

SPSS is an integrated system of computer programmes designed for the analysis of social science data. The system provides a unified and comprehensive package that enables the user to perform many different types of data analysis in a simple and convenient manner. In addition to the usual descriptive statistics, it contains procedures for correlation, analysis of variance, multiple regression, discriminant analysis, scatter diagrams, factor analysis and much more. It allows the data to be modified to generate new variables (as a function of existing variables) or convert existing variables into other units or classes, and allows missing data to be treated independantly of the rest without upsetting the statistics. Once set up the package is quick and simple to operate and the output can be produced, with complete labelling, in a form suitable for inclusion in reports.

III.4 PARISH RETURNS, AERIAL PHOTOGRAPHY AND LAND USE MAPS : A SPECIAL NOTE

During the early stages of the field work, parish returns, aerial photographs and land use maps were obtained from the schemes being studied (see Doley Brook scheme report in Annexe IX). Their value was found to be very limited and so for subsequent schemes no attempt was made to study them. Parish summaries of census returns generally cover such a large area and, as watercourses commonly form parish boundaries, most benefit areas fall into 2 or 3 parishes making the percentage of the parish in the benefit area so small that changes of interest cannot be isolated from changes that have taken place outside the benefit area. Aerial photographs, if taken at the right time can provide useful information on land use and drainage status, however those studied provided little that was not known from elsewhere (such as the farm survey) and they were very time consuming to study.

In some cases, land use maps yielded useful data (such as on the Beckingham Marsh scheme where a land use inventory was available for the year of the scheme) but generally the year of coverage was too long before the scheme to be of value.

APPENDIX III.A

DATA REQUIREMENTS AND SOURCES

III.A.1 REQUIREMENTS

III.A.1.1 Farm Level Data

Sources

(i) Pre-scheme drainage status: 10(ii),18

– Flood risk (frequency magnitude, duration, timing) by sub-areas within benefit area.

– Field drainage status (timing and duration of waterlogging) by sub-areas within benefit area.

– Extent to which drainage is a constraint on the management of the farm or choice of land use.

(ii) Post-scheme drainage status: 10(ii),18

– As above.

(iii) Actual nature and rate of uptake of agricultural benefits:

(a) 'Before' and 'after' scheme assessment: 18

– Changes in land productivity under the same enterprise/land use type; areas, yields, input levels, gross margin data, by field or sub-area.

– Changes in land productivity with a new enterprise/land use type; as above.

– Land reclamation cases, as above.

– Savings in production costs.

– Changes in fixed costs and management practices.

– Implications of improvements within the benefit area for the management of the farm.

(b) Motivation and reasons for change 18

(c) The timing and area of change 18

Sources

(d) The installation of underdrainage and other field drainage improvements: 10(ii),17,18

- Objectives of improvements.

- Acreage, drainage type, date of installation.

- Cost, source and method of finance.

- Reasons for timing/scheduling of installations.

(e) Farmers evaluation of actual benefits in comparison with expected or predicted benefits 18

(f) The adequacy of the drainage system and any problems encountered 10(ii),18

(iv) Farm characteristics:

(a) Whole farm - size, type, location, tenure system, management structure, standards of husbandry and investment 18

(b) Part of farm within benefit area: 13,18,19

- Location with respect to the rest of the farm.

- Location with respect to the river, drains, outfalls, etc.

- Percentage of total farm area.

- Field size, pattern, fragmentation.

- Ease of access and distance to farm buildings for machinery, dairy cows, etc.

- Sites of conservation, recreation or amenity important.

(v) Farmer characteristics:

(a) Personal characteristics: 18

- Age and sex.

Sources

- Leadership, innovativeness, social and political participation, willingness and ability to cooperate with neighbours, objectives, expectations and ambitions, expected lineage of farm management.
- Farming education, training and experience, farming interests.
- Attitudes towards risk, commercial farming, credit, conservation.

(b) Management/financial status: 18

- Land tenure status, management status, extent of owned resources.
- Farming prosperity, commitment to farming.
- Other activities and sources of income.

(c) Attitudes towards drainage: 18

- Exposure to sources of information and advice.
- Awareness of drainage opportunities afforded by the scheme.
- Perception by the scheme.
- Perception of potential benefits.
- Perception of drainage as an investment.

III.A.1.2 Scheme Level Data

(i) Scheme background: 12,16

- Objectives of the scheme.
- Initiation and reasons for the works.
- Timing and execution of the works.
- Area of direct and indirect benefit.
- Pre-scheme flood risk (frequency, duration, magnitude).
- Pre-scheme drainage status (timing and duration of waterlogging).
- Land capability (soil, topography, climate).

Sources

(ii) Engineering and management details: 12

- Nature of engineering works and responsibility.
- Nature and degree of land drainage improvement afforded by the scheme.
- Improvement potential afforded by the scheme.
- Cost and financing of works.
- Financial benefit predictions.
- Organizational and management structure (planning, execution and maintenance).

(iii) Pre-scheme agricultural situation: 5,10(i),12, 14,15,18

- Land use; cropping pattern, rotations, grazing regimes, livestock numbers.
- Performance levels, yields, stocking densities, inputs and outputs.
- Farm size, type and tenure.

(iv) Post-scheme agricultural situation: 5,10(i), 14, 15,18

- As above.

(v) Scheme uptake of benefits: 18

- Nature of uptake, type of benefit, necessity for field drainage.
- Rate of uptake, area and timing by type of benefit.
- Overview of factors determining uptake.

(vi) Overall scheme performance and 'impact': 10(i), 10(ii),12, 13,17,18

- Financial in terms of net benefit to farmers.
- Economic in terms of net benefit to the economy.
- Social; the effect on the farming community, eg. farm size, employment.

Sources

- Technical; the adequacy of engineering solutions.
- Environmental; the effects on wildlife habitats, amenity value and hydrology of the area.
- Political implications, in terms of local institutions, eg. Parish Council, NFU, CLA.
- A comparison between predicted and actual benefits and scheme performance.

III.A.1.3 Regional and Local Data

(i) Farming structure: 4,5,9

- Farm size (by area and employment status).
- Farm type, fragmentation, tenure, cropping patterns, livestock numbers and systems.
- Trends in the above.

(ii) Farming performance (by size and type of farm): 4,5,7,8,9

- Enterprise performance, gross margin data, (including yields and input levels).
- Fixed cost structure, labour, buildings and machinery, rent and rates, general overheads, investment patterns.
- Net farm incomes.
- Trends and prospects in above.

(iii) Support services to farmers: 2,3,6,8,10, 12,13,17

- Grant aid and subsidies.
- Advisory and training services relating to drainage and above improvements.
- Credit sources and conditions.
- Drainage contractor services and rates, including field drainage design criteria.
- Farmer pressure group; NFU, CLA.
- Local Authority, STWA, IDB, ADAS or farmer group support for drainage works and the extent of liaison.

Sources

- Conservation and amenity advice.

(iv) Land drainage policy: 2,11

- Expenditure, priorities.

III.A.1.4 <u>Farming Prospects: General</u> 1,2,3,4,7,8

- Input and output prices, trends and prospects.
- Agricultural policy issues.
- Trends in farm sector development.

III.A.2 DATA SOURCES

Source	Type	Code
1. Government Published Statistics	National and regional level commodity prices. National economic trend indicators, eg. 'Agricultural Price Review', 'Economic Trends'.	1
2. Published Literature	Policy statements at National and EEC level. Critiques and monitors of trends.	2
3. Farming Press	Trends in prices, incomes, etc. Critiques of agricultural policy, legislation and agro-economic climate. Input and output prices.	3
4. MAFF Published Statistics	National and regional analyses of farm structure, incomes, employment, crop areas, etc., by type and size of farm, eg. 'Farm Classification in England and Wales' and 'Farm Incomes in England and Wales'.	4

Source	Type	Code
5. MAFF Census Returns	Summaries of June Census returns at National, Regional or Parish level. Available from MAFF (Statistics Division) at Guildford (1970-present) or the Public Records Office at Kew (pre-1970). Details of cropping areas, livestock numbers, horticulture and farm structure (farm type, size, labour, tenure).	5
6. MAFF Published Field Drainage Statistics (FDEU)	Details of field drainage installations at MAFF Regional and Divisional level. Information on the total number of schemes, total area drained, total cost, and engineering details on a quarterly basis (eg. 'Drainage Statistics' - A.C. Armstrong: 1981).	6
7. University Agricultural Economics Units	The results of the annual Farm Management Survey, carried out jointly by ADAS and the University Agricultural Economics Units are published by the Universities. The STWA area is covered by the Universities of Manchester (Salop, Staffs.), Nottingham (Derbys., Leics., Notts.), Reading (Avon, Gloucs., Warwicks., Hereford and Worcs., W. Midlands), and Aberystwyth (Powys). Standardised enterprise input-output levels, gross margins, fixed cost estimates, net farm incomes and financial performance indicators published at Regional and County level by farm size and type.	7

Source	Type	Code
8. Marketing Boards	The Milk Marketing Board and Meat and Livestock Commission publish annual reviews of commodity prices and prospects, performance data from farm surveys, and specialist reports. Similar information was available from other producer organisations, eg. Potato Marketing Board. Local information can be obtained from regional offices.	8
9. ADAS Regional Offices	Staff at regional offices are able to provide a regional overview and regional summaries of census data. STWA area is covered by the Midlands and Western Region (Wolverhampton office) and the South Western Region (Bristol office).	9
10. ADAS Divisional Offices	(i) Farm management section. Local information on input-output levels, gross margins, fixed cost estimates, financial performance, etc. The results of local farm management surveys.	10(i)
	(ii) Land and water service. Details of field drainage activities in the area; physical details of soils, etc. Details of individual grant aided drainage installations.	10(ii)
11. STWA Head Office	Details of Land Drainage Policy, grant aid applications, Section 24(5) surveys and maps.	11

Source	Type	Code
12. STWA Land Drainage Divisions, Internal Drainage Boards	Information relating to particular schemes; engineering reports, maps and plans, costings, benefit appraisals, commissioned studies, aerial photographs.	12
13. Conservation and Amenity Interests	Local staff of the Nature Conservancy Council, Countryside Commission, County Trusts and the Farming and Wildlife Advisory Group can provide details of sites important for conservation or amenity purposes. Detailed studies of certain habitats are available along with lists of SSSI's.	13
14. Land Use Maps	Land use maps and inventories are available for various schemes. Most of the country was covered by the Second Land Utilization Survey during the 1960's and maps at 1:25,000 scale are available for most of the country.	14
15. Aerial Photographs	Air photos are available at a variety of scales from many sources. The Department of Environment Air Photographs unit will carry out a search of the known coverage of any area of U.K. Photos are generally available from County Planning Offices, local libraries, Ordnance Survey, soil survey, commercial aerial survey companies, or STWA offices.	15
16. Soil Survey	Soil and land capability data are available from the soil survey at a variety of scales. 1:25,000 maps are available for certain areas of the country.	16

Source	Type	Code
17. Field Drainage Contractors	Details of local field drainage practice and methods. Costs, demand, techniques, drainage design criteria.	17
18. Farmers	See Farmer Questionnaire (Appendix III.B).	18
19. Published and Unpublished Maps	Topographical maps, eg. Ordnance Survey, maps of benefit area (STWA), field plans.	19

APPENDIX III.B

National College of Agricultural Engineering

DRAINAGE BENEFIT AND FARMER UPTAKE QUESTIONNAIRE

Scheme ______________________ Farm ______________________

Interviewer ______________________ Interviewee ______________________

A. FARM AND FARMER DETAILS

1. How many holdings do you farm? ______

If more than one: briefly describe the relationship with other holdings:

____

____

____

The following questions refer to the holding that includes land within the benefit area.

2. Farm Size:

		(Acres/Ha)
Total Farm		______
Area Owned		______
Area Tenanted - Full		______
	364 day	______
	Summer-grazing	______

3. Cropping Pattern:

		(Acres/Ha)	(SMD)
Winter sown cereals	Wheat/Barley	______	____
Spring sown cereals	Wheat/Barley	______	____
Potatoes	Early/Maincrop	______	____
Sugar Beet		______	____
Forage Crops	______	______	____
Field Vegetables	______	______	____
Leys and Temporary Grass		______	____
Permanent Pasture		______	____

A.3. cont.

	(Acres/Ha)	(SMD)
Rough Grazing	______	
Woodland	______	______
Other ______	______	______

4. Horticulture:

Area under glass	______	______
Area cropped outside	______	______

5. Dairy Enterprises:

	No.	L.U.'s	(SMD)
No. of Dairy Cows	______	______	______
No. of Followers	______	______	______

Breed: 1. Friesian 1.

2. Channel Island 2.

3. Other 3.

Milk yield per cow ______ (l/gal)

6. Beef Enterprises:

	No.	L.U.'s	(SMD)
No. of Beef Cattle	______	______	______

System: 1. Dairy Beef . Specialist calf rearing 1.

2. Dairy Beef . Cereal Beef 2.

3. Dairy Beef . Grass/cereal Beef 18 m 3.

4. Dairy Beef . Grass/cereal Beef 24 m 4.

5. Suckler Herd (no. of cows) 5.

6. Finishing Stores . Winter finishing 6.

7. Finishing Stores . Grass finishing 7.

8. Finishing Stores . Overwintering/Grass 8.

7. Sheep Enterprises:

	No.	L.U.'s	(SMD)
No. of Ewes	______	______	______
No. of lambs reared per ewe tupped	______	______	

A.7. cont.

System: 1. Early lambing flocks (Dec-Jan) 1.

2. Lowland flocks selling off grass 2.

3. Lowland flocks selling off forage 3.

4. Upland flocks selling fat and stores lambs 4.

5. Upland flocks selling mainly breeding stock 5.

6. Extensive Upland flocks 6.

7. Hill flocks 7.

8. Store lamb finishing 8.

8. Pig Enterprises: No. (SMD)

No. of sows ______ ______

No. of weaners ______ ______

System: 1. Breeding 1.

2. Fattening 2.

9. Poultry Enterprises: No. (SMD)

Total No. of poultry ______ ______

10. Number of Workers: No.

Family ______

Regular Hired ______

Casual (no. of weeks) ______

11. Management Status:

1. Sole Proprietor 1.

2. Manager 2.

3. Partner 3.

4. Other (specify) ______________________ 4.

12. For how many years have you farmed this holding? ______ yrs.

13. Has the ownership of the holding changed hands since the scheme (date)? YES/NO

If YES, when? ______

14. Has the management of the holding changed hands since the scheme (date)? YES/NO

If YES, when? ________

15. Do you have any sons or daughters whom you expect to continue to farm this holding after you? YES/NO

16. Are you a member of:

0.

1. NFU 1.
2. CLA 2.
3. TFA 3.
4. Local Farmer's Group 4.

17. Do you represent the local farmers or community at any of the following levels?

0.

1. NFU/TFA 1.
2. CLA 2.
3. Local or Regional Land Drainage Committee 3.
4. Parish Council 4.
5. District or County Council 5.
6. Other (specify) 6.

18. What proportion of your total income is attributable to farming activities?

1. Greater than 80% 1.
2. 60 - 80% 2.
3. 40 - 60% 3.
4. 20 - 40% 4.
5. Less than 20% 5.

19. Briefly describe any alternative sources of income:

B. PRE-SCHEME DRAINAGE STATUS

1. Identify on the map, your fields within the benefit area (marked). Was any of that land prone to flooding before the scheme? YES/NO

If NO, go to (5).

2. Before the river improvement works were carried out, on average, how often did your land flood? Please indicate frequency of flooding for sub-areas within the farm.

1. Never 1.
2. Less often than once in 5 years 2.
3. Once in every 2 to 5 years 3.
4. Once every year 4.
5. More than once every year 5.
6. Can't remember/wasn't here 6.

3. When flooding did occur, on average, how long did your fields remain under water?

1. Days 1.
2. Weeks 2.
3. Months 3.

Field(s)	Frequency	Duration

4. What physical damage, if any, did flooding cause, and roughly what was the cost of remedial work (in terms of replacement, labour, etc.)?

1. Damage to fencing ______
2. Loss of stock ______
3. Damage to Buildings ______
4. Damage to standing crops ______
5. Litter and Debris ______
6. Other (specify) ______________ ______

5. How would you describe the drainage status of your land within the benefit area, before the completion of the scheme? (If not uniform, complete for sub-areas).

1. Rarely or seldom wet 1.
2. Occasionally wet 2.
3. Commonly wet 3.
4. Usually or permanently wet 4.

Field(s)	Status	Tick if Already Drained

C. LAND USE CHANGE

1. Please state pre- and post- scheme land utilization details for each field within the benefit area, and note date of change.

Field		Land Use		Grassland				Arable/Hort.		Fertilizer Appl$^{\underline{n}}$	
No	Date	Class	Livestock/ Crop type	Grazing Season		No. of grass cuts H. or S.	Approx. Yield of Grass	Rotation	Yield	Type	Quantity
				Possible	Actual						
	Before										
	Before										
	Before										
	Before										
	Before										

2. To what extent can the changes in land use and productivity identified above be attributed to:

(a) the river improvement scheme ______

(b) field drainage ______

(c) other factors, eg. change of management practice ______

D. DRAINAGE

1. Have you installed any field drainage within the benefit area following completion of the scheme? YES/NO

If YES, complete field drainage section.

2. Have you improved the field drainage of land within the benefit area in other ways, eg. improved ditches, or old drainage systems? YES/NO

If NO, go to 4.

If YES, explain: ______________________________

____

____

____

3. Would this have been possible if the river improvement works had not been carried out? YES/NO

4. Do you work with your neighbours in relation to drainage matters? YES/NO

If YES, specify the nature of work and method of organization:

____

____

____

5. How do the actual benefits of drainage within the area of the scheme compare with what you expected at the onset of the scheme? Are they:

1. Greater than expected 1.

2. Same as expected 2.

3. Less than expected 3.

Briefly explain your answer: ______________________________

____

____

6. Have you installed field drainage in any upland fields, ie. outside the benefit area? YES/NO/NA

7. Is any of your land within the benefit area without field drainage? YES/NO

If NO, go to (11).

8. Which of these statements, if any, best summarizes your reasons for not draining that land?

	Fields
1. The land is naturally free draining	1.
2. There is insufficient outfall for field drains	2.
3. Sufficient finances have not been available to drain	3.
4. The benefits from drainage would not cover the costs	4.
5. The land floods too often to consider draining.	5.
6. The land is of value as a site for wildlife conservation	6.
7. Several farmers in the area would have to get together to invest in draining and this would prove difficult.	7.
8. The way I wish to manage the land does not require under drainage	8.
9. I would achieve a better return from other forms of investment	9.

9. Do you have other reasons for not draining? YES/NO

If YES, elaborate: ____________________

____

____

____

10. What conditions would have to change before you would consider installing field drainage systems on this land?

____

____

____

____

11. For a given investment (say £20,000.00) which three items do you think would contribute most to your farm business:

1. Farm Buildings/Storage 1.
2. Farm Machinery/Equipment 2.
3. Land Purchase 3.
4. Field Drainage (in Benefit Area) 4.
5. Field Drainage (outside Benefit Area) 5.
6. Working Capital, eg. livestock feeds, fertilizer, etc. 6.

12. Have the changes identified on the land within the benefit area, in terms of land use or productivity, led to changes being made in the management of the farm regarding:

		Reduction –	No change o	Increase +
1.	Labour requirements			
2.	Machinery requirements			
3.	Buildings and storage			
4.	Use of contractors			

13. Consider the following points of view:

(a) "I consider farming as a commercial business. To me, achieving a high level of profitability is most important, even if this means taking risks. High profits are a sign of successful farming."

(b) "I consider farming is more a way of life. As long as I can make an acceptable and reliable living I am content. I am not interested in striving for high profits."

Where would you place yourself on the scale between the two points of view?

1. Completely agree with (a) 1.
2. 2.
3. 3.
4. 4.
5. 5.
6. Completely agree with (b) 6.

D.13. cont.

Comments: ____

____

____

14. How would you rank investment in field drainage against other investments that you have made on your holding?

____

____

____

____

____

15. As far as you are aware, is any of your land designated as a site of special scientific interest? YES/NO

16. In what ways, if any, do you attempt to improve the natural beauty and/or wildlife value of your farm?

____

____

____

____

____

17. Where did you learn to farm?

1. I was brought up on this farm. 1.

2. I was brought up on another farm. 2.

3. I attended a full-time agricultural training course. 3.

4. I gained experience from working on farms. 4.

5. Other (specify) ______________________________ 5.

18. Do you have any agricultural or academic qualifications? YES/NO

If YES, please specify ______________________________

____

DRAINAGE BENEFIT AND FARMER UPTAKE QUESTIONNAIRE

PART TWO: FIELD DRAINAGE INSTALLATION

Scheme: Farm:

Interviewer: Interviewee:

National College of Agricultural Engineering

SILSOE, BEDFORD MK45 4DT. ENGLAND Telephone Silsoe (0525) 60428

I, , give my permission to members of the NCAE Severn Trent Water Authority Project Group to study the records held by the Ministry of Agriculture, Fisheries and Food, relating to drainage matters of (Farm).

Signed:

Dated:

E. FIELD DRAINAGE INSTALLATION

1. Complete the Drainage Details sheet.

2. Was the drainage of the land within the benefit area carried out:

   1. As part of a major reorganisation of your farm? 1.

   2. In order to bring the management of this land into line with the rest? 2.

   3. To try a new approach to your farming? 3.

   4. None of the above (explain) 4.

   Comments: ______________________________

   ____

   ____

   ____

3. Have you encountered any problems with your drainage system since its installation? YES/NO

   If YES, elaborate: ______________________________

   ____

   ____

   ____

4. When considering drainage, from which sources did you obtain information or advice?

   1. ADAS 1.

   2. Contractors 2.

   3. Local farmers who had already drained 3.

   4. Other (specify) ______________________________ 4.

5. The following are commonly quoted as being benefits of improved drainage of arable land. Please rank, in order, the five most important in your opinion:

1. FIELD DRAINAGE DETAILS

Field Number							
Date of Draining and Reason for delay (if any)							
Gravity or Pump Drainage?							
Permiable Backfill							
Do you mole drain?							
frequency?							
spacing?							
Do you subsoil?							
frequency?							
Drain Spacing							
Drain Depth							
Total Cost of Drainage?							
Was it grant aided?							
Source of finance?							
If grant had not been available, would you still have drained?							
Av. Depth to Water in Ditches							
Depth to Outfall							

E.5. cont.

Higher yields per acre

Less variation across the field

Less risk of plant disease

The opportunity to drill earlier

Increased trafficability/extra work days

The opportunity to grow winter sown crops

Increased land value

Less risk of total failure

Not applicable

6. The following are commonly quoted as being benefits of improved drainage of grassland. Please rank, in order, the five most important in your opinion:

Reduced poaching

Improved species composition of sward

Greater stock carrying capacity

Earlier top dressing with fertilizer

Extended grazing season

Increased number of grass cuts

Improved trafficability/extra work days

Reduced disease risk

Not applicable

7. Is any of the land pump-drained YES/NO

If YES, please give details of pump, management and organisation:

Pump capacity ______

Pump Type ______

Power Source ______

Usage ______

Management ______

______

INTERVIEWER'S ASSESSMENT

(i) Farmer's Age Group

1. Under 35 — 1.
2. 35 - 60 — 2.
3. Over 60 — 3.

(ii) Percentage of farm within the benefit area (calculate from the map).

(iii) Farm Size (SMD)

(iv) Farm Type:

1. Specialist Dairy — 1.
2. Mainly Dairy — 2.

Livestock rearing & fattening:

3. Mostly cattle — 3.
4. Mostly sheep — 4.
5. Cattle and sheep — 5.
6. Predominantly Poultry — 6.
7. Pigs and Poultry — 7.
8. Cropping: mostly cereals — 8.
9. General cropping — 9.
10. Predominantly vegetables — 10.
11. Predominantly fruit — 11.
12. General Horticulture — 12.
13. Mixed — 13.

Tick if less than 250 SMD ☐

(v) Average grass stocking density ________ L.U./ac.

(vi) Topographic location: Lowland
Upland
Hill

APPENDIX III.C

Example of the Form FCG3 UD

UNDERDRAINAGE INFORMATION SHEET

NAME OF FARM..

	Cols.
GENERAL INFORMATION	
1. COUNTY PARISH HOLDING No.	1 - 9
1a. GRANT IDENTIFICATION (FCGS=1, FHDS=2) .. .. [0]	10 - 11
2. SCHEME No. [FCGS/FHDS] [1]	12
3. DATE APPROVAL RECOMMENDED	13 - 18
4. ESTIMATED COST (to nearest £1)	19 - 23
5. AREA TO BENEFIT (hectares to 1 decimal place - a decimal value or zero must be entered in box 29)	24 - 29
6. PREVIOUS GRANT AID IN BENEFIT AREA (None=1, Replacement/Record=2, Intensification=3)	30
7. FIELD IDENTIFICATION:	
8. TYPE: (Normal U/D=1, U/D with minor PD=2, U/D with substantial PD=3, Piped Ditch=4, Private Pumping =5, Recondition=6, U/D multi fields etc.=7, Moling, Subsoiling over ex. U/D=8, Others=9)	31
FIELD DETAILS	
9. TYPE OF TERRAIN (Fen or Marsh=1, Normal Upland=2, Hill Land=3)	32
10. ASPECT (North=1, East=2, South=3, West=4, Not significant=5)	33
11. GRADIENT (% to 1 decimal place - a decimal value or zero must be entered in box 36)	34 - 36
12. ELEVATION ABOVE SEA LEVEL (metres)	37 - 40
13. AVERAGE RAINFALL (millimetres)	41 - 44
14. LAND USE (See Key Sheet) — Before drainage	45
After drainage	46
15. DRAINAGE PROBLEM (Water Table=1, Impermeable subsoil=2, Springs or Springlines=3, Failure of old drains=4, Others=5, Glasshouse drainage=6)	47
16. OLD DRAINS IN BENEFIT AREA (Present but not working=1, Some working=2, No evidence=3)	48
17. TRENCHING HAZARDS (None=1, Unstable soil=2, Rock=3, Stones=4, Bog Oak=5, Others=6)	49
SOIL DETAILS	
18. EXPLORATORY HOLES (None=1, Auger holes=2, Profile pits=3, Both=4)	50
19. SUBSOIL DETAILS (See Key Sheet) — Texture	51 - 52
Structure, shape and size	53 - 54
Structural development ..	55
DESIGN DETAILS	
20. AVERAGE DRAIN SPACING (metres) (If layout completely random enter in box 58) ..	56 - 58
21. AVERAGE DEPTH OF DRAINS (millimetres)	59 - 62
22. MAJORITY OF DRAINS HAVE INDIVIDUAL OUTFALLS (No=1, Yes=2)	63
23. PERMEABLE FILL: Box A - Type (See Key Sheet); Box B - Depth from ground surface to perm. fill (millimetres) [A] [B]	64 - 69
24. SECONDARY TREATMENT: Box A - Type (None=1, Moling=2, Subsoiling=3); Box B - Depth from ground surface (millimetres) [A] [B]	70 - 73
25. TYPE OF MACHINE TO BE USED (None=1, Continuous Trencher=2, Backacter=3, Trenchless (Crawler)=4, Trenchless (Winched)=5, Other=6)	74
26. DESIGNER (DWSO - Chargeable=1, Contractor=2, Consultant=3, Applicant=4, DWSO Feas. - Contr. design=5, DWSO Feas. - Cons. design=6, DWSO Feas. - Appl. design=7)	75
27. CONSULTATIONS (None=1, Eng=2, Soil Sci.=3, Gen. Agric. Adviser=4, Others=5, Sen/Div. DWSO=6)	76
28. SOIL SERIES: Box A: Information (None=1, DWSO opinion=2, Soil Specialist opinion=3, Soil Surveyor opinion or map; specialist confirmed=4, Map, Soil Surveyor confirmed=5); Box B: Code (See Soil Code List) [A] [B]	77 - 80
30. PIPE DETAILS: [2]	12
Box A: Pipe Type See Key Sheet	13 - 23
Box B: Diameter in millimetres	24 - 34
Box C: Length in metres	35 - 45
	46 - 56
	57 - 67
[A] [B] [C]	68 - 78

APPENDIX III.D

FARM SURVEY PROCEDURES

The following section summarises the approach to survey work.

A.III.D.1 Farmer Identification and Interview Appointments

In the present study, a general letter was sent to the relevant county branches of the NFU and CLA with information about the intent and form of the study. In all cases branch secretaries replied saying their membership would be informed and full support encouraged.

Having obtained scheme maps and basic documentation from STWA Divisions, a brief reconnaissance visit to the scheme area was made. Preliminary enquiries were then made with STWA Divisional staff, local ADAS officers (Agricultural Advisory Officers and Drainage Officers), and IDB engineers where relevant, to identify the names, addresses and telephone numbers of farmers within a benefit area. Where complete lists were not available, information for a few key farmers was sufficient to begin field work. Farmers were contacted by telephone a week or so in advance of the survey to arrange an approximate time for interview on the farm. It was found best to telephone at meal times the day before to confirm the appointment, particularly during busy field work periods. The first few farmers can generally provide the names of other relevant occupiers who then with the aid of map and telephone directory can be contacted. For each scheme a log book was completed containing relevant data and contacts.

A.III.D.2 Equipment

The interview progressed more easily by using large scale plans of the benefit area, which could be used for scribbling on. 1:2500 plans with field numbers and sizes enable rapid identification of fields.

A printed questionnaire, which had been tested in a pilot survey, provided the basic structure of the interview. It was important that the questionnaire could be completed easily and quickly, with room for additional notes.

A.III.D.3 Obtaining an Overview

Discussions with relevant MAFF and STWA officers, a detailed study of STWA scheme files, and a 'walkabout' in the benefit area, were essential pre-requisities before beginning individual farm visits in order to obtain an overall perspective of the objectives, design features, and impact of a given scheme. Reference made by farmers to particular features of the scheme and its benefit area could then be appreciated at interview.

A.III.D.4 Conducting the Farmer Interview

Interviews were easiest to arrange during the less busy periods of the farming calendar, notably October through to mid-May, with hay/silage making and cereal harvesting being the most difficult. Poor weather hastened survey completion, and gave a conversation topic to begin the interview. Rather than attempt to conduct interviews at busy times, where the respondent is thinking of other things, rescheduling is advisable.

Having met the farmer at the appointed time, it was essential that the farmer understood the purpose and scope of the enquiry and his particular role in it. Emphasis was placed on STWA's wish to find out how the schemes had changed drainage conditions and how farmers had responded. A knowledge of this would help to improve the design and justification of future schemes. In virtually all cases farmers were well disposed to the enquiry, whether they had actually taken up benefits or not, because land drainage was a critical factor in the way they chose to farm. The interview was the first time they had been asked about either pre- or post-scheme conditions and farming practice, and some expressed surprise at this.

Wherever possible the interview was carried out in the farm office or farmhouse. The need for a warm, dry, well-lit location with table and chairs, precludes most farm buildings, and for that matter most fields. In most cases the kitchen table served as a good base for spreading out maps, and filling in questionnaires.

Having explained the purpose of the study, the interview began by identifying the farmer's fields lying within the area of influence of the scheme. Large scale maps for the identification and recording of field boundaries, land use and field drainage were a necessity. Changes in post-scheme field boundaries were recorded on the map. Identifying fields was not without its difficulties: the 'five acre meadow' often seemed to grow to an 8 hectare field of winter wheat with the passage of time.

The interview then used the structured questionnaire as a basis for recording qualitative information in the form of a discussion rather than a series of discrete questions and answers. This helped to maintain interest for both interviewer and interviewee.

Suffice to say, it is important that the interviewer be familiar with and sympathetic towards farming both as a business and a way of life. Farmers are quick to sense concealed ignorance or feigned interest. Interviewers need to be well briefed in farm management and agricultural drainage. Where, as often happens, interviewers are not familiar with localised farming practice, it is best to admit this and seek information from the farmer, who in most cases is only too willing to act as tutor. For each scheme, the first few farmers surveyed were usually the main beneficiaries, and the interview often touched on local matters relevant to scheme performance, notably general river/drainage regimes, soils, farming systems, and types of farmers. This proved invaluable background for subsequent interviews.

Generally, the interview took about 1½ hours to complete, and longer if it was deemed appropriate to make site inspections with the farmer. Once the farmer's interest had been gained, interviewer's time often became the limitation. The interviews were conducted by professionally trained staff responsible for completing the entire evaluation study, and not by temporary enumerators. Problems of enumerator management did not arise. The aim was to conduct at least 3 interviews per day, with 4 as a maximum. Any more proved exhausting to the interviewer, and the quality of interview suffered. Time was reserved each day to check through the completed questionnaires.

ANNEXE IV
ESTIMATING THE PRODUCTIVITY OF GRASS WITH AND WITHOUT DRAINAGE

ANNEXE IV

ESTIMATING THE PRODUCTIVITY OF GRASS WITH AND WITHOUT DRAINAGE

Contents

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Abbreviations Used in Annexe IV

ADAS	Agricultural Development and Advisory Service
AWC	Available Water Capacity
DM	Dry Matter
FDEU	Field Drainage Experimental Unit
FMS	Farm Management Survey
FYM	Farmyard Manure
GJ	Gigajoules
GRI	Grassland Research Institute
LU	Livestock Unit
MAFF	Ministry of Agriculture, Fisheries and Food
ME	Metabolizable Energy
MMB	Milk Marketing Board
N	Nitrogen
STWA	Severn Trent Water Authority
UME	Utilized Metabolizable Energy

ANNEXE IV

ESTIMATING THE PRODUCTIVITY OF GRASS WITH AND WITHOUT DRAINAGE

IV.1 INTRODUCTION

This Annexe describes the development and validation of a working procedure for estimating the impact of poor drainage on grassland, and the potential productivity improvements attributable to an alleviation of the drainage problem.

Particular attention has been given in the present study to the assessment of grassland benefits because most of the study areas were predominantly under grass before the river schemes were enacted. Indeed, a large part of the benefit areas (55% of the total) have remained in grass after the schemes. It became apparent, however, that reliable data were not available from farmer interviews to assess grassland productivity, given the need for field-specific estimates of such variables as turnout weights and dates, liveweight gains at grass, and number of grazing livestock days. It was necessary therefore to develop a method which could use more readily assessable proxy variables, notably site classification for both water availability and drainage status, fertiliser use and conservation practice as a basis for estimating grassland productivity. The method, which draws on available research data, is validated by reference to livestock management survey observations.

IV.2 BACKGROUND

IV.2.1 Soil Water Content and Grass Growth

Grassland production is closely related to water supply. Yield of grass may be limited either by a shortage or an excess of water.

Where yield is not limited by excess water it increases in relation to the amounts of water available in the growing season from summer rain and from the soil. These relations have been well researched (see Annexe II) and it is possible to estimate with some confidence the production of grass on a particular site according to the water availability on that site (Morrison et al, 1980). Nearly all sites in the U.K. have sufficient moisture to support maximum growth of grass in spring, but in summer rainfall rarely matches the demand for water, except for the wettest sites, so production during the summer falls away from the maximum. The reservoir of water in the soil supplies a certain amount of the shortfall in water supply, but in most sites in the U.K. there will still be a substantial summer deficit and hence a limitation on yield due to a lack of water availability. The amount of water available from the soil depends largely on the soil texture. For example, a coarse, sandy soil holds relatively little water available to the plant and such a soil may be drought-prone. It should be noted that these estimations of grass yield according to site water availability assume that there is no contribution from incoming groundwater; only summer rainfall together with the amount of water stored in the soil from winter rainfall are considered.

Excess water, in a severe case, prevents growth by excluding oxygen from the root zone and thus preventing respiration. This, though, represents the extreme case of marshland and is not typical of most of the cases needing to be considered in this study, where excess water is periodic and growth is limited through different mechanisms. These typical sites are flooded or waterlogged in the winter, remain wet into the spring and, although they dry out during the summer, they suffer a reduced yield. The yield penalty is due mainly to the restriction of root development by the periodic high water table and to the low spring temperature of the wet soil. The former reduces growth overall, especially in dry summers when the roots, being shallow, are stranded in the dry upper soil layers, unable to tap moisture below. The latter delays the spring flush of growth, which only begins when the soil temperature rises to a certain point and thus shortens the growing season. Excess water also causes deterioration in the composition of the sward, favouring less productive species, and may adversely affect soil fertility, further depressing productivity. The supply of nitrogen from the soil is particularly affected, although it can be replaced by fertilizer nitrogen.

IV.2.2 Causes of Excess Water

The cause of excess soil water conditions is simple: the sink for soil water is inadequate for the source. There are, however, a number of ways in which this can arise. The main sources of soil water and limitations on the sink are:

(i) Sources of soil water
- rain
- flood
- seepage
- high regional water table

(ii) Limitations upon the sink for soil water
- inadequate arterial drainage, leading to a high regional water table
- impermeable soil layer

It is particularly important to distinguish between the two sink constraints because while arterial drainage can be improved by engineering works and the regional water table lowered, soil permeability cannot be so improved. The removal of water from soils with impermeable layers can be improved up to a point by a combination of underdrainage and secondary treatments to increase permeability, such as subsoiling, but the nature of the soil will set a limit on the extent of the improvements.

The correction of excess soil water conditions can be summarised in terms of the source-sink description. If the problem is mainly at source, for example flooding, its correction consists of the elimination of that source, in this case by flood alleviation. Rain, however, cannot be eliminated. If excess soil water conditions arise where the source is rain only, the only recourse is to improve the sink, as far as this is possible given the limitations which may be imposed by the soil type as mentioned above. It should be noted that some sites receive water from more than one source and suffer from both sink constraints; in such cases, not only are engineering works needed to effect an improvement but the extent of the improvement will still be limited by the low permeability of the soil.

IV.2.3 Effects of Excess Water on Yields and Utilization

An important definition needs to be made at this point. Throughout this Annexe the source-sink characteristics of a particular site and the soil water conditions which result in the root zone will be referred to as the drainage status. The word "drainage" is thus used widely and does not refer merely to arterial or underdrainage but also to soil permeability, flooding and groundwater conditions, including seepage. The drainage status of a site may be classified as bad even though arterial drainage is good if, for example, it suffers from flooding or if the soil has impermeable layers and no underdrainage. An attempt is made here to relate drainage status, so defined, to yield. Bad drainage leads to excess soil water conditions in the root zone at certain times which in turn cause yield depression.

A complication immediately ensues because it is necessary to consider not merely the yield of grass but also the extent to which it is utilized for animal production, and utilization is also affected by excess soil water conditions. The complication is that a different set of soil water conditions relates to utilization from the set defined above as drainage status which relates to yield. For one thing, yield is affected by soil water conditions throughout the root zone (ie. to a depth of 0.5m or more) whereas utilization is affected only by conditions in the surface layer. This distinction will, it is hoped, become clearer below, after the following brief discussion of utilization.

Some losses in the energy yield of grass are inevitable during its utilization for animal production. There are various types of losses, some of which are normally unrelated to soil water conditions, such as losses during the harvest and storage of conserved grass and losses resulting from the difficulties of grazing management which at times lead to the grazing of grass which is past its best. Other losses in utilization, though, are controlled very closely by soil water conditions, such as poaching or the contamination of grass by treading.

Poaching is the penetration of the soil surface by animal hooves, damaging both the grass sward itself and the structure of the top soil layer. Poaching occurs when the bearing capacity of the upper soil layer is reduced by excess soil water. This may occasionally be the result of a high water table but usually it occurs on soils of low permeability following rain. Once poached, the permeability and bearing capacity of the soil are both reduced still further. If stock are removed to avoid poaching, productivity is still reduced because grass matures and becomes less nutritious, so utilization is affected at times of poaching risk whether or not poaching is allowed to take place. For present purposes it is assumed that the loss in utilization due to foregone production when stock are removed at times of poaching risk is the same as that occurring if the cattle are left out at grass and poaching takes place.

It is important to realize that the soil water content of the surface layer may be excessive in terms of bearing capacity and poaching without affecting yield, depending on the soil. Indeed some soils are sufficiently weak as to sustain poaching at precisely the water content which is the optimum for growth. For this reason poaching status is distinguished from drainage status, and the effect of poaching on utilization is treated separately from the effect of bad drainage on yield, even though excess soil water is the immediate cause of loss of productivity in each case. The distinction is summarized in Figure IV.1.

Since poaching is usually caused by impermeable soil, and this is also a contributory cause of bad drainage, it might be expected that the two would go together, and so they do in many cases. It is possible, though, for a site to have bad drainage, as defined above, yet not suffer from poaching. A site may have a very permeable soil (sandy or peaty) and a seasonally high water table which is high enough in winter and spring to affect yield, but low enough in summer to leave the soil's bearing capacity unaffected and the poaching risk low. On the other hand, a site may have good drainage, as defined above, and still suffer from poaching. This may occur where underdrainage has been installed but the soil is nevertheless too weak

FIGURE IV.1

The Distinction Between Drainage Status and Poaching Status, as defined:

Drainage status	Poaching status
defines	defines
soil water conditions in the root zone during winter and spring which affect yield	soil water conditions in the surface layer during the grazing season which affect utilization
Typical causes and treatments for improvement:	Typical causes and treatments for improvement:

Cause	Treatment	Cause	Treatment
(1) Flooding	Flood alleviation scheme	(1) Impermable soil layer (eg. surface water gleys)	Install field drainage and apply secondary treatments as necessary. Not treatable in all cases.
(2) Seepage	Interception	(2) High regional water table	Improve arterial drainage and install field drainage as necessary
(3) High reg'l water table	Improve arterial drainage and install field drainage as necessary		
(4) Impermeable soil layer	Install field drainage and apply secondary treatments (eg. subsoiling) as necessary		

after rain to avoid poaching. The soils which are most difficult in this respect are those with impermeable upper layers known as surface-water gleys. Underdrainage of these soils may be successful in terms of improved drainage status and increasing the yield of grass, but utilization will still be low if rain still causes poaching. In such circumstances investment in underdrainage may not be worthwhile.

IV.2.4 The Prediction of Yield and Utilization Percentage

Full experimental data are not yet available for the quantitative prediction of either grass yield or percentage utilization according to soil and drainage conditions. An attempt is made here to use such data as are currently available to estimate yield and percentage utilization and the twofold penalty incurred on wet sites of reduced yield and reduced utilization of yield. Every endeavour will be made to maintain the distinction between these two types of penalty and it is hoped that the definitions given of the terms "drainage status" and "poaching status" (see Figure IV.1) will enable it to be maintained without undue confusion due to ambiguities in the use of the word "drainage".

Grass yields are measured throughout this Annexe in terms of metabolizable energy (ME), given in gigajoules per hectare (GJ/ha). The grass ME production which is not lost but becomes part of animal production is termed utilized metabolizable energy (UME), also given in GJ/ha.

Summer flooding which occurs during the growing season itself is not accommodated in the preceding discussion but receives separate treatment in section IV.4 since its effects are additional to those described above.

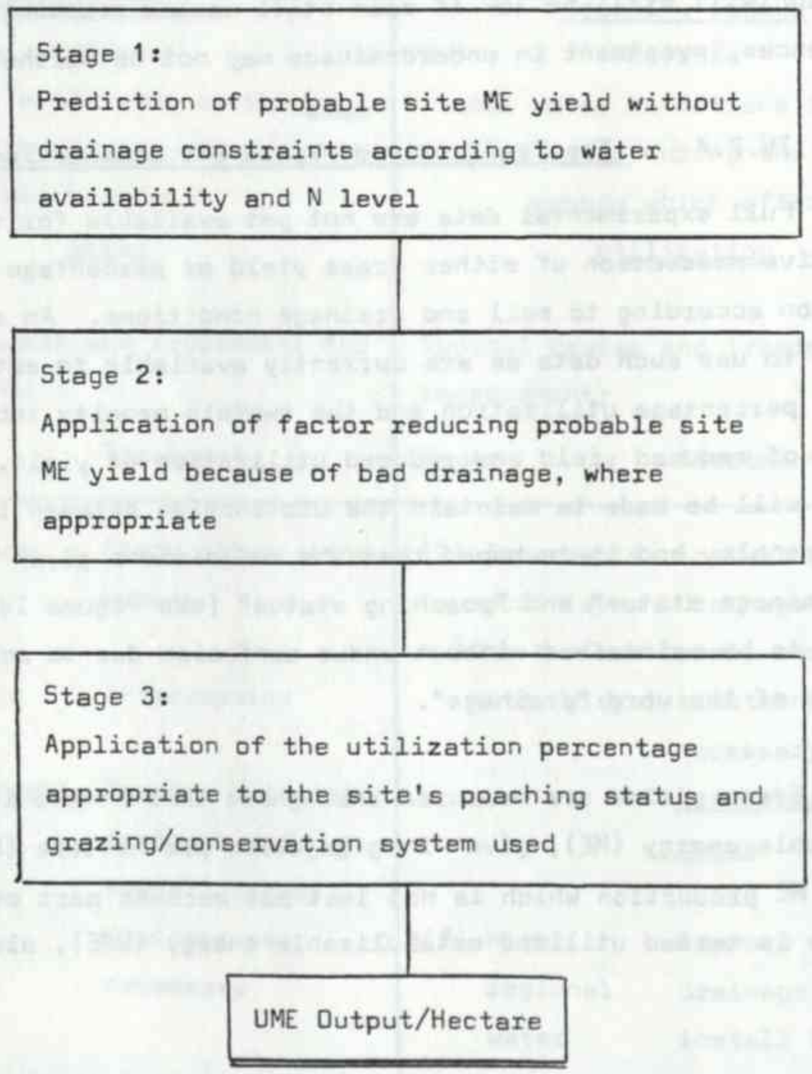
IV.3 METHODOLOGY

IV.3.1 Overview

A three stage method is employed, shown in Figure IV.2. UME output is calculated according to water availability (taking into account summer rainfall and soil type), nitrogen (N) level (taking into account both fertilizer and organic N), drainage status, poaching status and the system of utilization.

FIGURE IV.2

Method of Calculation of UME Output per Hectare



Stage 1 : Probable farm ME yields over a range of fertilizer N rates of application and a range of five site classes for water availability have been published by MAFF and are used as the basic data (MAFF, 1982; see also Annexe II). It must be remembered that these are the energy yields of grass in the field, before any deduction is made for energy losses during its utilization for animal production. Adjustment is made for N contributions other than fertilizer, eg. dung, farmyard manure.

Stage 2 : A penalty may be applied for wet soil conditions in spring resulting from waterlogging or flooding in winter or early spring up to 31st March. The grass production season is taken to be from April to September (six months). Bad drainage is considered to result in the loss of half a month's production, so that the probable farm ME yield for the season is reduced by 1/12 (8.3%) where this penalty is applied (see section IV.5.2.6). Very bad drainage is considered to cost a month's production, so that a reduction factor of 1/6 (16.7%) is used.

Stage 3 : A further penalty may be applied for wet soil conditions leading to lower utilization than on dry sites, mainly because of poaching. Where poaching is zero, utilization has been taken as 70% of probable farm ME yield for grazing or silage conservation systems and 60% for hay conservation systems (see section IV.5.2.8). Where poaching is a hazard utilization is reduced to 60% for grazing and silage systems and 50% with hay conservation (see section IV.5.1.3).

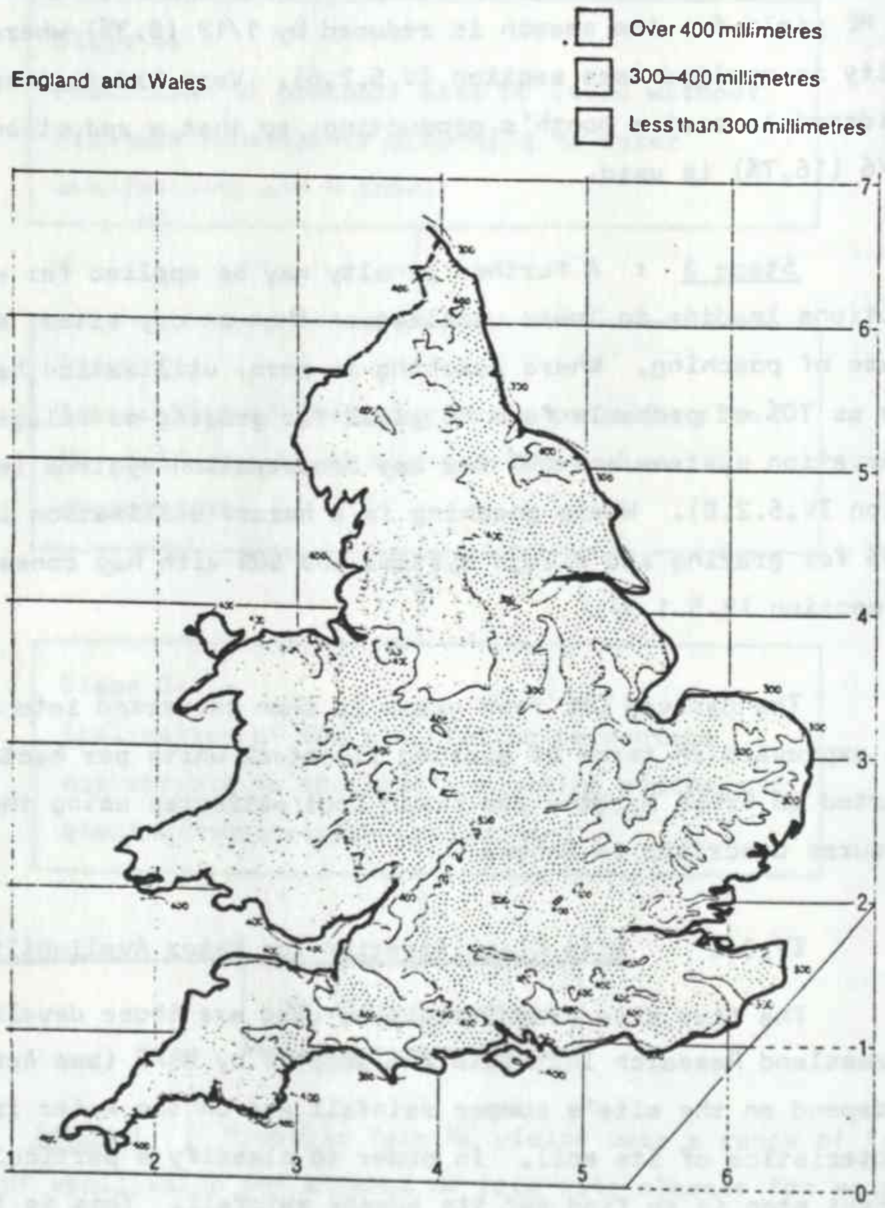
The derived UME from grass is then converted into stocking rates expressed in terms of grazing livestock units per hectare and converted to Gross Margins and Fixed Cost estimates using the procedures described in Annexe V.

IV.3.2 Site Classification for Water Availability

The five site classifications used are those developed by the Grassland Research Institute and adopted by MAFF (see Annexe II). They depend on the site's summer rainfall and on the water retention characteristics of its soil. In order to classify a particular site the first step is to find out its summer rainfall. This is largely a regional variable, as Figure IV.3 suggests, but account should be taken of local variations, which may be significant. The second step is to determine the available water capacity (AWC) of the soil, ie. the amount of water it holds per unit depth which is available for extraction by crops (see Table IV.1 or, for a more detailed treatment, Appendix IV.A). The site is assigned to one of three classes in each case and these are combined in a matrix to generate

FIGURE IV.3

Average Rainfall Summer Half Year (April-September)



the five overall classes for water availability, from Poor to Very Good (see Table IV.2).

TABLE IV.1

Available Water Capacities of Soils

AWC	Description
1. Low (100 mm)	Soils consisting of sand and gravel and shallow stony soils with rock at less than 40 cm
2. Medium (100 - 150 mm)	All soils not in the low or high group, including clay with flints over chalk, loamy soils with rock or gravel at 70 - 80 cm, poorly drained clay soils, shallow loamy soils over clay and loamy soils over chalk
3. High (Over 150 mm)	Deep organic and peaty soils, well drained loamy soils over 75 cm deep and well drained clay soils more than one metre deep

Source: MAFF (1982)

TABLE IV.2

Classification of Grassland Sites on Basis of Soil Available Water Capacity and Rainfall from April - September Inclusive

Soil available water capacity (mm)	April - September rainfall (mm)		
	Less than 300	300 - 400	More than 400
Less than 100	Poor	Fair	Average
100 - 149	Fair	Average	Good
More than 150	Average	Good	Very good

Notes: 1. Reduce by one class for altitude above 300 m

Source: MAFF (1982)

IV.3.3 Nitrogen Level

The supply of nitrogen (N) is a critical influence on grassland productivity. The rate of application of fertilizer N has been determined in this study by farmer questionnaire. If this type of information is not available Table IV.3 gives the average application by farm type. An addition needs to be made for organic N recycled in dung or manure. This depends on the stocking rate. The supply of organic N has been estimated at the rate of 23 kg N/grazing livestock unit/year. This represents the fertilizer equivalent of dung, urine, slurry or farmyard manure typically produced by one (600 kg) dairy cow. The assumptions are made that the beast produces 48 kg of dung and urine per day with a mean value of available nitrogen of 0.13% by weight.

TABLE IV.3

Average Fertilizer N Application by Farm Type (kg/ha)

Farm Type	Fertilizer N (kg/ha)
1. Dairy	154
2. Beef (excluding suckler herds)	65
3. Beef (suckler herds only)	42

Note: Appendix IV.D contains more refined data relating average fertilizer N application to climatic zones as well as farm type.

Source: Joint ADAS/GRI National Farm Study (Forbes et al. 1980)

IV.3.4 Site Classifications for Drainage Status and Poaching Status

Three classes are distinguished for drainage status, good (= G), bad (= B) and very bad (= VB), and two classes for poaching status, either zero poaching (= Z) or with poaching (= P). In combination these give six site classes for wetness limitations on productivity: GZ, GP, BZ, BP, VBZ and VBP. These classes are described briefly below and more details are given in Appendix IV.B.

Class GZ sites have no constraints due to soil or drainage conditions. Soil permeability is sufficiently high that summer rain does not cause poaching, nor winter rain waterlogging. Arterial drainage is adequate and neither flooding nor seepage are serious problems. Sites in this class may have winter floods of short duration provided that the soil is quite permeable and arterial drainage adequate for their dispersal, since such floods have little effect on yield. Soil types to be expected include deep loams, sandy soils, soils based in alluvial gravel, and well-structured clay loams. This class also includes sites with underdrainage provided there is no poaching hazard; surface water gleys, for example, are excluded from the group because even with underdrainage poaching is a hazard. Groundwater gleys may be placed in this group if they have underdrainage, but with reservations about their poaching status. Many such soils also have slowly permeable upper layers such that poaching is still a hazard even with underdrainage.

Class BP sites have bad drainage leading to wet conditions in spring, which reduce yields, and they also suffer from poaching, which reduces utilization. Where flooding, seepage or a regional high water table are the cause all soil types may be represented. Clayey soils will mostly fall into this class even without any influx of water in addition to rain unless they have good structure, layers of gravel or sand, or of course, underdrainage.

Class GP sites are those whose drainage is good, including those where underdrainage has been installed, but where the soil is weak after rain and poaching remains a risk which cannot be eliminated. As such, it is the highest class attainable on sites with low permeability at or near the surface such as those with clayey surface water gley soils.

Class BZ sites have soils with a high enough bearing capacity under summer water table conditions that poaching does not occur, but also have bad drainage in winter and spring, for example flooding or a high regional water table. Soil types to be expected are sands, gravels and peats and, in general, any permeable alluvial soils. Sites in this class do not have operational underdrainage.

Class VBP sites have such bad drainage that wet conditions persist throughout spring into the growing season, preventing early season utilization and further reducing overall yields. All soil types may be represented since such sites suffer from impeded arterial drainage leading to a high regional water table (or even standing water) and/or influxes of water from flooding or seepage.

Class VBZ sites are rare, since any site with such bad drainage is likely to have a poaching hazard whatever its soil type, and therefore be assigned to class VBP.

The questionnaire used in this study asked farmers to put their fields into one of the following categories (see Annexe III):

- rarely or seldom wet
- occasionally wet
- commonly wet
- permanently or usually wet

The farmers' opinions, in combination with information about flooding, were used to classify a site's drainage status. Sites described as "permanently wet" were likely to belong to drainage class VB. Sites described as "commonly wet" were assigned to class B and the others to class G. The poaching status of a site was determined by a consideration of the soil type and/or the farmer's assessment.

Appendix IV.B contains a guide to the six soil and drainage site classes to aid the classification of a site in practice. It is appropriate, though, to make a few remarks at this point concerning the classes. It is possible to define the wetness of a site in a more quantitative manner than is attempted here. This has been done, for example, by the Soil Survey in defining six Wetness Classes according to the relative duration of water tables at depths of 70 cm (affecting roots) and 40 cm (affecting both roots and bearing capacity) (Hodgson, 1976). This work points the way ahead, particularly as the Soil Survey covers and classifies ever larger areas of the country, but it is not thought to be suitable for present purposes for two reasons. Firstly, the determination of the Wetness Class requires careful and expert examination, preferably by the Soil Survey themselves. Secondly, the discrimination of six objective Wetness Classes is futile as long as it is not possible to relate yields to site wetness with equal discrimination and this cannot be done until experimentation in this country, currently getting under way (see section IV.5.1) begins to supply the missing data.

The approach taken in this Annexe in effect defines just three site classes, dry, wet or very wet. But each site is assessed twice, once in respect of yields ("drainage status") and once in respect of utilization ("poaching status"). This approach involves some oversimplification, notably that all sites with "good", "bad" or "very bad" drainage are equally good or bad, and that the drainage status of all sites can be improved by appropriate investments in flood alleviation, arterial drainage improvement, underdrainage and secondary treatments, irrespective of soil type (but with the caveat that poaching status may be incapable of improvement for certain soil types). The latter is an oversimplification because soil water conditions will always be wetter on less permeable, clayey soil even with underdrainage than on loams. These simplifications are felt to be justified because a greater range of site classes could not be related with any confidence to yields and utilization.

In addition to the guidelines in Appendix IV.B for the recognition of sites with bad drainage it may be worth repeating here that the general criteria used to define bad drainage are flooding or waterlogging through the winter which lead to wet soil conditions in spring, restricting root development and delaying the spring flush of growth.

IV.3.5 Operating Procedure

Table IV.4 gives the utilized metabolizable energy (UME) yield from a site with a given total N level and given site classes for available water, drainage status and poaching status. To identify the appropriate site classes and discover the UME yield the following procedure should be adopted:

(i) Identify summer rainfall from Figure IV.3 or local information.

(ii) Identify the available water content of the site's soil type from Table IV.1 (more detailed information is given in Appendix IV.A).

(iii) Refer to Table IV.2 and identify the site classification for available water.

(iv) Identify the level of fertilizer N application from farmer questionnaire or Table IV.3. Make the appropriate addition for organic N according to stocking rate. Add together fertilizer and organic N to give total N.

(v) Select drainage status on the basis of farmer questionnaire and other first-hand sources. Appendix IV.B sets out indicators of bad drainage.

(vi) Select poaching status. If this is not known independently, Appendix IV.B contains indicators of poaching.

(vii) Referring either to Table IV.4 or Figures IV.4 to IV.8 read off UME for the site. This figure applies to grazed grass and grass conserved as silage. For grass conserved as hay UME should be reduced further; multiply the figure for UME by 0.84.

TABLE IV.4

Estimated UME Output (GJ/ha); 5 Site Classification by Available Water at 2 Levels of Drainage and 2 Levels of Poaching

Site Class for Available Water	Drainage Status	Poaching Status	Total N (kg/ha) = fertilizer N + Organic N									
			0	50	100	150	200	250	300	350	400	450
Poor	G	Z	12	21	31	40	48	57				
	G	P	10	18	26	34	41	49				
	B	Z	11	19	28	36	44	52				
	B	P	10	16	24	31	38	44				
	VB	Z	10	18	26	33	40	47				
	VB	P	9	15	22	29	35	41				
Fair	G	Z	15	25	34	43	53	60	67			
	G	P	13	21	29	37	46	52	58			
	B	Z	13	22	31	40	49	55	62			
	B	P	11	19	26	34	42	47	53			
	VB	Z	12	20	28	36	44	50	56			
	VB	P	11	18	24	31	36	43	48			
Average	G	Z	18	28	38	47	57	64	71	76		
	G	P	15	24	32	40	49	55	61	65		
	B	Z	16	26	34	43	52	58	65	69		
	B	P	14	22	29	37	44	50	56	59		
	VB	Z	15	23	32	39	47	53	59	63		
	VB	P	13	20	27	34	41	46	51	54		
Good	G	Z	20	31	41	52	61	69	76	85		
	G	P	17	26	35	44	52	59	65	73		
	B	Z	19	28	38	48	56	64	69	78		
	B	P	16	24	32	41	48	55	59	67		
	VB	Z	17	26	34	43	51	58	63	71		
	VB	P	15	22	30	37	44	50	54	61		
Very Good	G	Z	24	34	45	55	65	74	80	85	90	
	G	P	20	29	38	47	56	63	68	73	77	
	B	Z	22	32	41	50	60	67	73	78	82	
	B	P	19	27	35	43	51	58	62	67	70	
	VB	Z	20	29	37	46	54	61	67	71	75	
	VB	P	17	26	32	39	47	53	57	61	64	

Note: For grass conserved as hay utilization is lower; UME should be reduced further; multiply the given figure by 0.84.

Source: Probable farm ME yields (MAFF, 1982), derived from ADAS/GRI GM-20 trials

Drainage status: G = good = no yield reduction
B = bad = 1/12 reduction
VB = very bad = 1/6 reduction

Poaching status: Z = zero = utilization of 70%
P = poaching = utilization of 60%

FIGURE IV.4

Estimated UME; AWC site class "Poor"

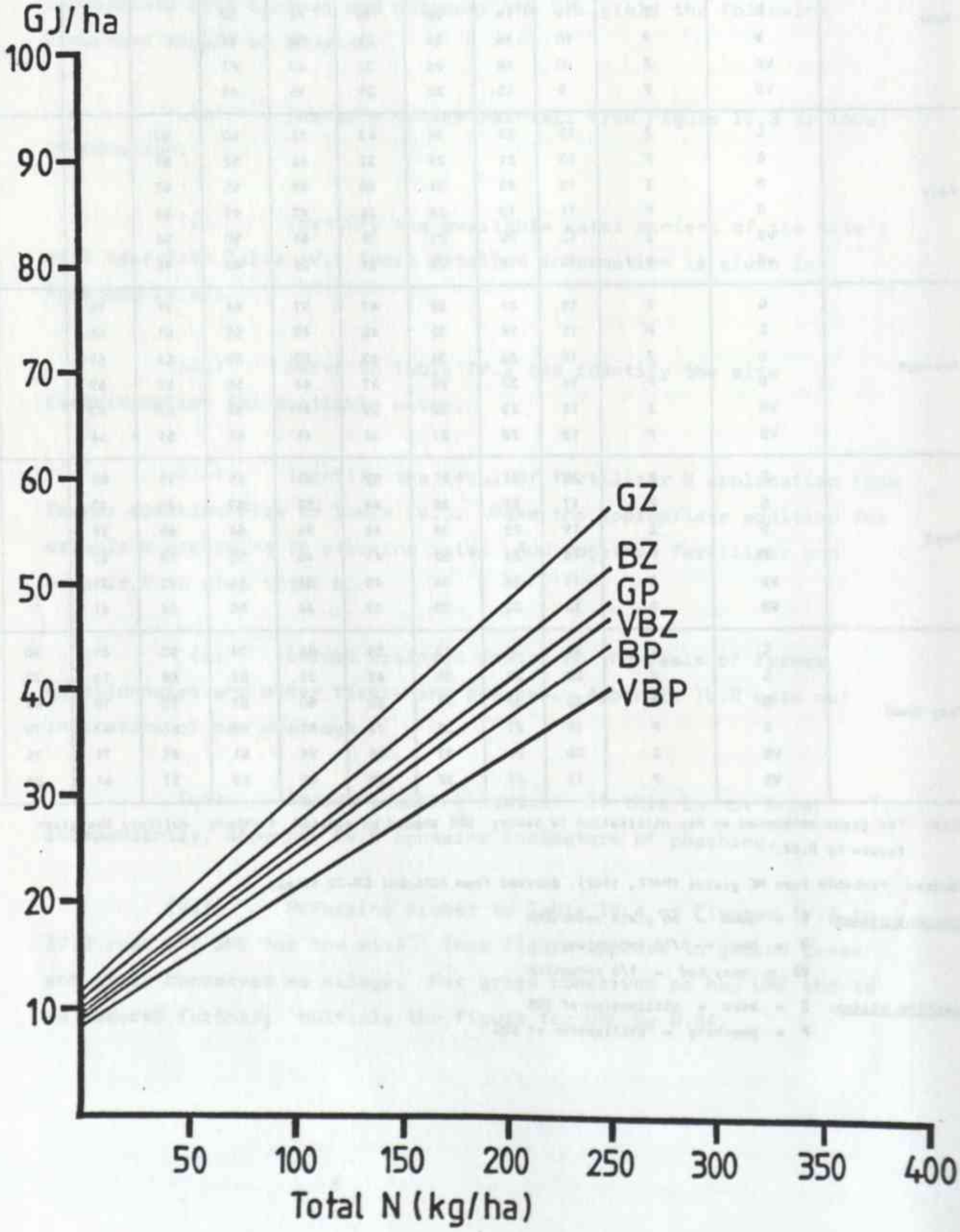


FIGURE IV.5

Estimated UME; AWC site class "Fair"

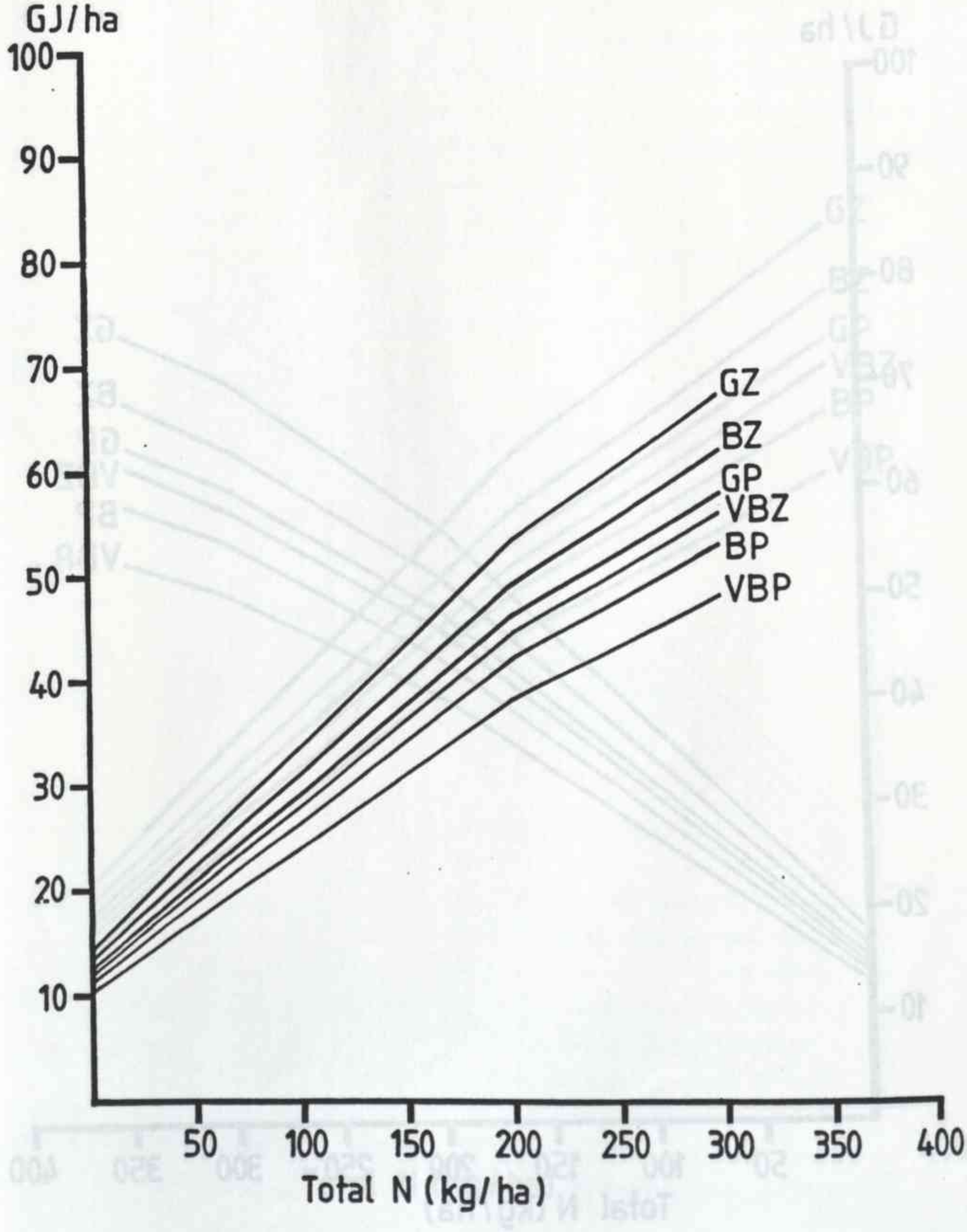


FIGURE IV.6

Estimated UME ; AWC site class "Average"

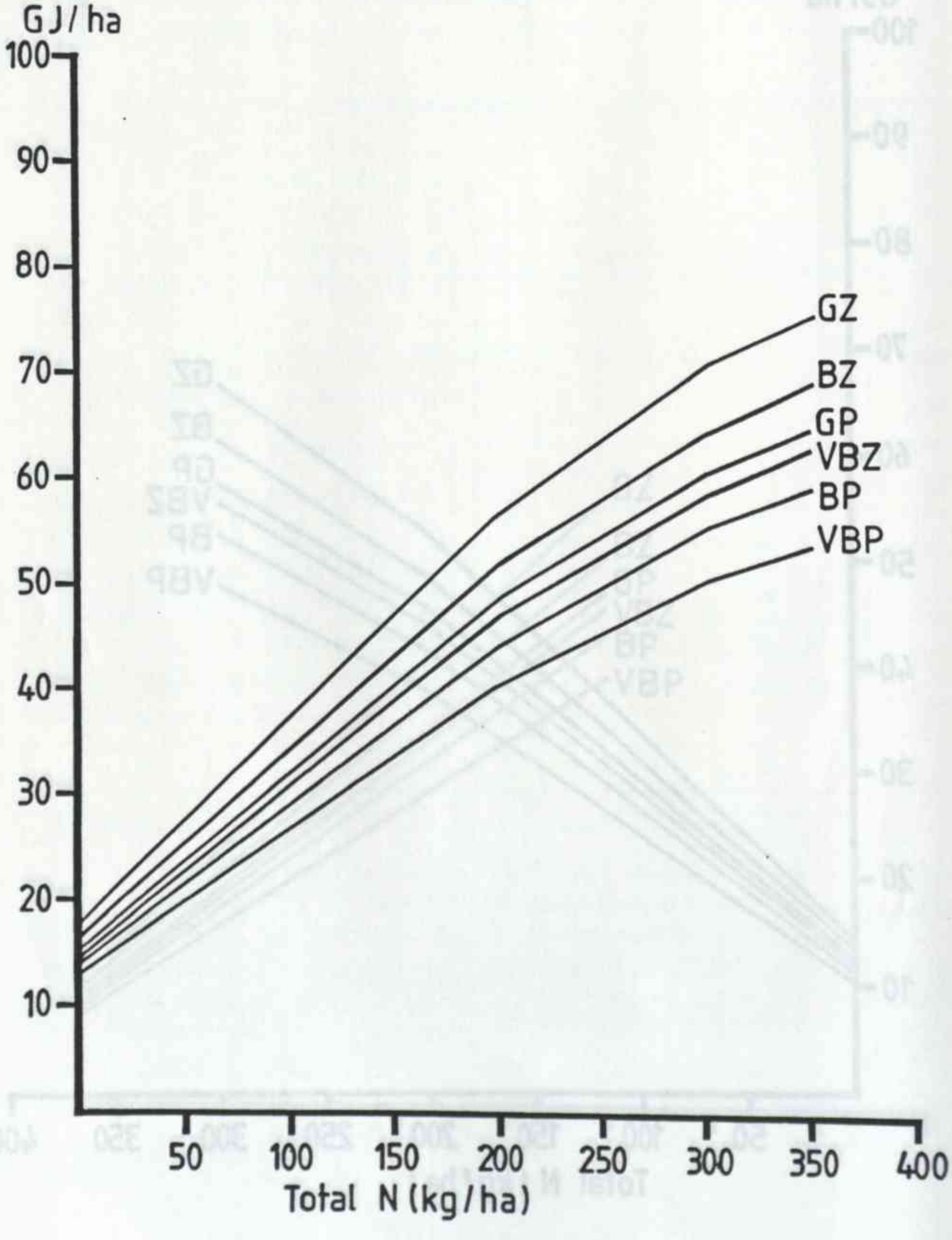


FIGURE IV.7

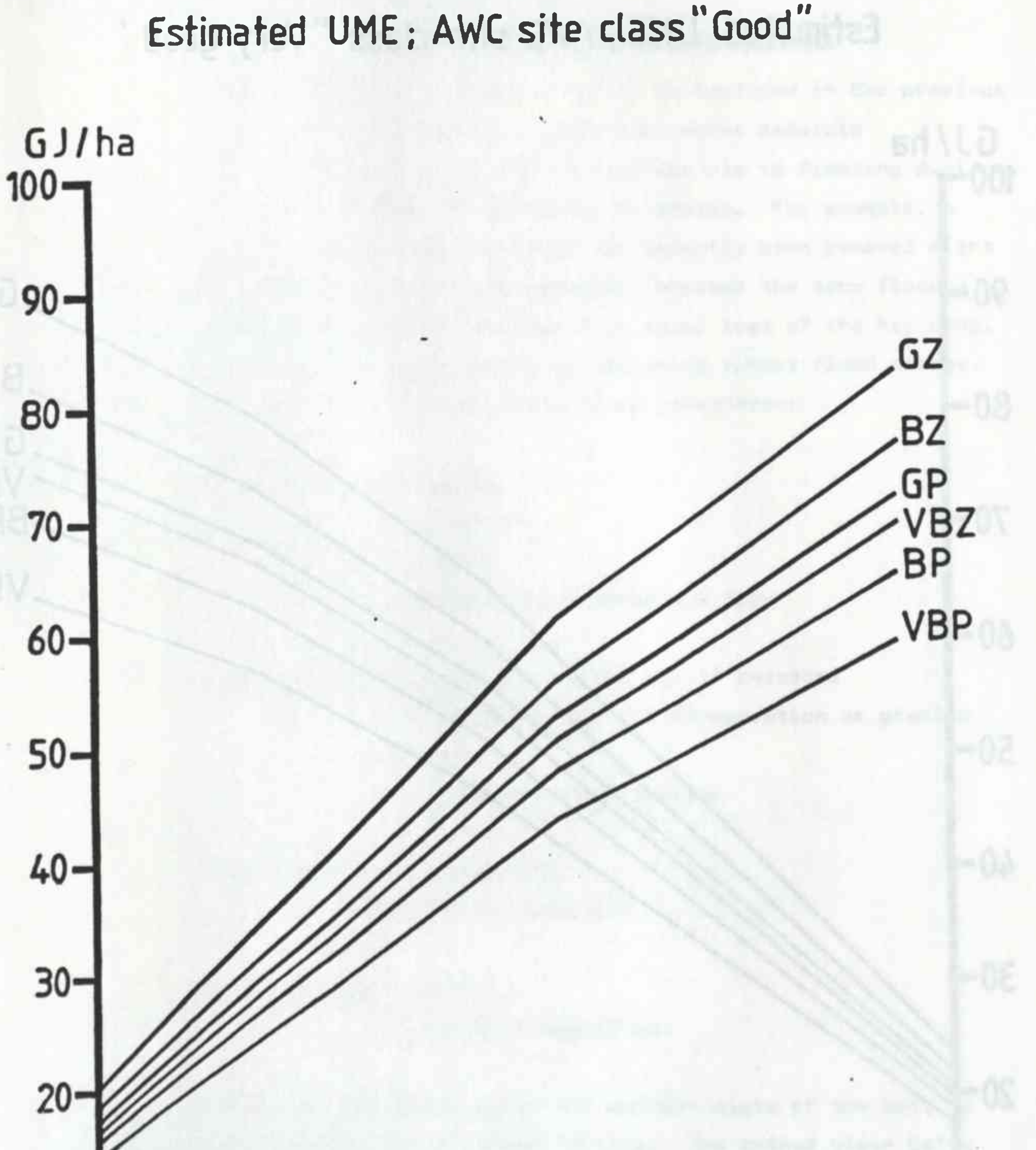
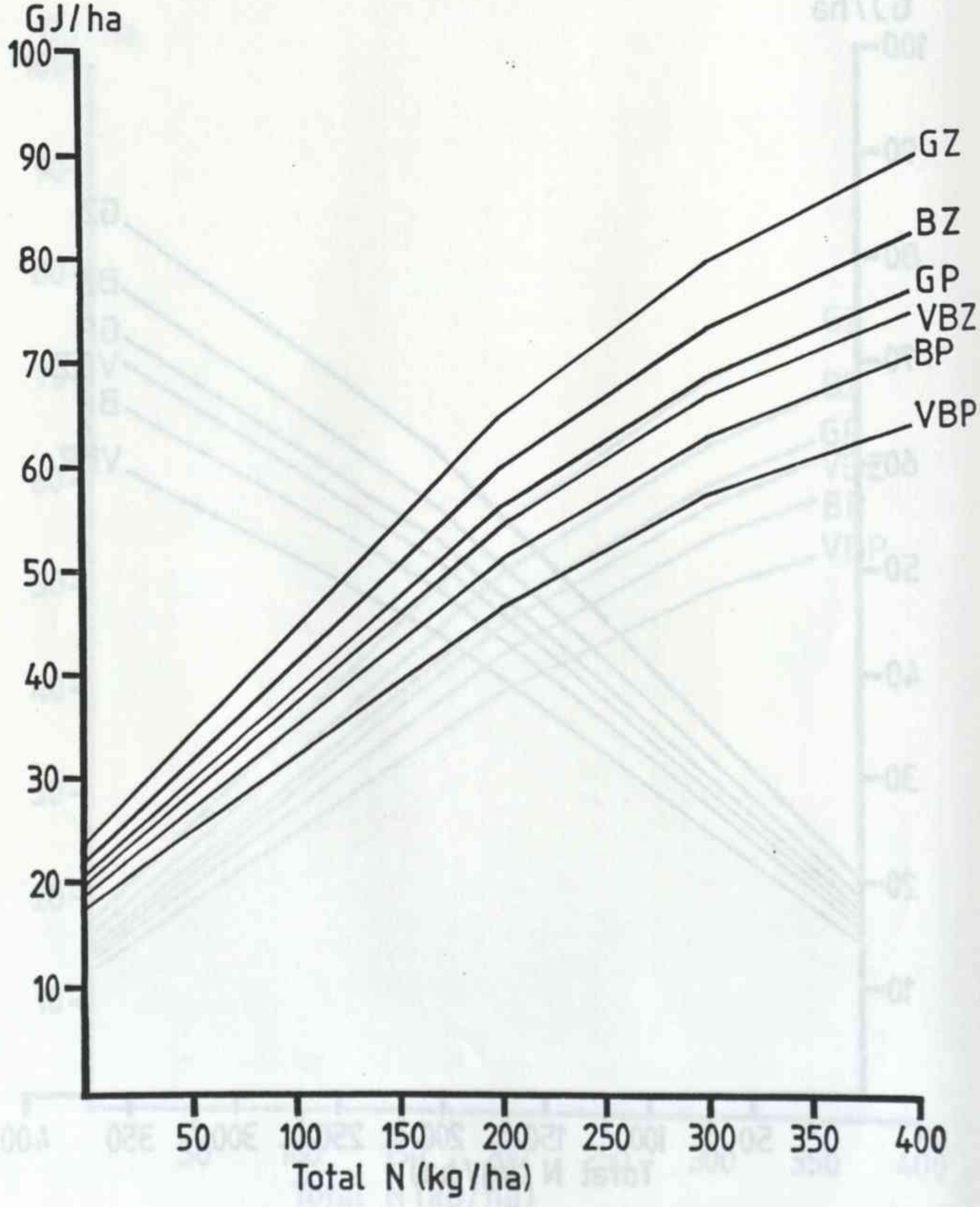

Estimated UME; AWC site class "Good"
GJ/ha
100
90
80
70
60
50
40
30
20
10
GZ
BZ
GP
VBZ
BP
VBP
50
100
150
200
250
300
350
400
Total N (kg/ha)

FIGURE IV.8

Estimated UME; AWE site class "Very good"



IV.4 FLOODING IN SUMMER

IV.4.1 Factors Affecting Summer Flood Damage

Winter flooding (October - March) is included in the previous section. Summer flooding (April - September) needs separate consideration. Lost production and utilization due to flooding during the grass production season is difficult to assess. For example, a summer flood on a field from which hay has recently been removed might cause no loss and might even be beneficial, whereas the same flood a fortnight earlier would have resulted in a total loss of the hay crop. Timing is just one important factor in assessing summer flood damage. The following groups of factors ought to be considered:

flood factors - timing
- duration
- depth
- occurrence of overland flow

crop factors - sward species and age if reseeded
- management (type of conservation or grazing system)
- fertilizer N application

soil factors - permeability
- strength when wet

water factors - quality
- sediment deposition

It is not possible, given the current state of the art, to include quantitatively all of these factors. The method given below attempts to take account of roughly half of them: flood timing and duration, crop management and fertilizer N application, and soil strength and permeability. In any particular case the damage calculated thereby may be open to revision in the light of local experience, particularly of the factors not taken account of. For example, sediment deposition may be locally very heavy, leading to a much greater retardation of growth than is allowed for. Figure IV.9 summarizes the logic of the method adopted.

FIGURE IV.9

UME Output Under Summer Flood Conditions

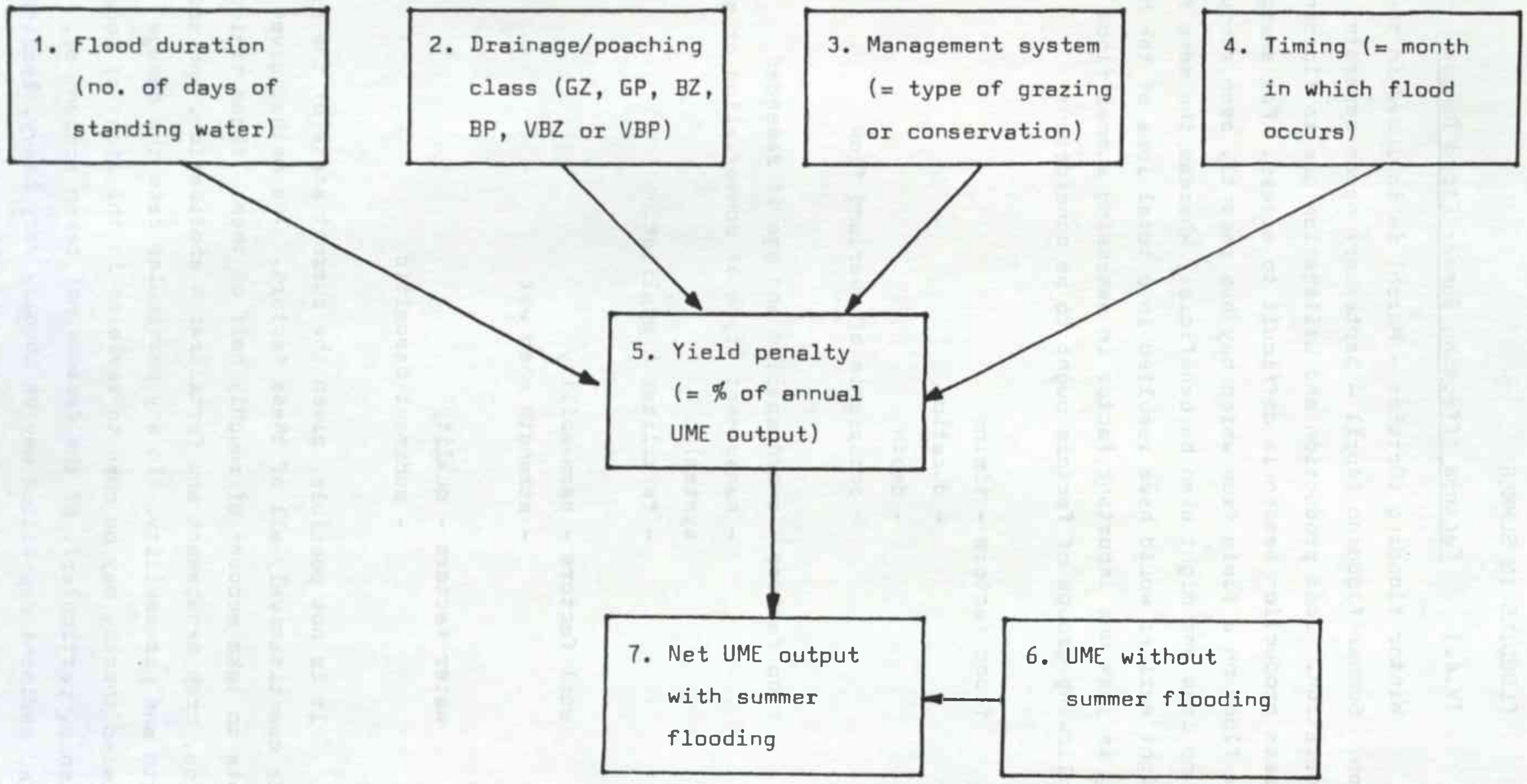


Table IV.5 gives the percentage of annual grass production occurring in each month from April to September for each site class of available water.

TABLE IV.5

Seasonal Distribution of DM/ME Production

% production in each month (April includes March production)

Site Class for Available Water	Month						Total
	April	May	June	July	August	September	
Very Good	14.8	29.2	17.9	15.4	12.8	9.7	100
Good	16.3	30.3	16.9	15.2	11.8	9.6	100
Average	18.0	31.7	16.1	14.3	11.2	8.7	100
Fair	20.2	34.0	15.3	12.5	10.4	7.6	100
Poor	22.6	37.5	14.1	10.9	8.6	6.3	100

Source: Growth curve of perennial ryegrass (cv. S.23) due to Corrall (1978)

IV.4.2 Method of Calculation of UME Output Under Summer Flood Conditions

(i) Select appropriate inputs for the following:

- flood duration (days of standing water)
  - = (a) 1 day (flash floods)
  - (b) 2 - 5 days (single floods)
  - (c) 6 - 10 days (single floods)
  - or (d) >10 days (multiple floods)

- soil/drainage class
  - = (a) GZ
  - or (b) other (ie. GP, BZ, BP, VBZ or VBP)

- management system
  - = (a) grazing
  - or (b) conservation

(ii) Identify the proportional UME penalty for these inputs from Table IV.6.

(iii) Select the appropriate month and identify the percentage of annual grass production affected by reference to Table IV.5.

(iv) Reduce accordingly the UME output without summer flooding, as calculated in section IV.3.

Appendix IV.C contains a worked example and some cases where the calculated flood damage may need to be revised.

IV.5 VALIDATION OF METHOD OF UME ESTIMATION

The theory and assumptions underlying the estimation of UME according to drainage and poaching status have been outlined briefly in section IV.1. They are stated more explicitly below, following a survey of published data which, in view of the lack of formal data, is offered in place of a formal validation.

IV.5.1 Data Survey

IV.5.1.1 ME Yields:

The MAFF figures for probable farm ME yields (MAFF, 1982) are derived from the GM 20 trials conducted by ADAS/GRI (Morrison et al, 1980).

IV.5.1.2 UME Yields:

Results from the ADAS/GRI National Farm Study (Forbes et al, 1980) are summarised in Table IV.7.

TABLE IV.6

Proportionate Yield Penalty of Summer Flooding According to Duration, Management System, Soil/Drainage Class and Timing

Flood Duration (Days of Standing Water)	Management System	Soil/Drainage Class	Timing (month)	Penalty
1 day	Grazed	GZ	Any	Nil
	Grazed	Other	Any	1/3 x production of month of flood
	Conserved*	GZ	April/May	Nil
	Conserved*	GZ	June	2/3 x production April - June
	Conserved*	Other	April/May	All production of month of flood
	Conserved*	Other	June	All production April - June
2-5 days	Grazed	GZ	Any	1/3 x production of month of flood
	Grazed	Other	Any	2/3 x production of month of flood
	Conserved	GZ	April/May	All production of month of flood
	Conserved	GZ	June	All production April - June
	Conserved	Other	April/May	All production of month of flood
	Conserved	Other	June	All production April - June
6-10 days	Grazed	GZ	Any	2/3 x production of month of flood
	Grazed	Other	Any	All production of month of flood
	Conserved	All	April-June	All production up to and including month of flood
Over 10 days	Grazed	All	Any	All production of month of flood
	Conserved	All	April-June	All production up to and including month of flood

* Either hay or silage, assumed to be cut on 1st July and grazed afterwards. If a 2-cut silage system is in use, assume that the first cut is taken on 1st June and extend period of conservation

TABLE IV.7

Summary of Results of the ADAS/GRI National Farm Study

Farm Type		Farm ME (GJ/ha)	UME (GJ/ha)	Utilization (%)	N Fertilizer (kg/ha)	Stocking rate (LU/ha)
Dairy	Top third	-	57	-	196	2.2
	Average	70	44	63	154	1.8
	Bottom third	-	31	-	121	1.5
Beef (excl. suckler herds)	Top third	-	54	-	95	1.7
	Average	55	40	73	65	1.3
	Bottom third	-	28	-	48	1.1
Beef suckler herds	Top third	-	50	-	53	1.5
	Average	50	38	76	42	1.2
	Bottom third	-	25	-	30	0.9

Source: Forbes *et al* (1980)

UME estimated by the method presented in this Annexe, assuming a site classed 'Average' for AWC and appropriate nitrogen inputs, is slightly higher than that observed by the National Farm Study for dairy farms but lower for beef farms. Table IV.8 compares observed UME with estimated UME.

TABLE IV.8

Comparison of Estimated UME and National Farm Study Data

	UME Observed by the National Farm Study (GJ/ha)	Estimated UME (GJ/ha) Site class:	
		Average/BP	Average/GZ
Dairy farms average: (Fertilizer N = 154 kg/ha, Stocking rate = 1.8 LU/ha)	44	43	56
Beef (non-suckler) average: (Fertilizer N = 65 kg/ha Stocking rate = 1.3 LU/ha)	40	29	37
Beef (suckler) average: (Fertilizer N = 42 kg/ha Stocking rate = 1.2 LU/ha)	38	25	32

For the beef farms this difference in UME arises because the utilization efficiencies found in the National Farm Study are higher than those assumed in this Annexe, at 73% for non-suckler and 76% for suckler beef. This possibly reflects the easier management of these less intensive systems. Farm ME levels, however, were in the range estimated by MAFF and used herein. Utilization found on dairy farms in the National Farm Study was, at 63%, within the range allowed for in this Annexe, but farm ME yields were rather lower than predicted, so UME estimations were also lower.

The Milk Marketing Board's analysis of Farm Management Services costed farms (MMB/FMS, 1982) compares the performance of the top and bottom 25% of farms in their sample when ranked according to gross margin per hectare. The top farms in this financial ranking, though, may owe their position to a higher level of farm or financial management rather than possession of a favourable site. Farm ME is not stated, so it is difficult to relate the observed UME figures given to the site classes used for estimation. Nevertheless, if the top 25% of farms are assumed to have a site classed 'Good' for available water and no drainage or poaching penalties (ie. class GZ) and the bottom 25% are assumed to have a site classed 'Average' for available water and 'BP' for drainage and poaching, some sort of comparison can be made, using the N level given for the FMS costed farms. Table IV.9 compares UME estimated on these assumptions with the FMS figures.

The FMS sample as a whole is of farms larger and more progressive than the average and so the top 25% can be taken as a guide to the maximum currently attained in practice by the better farmers on the better sites.

The ICI DAIRYMAID scheme records the performance of farms ranked by margin over feed and forage. In 1981 UME for the top 25% of farms recorded was 91 GJ/ha (summer milking) or 85 GH/ha (winter milking), compared with 64 and 68 GJ/ha respectively for the bottom 25%. These figures represent a further step away from the average level of management towards the optimum and are probably recorded on sites somewhat above average.

Another set of data showing the level which can be reached with good management concerns silage beef production (zero concentrates) on a farm run by the Weed Research Organisation (Elliott and Dale, 1980). Productivity on a site thought to be of class 'Good' for available water but class BP for drainage and poaching status ranged from 41 GJ/ha in 1975-76 to 87.9 GJ/ha in the best year recorded, 1977-78. Fertilizer N application was 140-190 kg/ha and stocking rate around 1.6 LU/ha. Estimated UME output for these inputs (1.6 LU/ha, fertilizer N application of 165 kg/ha and composite site class Good/BP) is

TABLE IV.9

Comparison of Estimated UME and MMB/FMS Data

	UME Observed by FMS (GJ/ha)	UME Estimated (GJ/ha)
Top 25% FMS costed farms (Fertilizer N = 313 kg N/ha, Stocking rate = 2.41 LU/ha, Assumed site class = Good/GZ)	81.9	84
Bottom 25% FMS costed farms (Fertilizer N = 212 kg N/ha, Stocking rate = 1.5 LU/ha, Assumed site class = Average/BP)	46.1	50

49 GJ/ha, whereas the average UME output recorded was 66 GJ/ha. This type of livestock system (zero concentrates) will in any case tend to give high UME figures as a result of the way UME is calculated. The high output of UME in this case, however, probably reflects the high level of management rather than anything else. In particular, well managed fertilizer application resulted in a well-composed sward despite the handicap of a wet site.

National and regional averages for UME output are available from various sources, and are listed in Table IV.10. They vary according to the sample, reflecting variation in the level of inputs, particularly of fertilizer N, and in management. Nevertheless, they show that the average site ought to have a UME output in the range 40-60 GJ/ha, depending whether management is average or higher.

The National Farm Study gives an overall UME output for all types of enterprise of 41.5 GJ/ha, with a mean level of fertilizer use of 101 kg N/ha and a mean stocking rate of 1.50 LU/ha. With these inputs and a site classed 'Average' for available water, estimated UME varies between 35 and 45 GJ/ha according to drainage and poaching status, the mean being 40 GJ/ha. It is felt that this comparison, with the others made above, indicates that the method of estimation gives UME figures very close to those appearing in the most reliable surveys.

IV.5.1.3 Utilization Efficiency Estimates:

Utilization efficiency was estimated at 69.5% overall for the purposes of evaluating land drainage benefits for a scheme in Ireland (Walsh and Lee, 1983). There are some indications that utilization is higher in general in moister areas, where grass growth is more reliable and therefore management easier (Wolton and Brockman, 1979). Since the figure of 69.5% applies to an area of high rainfall as compared to Southern England, it may be considered a 'high average'. Recent work concerning farms in Buckinghamshire (Peel, 1982) gives a calculated utilization (for one year only) of 70% on the best-drained farm, which was on chalk, going down to 44% on the worst-drained farm, which was on Oxford clay. Similar work in Devon gave a range from 72%

TABLE IV.10

Average UME Output (GJ/ha)

	UME (GJ/ha)	Date	Source	Reference
National Averages	41.5	1975-78	ADAS/GRI	Forbes *et al* (1980)
	52	1977-78	NIEMP	MMB (1978)
	56	1977-78	MMB (LCP)	Amies *et al* (1978)
	64	1978	ICI	ICI (1978)
	37	1976	GRI	Green and Baker (1981)
Regional Averages				
East Midlands	40	1975-78	MMB (LCP)	Peel and Matkin (1982)
	47	1976-79	BOCM (Silcock)	Peel and Matkin (1982)
West Midlands	53	1975-80	MMB (LCP)	Peel and Matkin (1982)
	54	1976-79	BOCM (Silcock)	Peel and Matkin (1982)

to 58% according to the standard of drainage and soil type. Poor utilization was due, not simply to poaching itself, but to understocking, which prevented poaching but wasted grass.

These figures are felt to accord reasonably with the figures of 70% and 60% chosen in this Annexe (60% and 50% respectively for hay conservation).

IV.5.1.4 Effect of Drainage on Yields:

No experimental data are as yet available for the yield response of grass in the U.K. to drainage. An experiment initiated in 1982 by FDEU and GRI (North Wyke) should provide this data and results are awaited with some eagerness. The first indications are that drainage has improved the bearing capacity of the soil (which is only slowly permeable throughout the profile), so that access at least has been improved; this ought to lead to better utilization (ie. poaching status).

A MAFF experiment at Hayes Oak (A. Parker, personal communication) is also under way and shows an average dry matter (DM) yield which appears 13% higher on drained compared to undrained plots. This is a preliminary result from 3 years' data. The site suffers from both impermeability and high water table problems.

In the Netherlands, de Jong (1982) measured the yield depression below potential due to excess water. He found that underdrainage of grassland resulted in an improvement in yield up to a maximum of 14-20% depending on soil type and pre-scheme groundwater table levels. In the method of UME estimation given in this Annexe the increase in yield resulting from the improvement of drainage status from 'Bad' to 'Good' following underdrainage would be 8.3%. In the case of a site previously regarded as permanently wet and classified as 'Very Bad' an improvement of 16.7% is possible. These estimated improvements therefore fall within the range found by de Jong.

The National Farm Survey (Forbes et al, 1980) found no simple correlation between UME and drainage. An indirect effect was found whereby bad drainage had a significant effect on sward composition which in turn had an effect on UME output when associated with other factors affecting the overall manageability of the land.

IV.5.2 Theory and Assumptions

This method of UME estimation contains a number of assumptions, some born of the need to simplify complex subject matter, some born of the lack of experimental data. The main assumptions are listed below and where they imply a particular theory of grassland response it is discussed briefly.

IV.5.2.1 Farm Yield Levels:

The MAFF estimate of probable farm yields are based on the GM-20 and 21 trials but make a deduction of about 12% from the experimental results to arrive at estimated farm yields. This deduction is based on these assumptions (MAFF, 1982):

- less frequent cutting, as on farms, increases DM yield as compared with a monthly, experimental cutting pattern

- experimental plot yields overestimate farm yields

- under actual grazing, as distinct from simulated grazing, the animal's presence does not affect yield

- ME output is not affected by the wider botanical diversity of farm sward in comparison with perennial ryegrass, which was used in the trials

- DM is proportional to ME in the ratio 10.5 MJ/kg DM

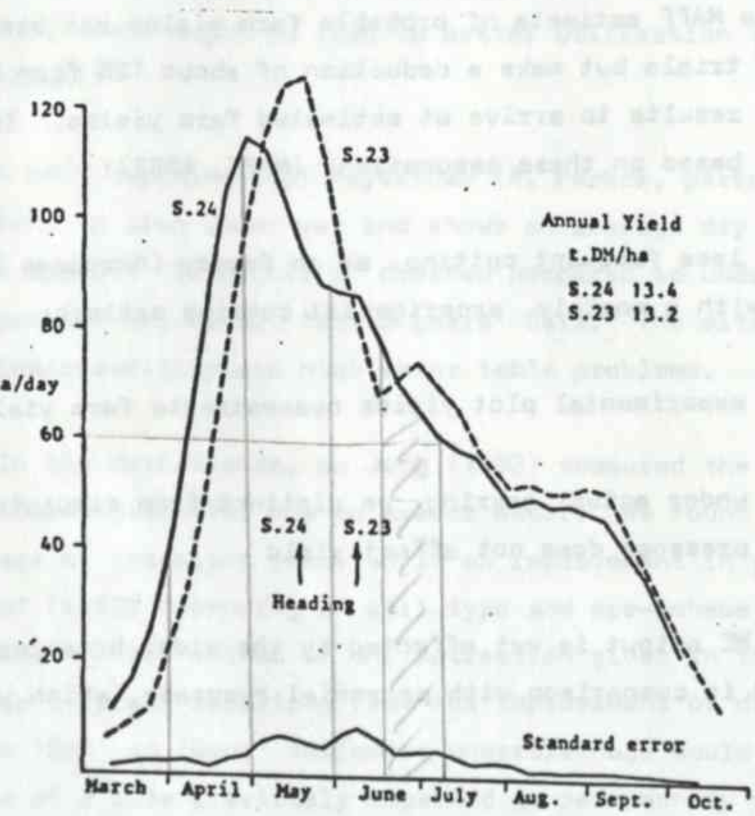
MAFF also suggest adjustments to be made in respect of available soil N, the N contribution of clover in mixed swards and of farmyard manure and slurry. These have been simplified for present purposes.

IV.5.2.2 Growing Season:

Grass grows all year round, merely slowing in winter, but as Figure IV.10 shows the bulk of production occurs between April and September. This period is therefore taken as the grass production season, even though growth actually begins to speed up in March over most of the study area. Some parts of the country, especially in the south and west, experience an autumn flush of growth because rain reduces the soil water deficit before the temperature falls below the point where grass growth slows drastically. Only the fringe of STWA's area is thus affected, however, and no allowance is made for the contribution of an autumn flush, although a note in Appendix IV.B describes a possible adjustment.

FIGURE IV.10

Seasonal Grass Growth



Corrall. A.J.
(1976)

IV.5.2.3 Management:

An average level of management is presumed. UME output is sensitive to the level of management but no attempt is made here to allow for variation in this respect. The observed rate of N fertilizer use and the systems of grazing and conservation provide an insight into management expertise and are automatically included in the analysis.

IV.5.2.4 Dry Years:

Wet sites may have a benefit not accounted for in this estimation of productivity, namely their utility value in dry years. It is conceivable that the benefit of a wet field as insurance against drought may outweigh the penalty suffered in wet years, if the effect on the whole farm is considered.

IV.5.2.5 Groundwater Contribution:

No allowance is made for any groundwater contribution to grass production. This undoubtedly happens on many sites but it is exceptionally difficult to assess, especially as a high water table implies some deleterious effects such as low soil nitrogen.

IV.5.2.6 Yield Penalty of Bad Drainage:

It is assumed that bad drainage delays spring growth and reduces overall yield. While there is no doubt that wet soil in spring delays growth because of the controlling effect of soil temperature on the rate of grass growth and of nitrification, it may be argued that overall production on wet sites will be the same as on dry sites, merely occurring later. There is no conclusive evidence to settle this argument either way but the following reasons are adduced to defend the assumption made that overall production is <u>reduced</u> by wet soil conditions in spring and not merely <u>delayed</u>.

(i) A delay in spring growth reduces the total amount of water available to the sward in the growing season. Rain falling during the delay period is lost to drainage and the higher evapotranspirative demand in summer exhausts soil water faster so that the growing season is effectively compressed.

(ii) N fertilizer is less effectively used due to the abbreviation of the period between its application becoming possible and the time in summer when it is unavailable to the plant because of dryness in the upper soil layer.

(iii) Root development is reduced.

(iv) Sward composition is adversely affected.

(v) Soil available nitrogen is reduced.

The size of the yield penalty has been set by approximating the effect of compressing the grass growth curve by a typical delay period as found in the Silsoe College farm survey. A typical delay period in spring on wet sites was found to be two weeks, taken as half a month for convenience. It has been assumed that all parts of the growth curve (Figure IV.9) are compressed equally, so that the amplitude of the spring peak is the same but its duration reduced. If the grass production season is taken as six months (April to September) the loss of half a month's production implies, on these assumptions, a reduction in seasonal yield of one-twelfth (8.3%) on sites with typically 'Bad' drainage status.

The actual penalty in a few cases will be greater than the typical penalty for a site with 'Bad' drainage. A delay of one month may be more appropriate. Using similar logic a reduction in yield of one-sixth can be made in such cases, classified as having 'Very Bad' drainage status.

The assumptions made above mean that the UME estimations are applicable only for lowland sites in central England.

IV.5.2.7 Effectiveness of Drainage:

There is enormous variation due to both sites and soils in the degree of improvement of soil water conditions which it is possible to achieve through drainage. No attempt is made to reflect this variation and it is assumed that in all cases an improvement is possible of the size implied by the difference in UME output under 'Good', 'Bad' or 'Very Bad' drainage status.

This is clearly a simplification. In practice the benefit from drainage may be smaller than this, for example in cases where the soil is particularly difficult to drain, such as soils which combine very slow permeability with poor suitability for moling.

IV.5.2.8 The Productivity of Hay and Silage Systems:

Grass conservation is critical for the management of overwintered stock. In winter, forage demand exceeds grass production, whilst in spring grass sopply usually exceeds the demand of grazing stock. The forage conservation system is the link between seasonal grass production and all year round feed requirements. Improvements in forage conservation technology can increase annual stocking rates by exploiting grass production peaks. Improved drainage conditions encourage more intensive grazing management usually associated with higher nitrogen use. This in turn encourages the adoption of more sophisticated and reliable silage systems.

The critical variables defining the performance of the conservation system are dry matter loss and digestibility. Silage systems have been popular because they can avoid the considerable dry matter and digestibility losses associated with making hay in poor weather conditions (Wilkinson, 1979).

Haymaking, whereby grass previously closed off to stock is cut, field dried for three to eight days and baled at about 85% dry matter content, is notoriously susceptible to weather conditions during the harvesting period. Dry matter losses in field range between about 12% and 30% for good and poor weather conditions respectively (Zimmer, 1977).

Silage making can involve a range of cutting, wilting, packaging and storing permutations. Direct cut silage is taken at 20-25% dry matter, whereas wilted silage left for one to four days in the field, can range between 25% and 50% dry matter. Wilted silage is a more concentrated product and has advantages during fermentation, storage and handling. Furthermore, it gives lower overall dry matter losses, since the much lower storage losses outweigh slightly higher harvesting losses as compared with direct cut silage. It is, however, at risk from rain during the period of wilting.

For the purpose of assessing the productivity of alternative conservation practices, a broad distinction is made btween hay and silage making in terms of likely UME. Grazing, silage and hay systems are considered to offer equivalent farm ME productivity. From the point of view of utilisation, grazing and silage making are assumed to achieve similar rates (70%) (Holmes, 1980), but hay making due to greater losses of dry matter and digestibility is assumed to be less efficient (at 60%) (Wilkinson, 1979). Thus whereas 1 kg DM of grass cut for silage is assumed to produce 10.5 MJ (UME), 1 kg DM of hay generates 8.8 MJ (UME). Silage making therefore offers greater stock carrying potential.

In addition to the choice of hay versus silage, farmers can choose single or multiple cutting regimes, with the residual used for aftermath grazing. Multiple cutting is usually associated with higher digestibility and therefore higher GJ/kg DM. The number and timing of cuts are the main determinants of the proportion of total annual grass production conserved, as shown in Table IV.10. These proportions, derived from Doyle (1982) and based on Corrall (1978) (see Figure IV.9), are applied to relevant site/drainage class yield estimates to estimate the energy value of conserved grass.

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APPENDIX IV.A

THE AVAILABLE WATER CAPACITY OF SOILS

Soils are usually classified in one of two ways, either by their texture (the relative proportions of particles of different sizes) or by their soil series or association (their resemblance to certain characteristic soils named from the place where they were first identified) as defined by the Soil Survey. Texture can be established in the field by auguring profile samples and hand-texturing, in other words assessing the texture by feel. Soil series and associations can be found from the Soil Survey maps.

A.IV.A.1 Relation Between AWC and Texture

Table IV.1 should be enough to classify soils in most cases. The exact AWC, though, can be determined from Table A.IV.A.1 below. AWC is given in mm per 30 cm depth of soil from two sets of data. In order to calculate overall AWC this figure should be multiplied up to give the quantity of available water contained in the root zones, which is taken to be 1.0 m for present purposes unless an obstructing layer is present which limits root development. Such a layer may consist of rock or chalk and be easily recognised but it may also consist of clay, if it is dense or poorly structured, and be harder to recognise. Visual examination of the profile should reveal both the depths of the soil textures making up the profile and the rooting depth. It is sometimes difficult to pick out the root zone, though, especially as a few dead roots may remain where a clay layer has cracked during a drought year, allowing root penetration where ordinarily there is none. Indications that a clay layer will obstruct roots are its wetness and structure (ie. the formation of soil material into units, or peds). Permanently wet clay layers or ones with large, tight structures, offering few channels for roots will both obstruct root development. A guide to the recognition of such features (eg. gleying) is given in the Soil Survey Field Handbook (Hodgson, 1976). Detailed information describing soil profiles in a locality may be available where there has been a detailed Soil Survey (published as Soil Survey Records). See also Soil Survey Technical Monograph 9 for a full explanation of the principles and criteria involved (Hall *et al*, 1977).

A high water table will also restrict roots but its effect on water availability is uncertain because if it remains high, not receding beyond the range of the roots, it will supply a certain amount of water to the roots by capillary action. This groundwater contribution is extremely difficult to estimate and for present purposes it is suggested that all sites with a summer water table within 1 m of the surface should be placed in group 'Medium' (100 - 150 mm) for AWC except for coarse sands and gravels which should be placed in group 'Low' (less than 100 mm) because of their limited capillary fringe, unless there is positive information that the water table remains not only high but steady throughout the summer. It should be noted that a fluctuating water table reduces the groundwater contribution. There needs to be a zone where the balance of water and air encourages water uptake by roots. Excess water inhibits root growth and dryness inhibits water uptake.

FIGURE A.IV.A.1

Soil Particle-Size Class Diagram

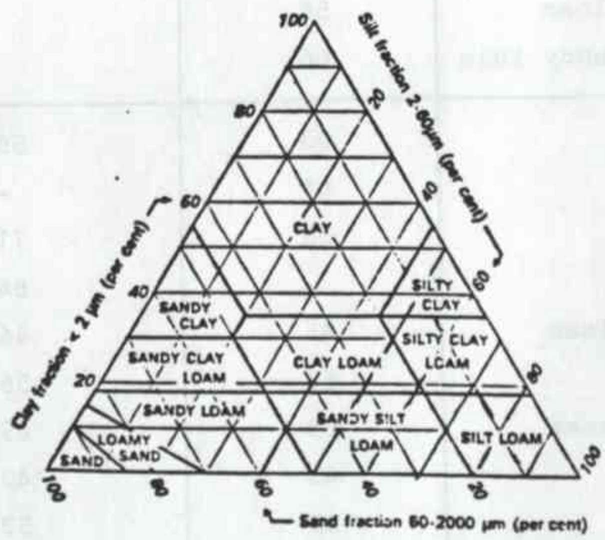


TABLE A.IV.A.1

Mean Values of AWC (mm/30 cm) by Textural Class

Texture Class	Data of Pizer (1963)	Data of Soil Survey (1960)
Sands:		28-51 (sands)
Coarse sand	25	
Sand	46	
Fine sand	61	
Very fine sand	69	
Loamy sands:		33-56 (loamy sands)
Loamy coarse sand	33	
Loamy sand	48	
Loamy fine sand	58	
Loamy very fine sand	66	
Sandy loams:		41-66 (sandy loams)
Coarse sandy loam	38	
Sandy loam	53	
Fine sandy loam	58	
Very fine sandy loam	66	
Loam:	53	56
Silty loam	61	-
Silt loam	58	71
Silt	-	84
Sandy clay loam	46	46
Clay loam	56	56
Silty clay loam	58	69
Sandy clay	43	43
Silty clay	53	53

Source: Salter and Williams (1967)

A.IV.A.2 Relation Between AWC and Soil Association or Series

For ease of reference the AWC is given below of some soils commonly occurring in areas of land drainage. Some have already been published by the Soil Survey while others have been calculated for present purposes from representative profiles. The table gives available water for a root zone of 100 cm and this should be adjusted pro rata where the root zone is restricted for any reason to a shallower depth. Soils where this is relatively common are indicated. AWC is also lower if the soil in a particular site is stony or is coarser than usual for the type represented (whether coarser in texture for upper layers or in structure for lower, clayey layers). Organic carbon percentage and bulk density also affect the AWC but for present purposes it is not proposed to attempt to account for variation due to these factors, considerable though it is.

TABLE A.IV.A.2

Representative Values of AWC for Some Common Soils (mm)

AWC = water held between 0.05 and 15 bar to a depth of 100 cm. This figure should be reduced pro rata where the soil available for rooting is shallower.

Soil Series	AWC (mm)	AWC class[1]
Arrow	100-200[2]	Medium/high
Blacktoft	160	High
Blackwood	130[3]	Medium
Brockhurst	170	High
Clifton	150[3]	Medium
Compton	160	High
Conway	160	High
Crewe	140	Medium
Denchworth	160	High
Evesham	170[3]	High
Fladbury	160[3]	High
Flint	120	Medium
Newport	75-150[2]	Low/medium
Quorndon	100-200[2,3]	Medium/high
Salop	135	Medium
Sherborne	55[4]	Low
Spetchley	120	Medium
Stixwould	140	Medium
Tewkesbury	170	High
Thames	125	Medium
Whimple	140	Medium
Wick	100-200[2]	Medium/high
Worcester	115[3]	Medium
Wyre	150	Medium

Notes:

1. AWC classes are: Low = 100 mm
   Medium = 100-150 mm
   High = 150 mm
2. Varies greatly according to content of fine sand and organic matter.
3. Lower if there is a rooting restriction.
4. Roots normally restricted to 35 cm.

APPENDIX IV.B

INDICATORS OF DRAINAGE AND POACHING STATUS

A.IV.B.1 Drainage Status

The principle underlying the classification of drainage status is that bad drainage reduces yield by restricting root development and keeping the soil wet and therefore cold into spring, beyond the point where the spring flush of growth is under way on well drained sites. Ideally, then, one would classify a site by measuring root development and spring soil temperature, or at least by observing the onset of rapid growth as compared to a nearby site whose drainage status is plainly good. Soil temperature measurements are unlikely to be available but criteria can be suggested for assessing root development and spring growth. These are given below, along with other indicators of bad drainage status.

Group A: Plant-based indicators of drainage status 'Bad'

(1) Rooting depth < 40 cm.

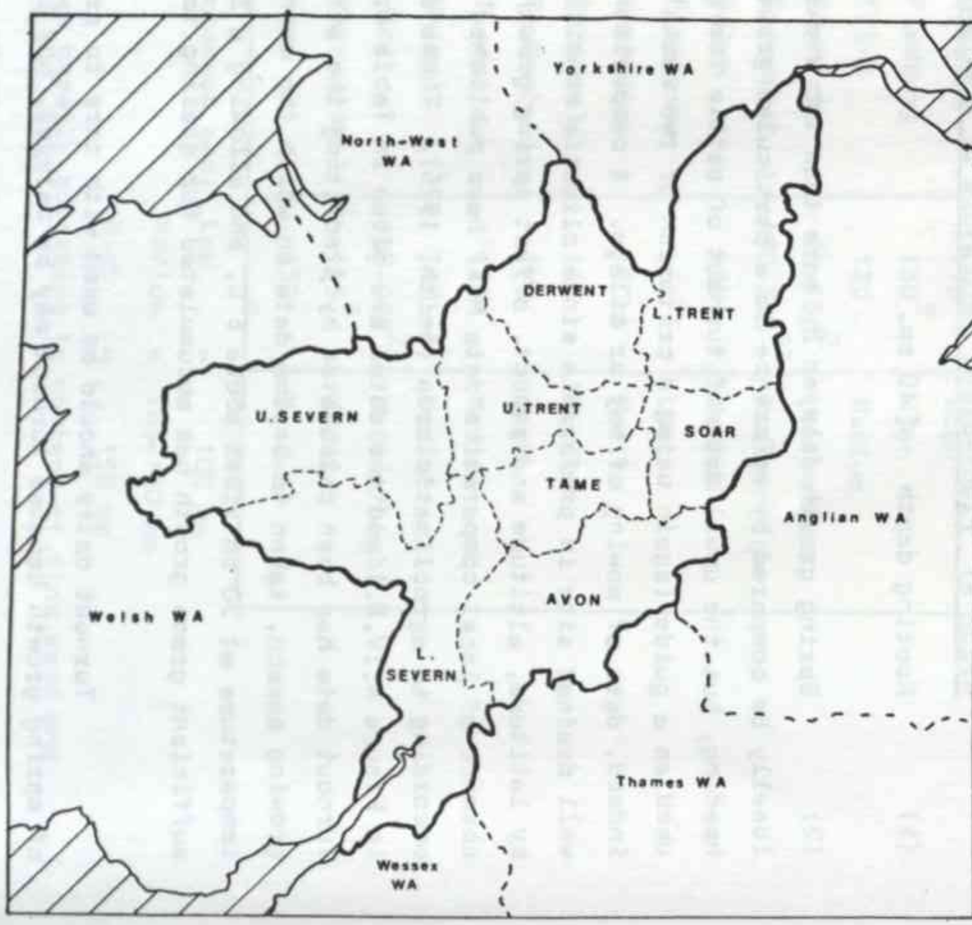
(2) Spring growth delayed by more than two weeks. Growth should ideally be compared by reference to a particular growth stage, eg. heading, but the usual date of turnout of cattle for grazing may be used as a guide (again using a criterion of two weeks' delay), or indeed, date of mowing of hay or silage. A comparison with a local, well drained site is preferable since climatic conditions, influenced by latitude, altitude and aspect, affect spring growth. In the absence of local comparative data MAFF have published turnout dates according to agroclimatic area (Smith, 1976). These areas are shown in Figure A.IV.B.1 and the dates are given in Table A.IV.B.1. Turnout date has been calculated by predicting the start of the growing season, taken to be the date on which the mean soil temperature at 30 cm rises above 6^{o}C, and allowing a lapse until sufficient grass growth has accumulated for grazing to begin.

Turnout dates should be used with care to predict the start of spring growth because turnout may be delayed, not because there is

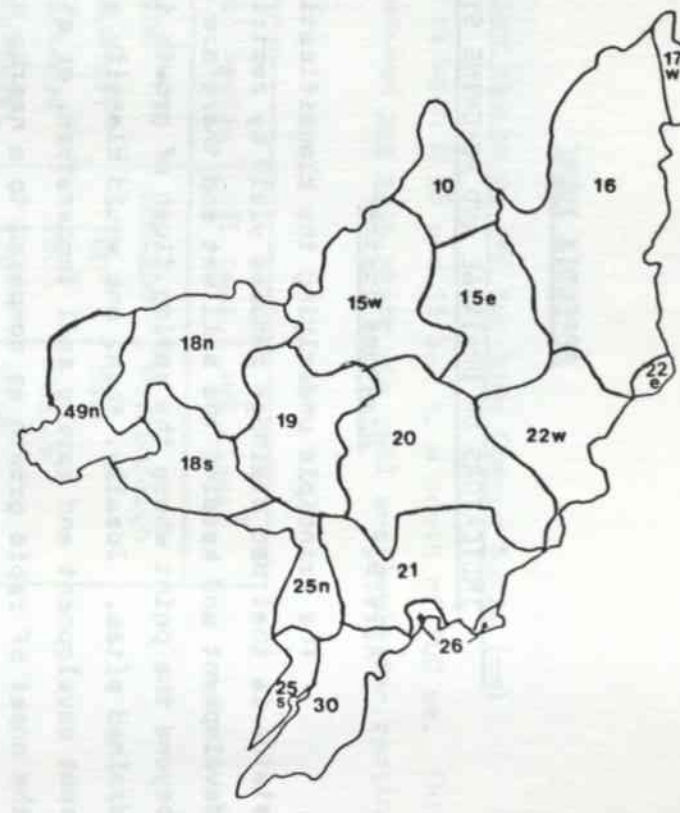
FIGURE A.IV.B.1

STWA and Agroclimatic Areas

SEVERN-TRENT WATER AUTHORITY:
Land Drainage Divisions



AGROCLIMATIC AREAS



no grass, but because of the risk of poaching. Conversely cattle may sometimes be turned out before the spring flush of growth, provided that the underfoot conditions are suitable, simply in order to save housing costs. Such cattle may be on a maintenance diet only, for example dry cows or stores, and the farmer will be happy for them to forage for the small amount of grass accumulated over the winter or to feed them in the field. Dairy cows in milk and beef stock for fattening are unlikely to be turned out until there is grass for them. With these two cases in mind, it is plain that in asking farmers for average turnout dates background information should also be sought in order to interpret the significance of those dates vis-a-vis the onset of the spring flush of growth. Is turnout delayed because of poaching rather than shortage of grass? Are cattle turned out just to save costs, before there is any new grass for them?

TABLE A.IV.B.1

Turnout Dates and Start of Growing Season Dates by Agroclimatic Area

Area Number	Start of Growing Season	Turnout Date
15 W	March 29	April 5
15 E	March 29	April 5
16	March 29	April 4
18 N	March 27	April 4
18 S	April 6	April 17
19	March 31	April 7
20	March 29	April 6
21	March 23	March 29
22 W	March 30	April 7
22 E	March 30	April 5
25 N	March 24	April 1
25 S	March 21	March 28
26	March 27	April 4
30	March 19	March 26

Source: MAFF Technical Bulletin 35 (Smith, 1976)

Start of growing season = mean 30 cm soil temperature over 6°C.

Turnout date = start of growing season plus 5 days' delay, or more at altitudes over 50 m.

Group B: Site-based indicators of drainage status 'Bad'

(1) Water table within 40 cm of surface on February 15th.

(2) Floods exceeding 20 days of standing water between October 1st and January 31st. Floods of shorter duration should be dicounted as far as grass yield is concerned, although if cattle have to be housed when they would otherwise be left out the extra cost should be counted as a result of flooding.

(3) Floods exceeding seven days of standing water between February 1st and March 31st on slowly permeable soils (= clays and clay loams lacking good structure) or ten days of standing water in the same period on permeable soils (= loams and sands). Again, floods of shorter duration should be discounted.

Group C: Soil-based indicators of drainage status 'Bad'

(1) Gleying within 40 cm of the surface, indicated by greyish colours, often with rusty mottling.

(2) Undecomposed organic matter (eg. straw) within 40 cm of the surface, visible or indicated by blackish staining and 'bad egg' smell typical of anaerobic decay.

(3) Structureless layer within 60 cm of surface, ie. no cracks or fissures.

These are three readily recognised indications of bad drainage and represent severe cases. In less severe cases bad drainage can also be inferred from the gley morphology of the profile, but some expertise is required. The Soil Survey Handbook (Hodgson, 1976) provides a guide to the interpretation of gley morphology, and defines six Wetness Classes (Table A.IV.B.2).

TABLE A.IV.B.2

Wetness Class

Class	Average Duration of Waterlogging per Annum
I	30 days within 70 cm depth
II	30 - 90 days within 70 cm depth
III	90 - 180 days within 70 cm depth
IV	180 - 335 days within 70 cm depth but 180 days within 40 cm depth
V	180 days within 40 cm depth or 335 days within 70 cm depth
VI	335 days within 40 cm depth

Source: Hodgson, 1976

Wetness Classes I and II may be related to drainage status 'Good' as used in this Annexe, Class IV to drainage status 'Bad' and Class VI to 'Very Bad'. Classes III and V are intermediary. Recognition of Classes V and VI by gleying and mottling around 40 cm ought to be straightforward, but Classes III and IV require considerable practice and expertise.

Indications of poor drainage are reproduced below from the ADAS Drainage Leaflet No. 1 (MAFF, 1977).

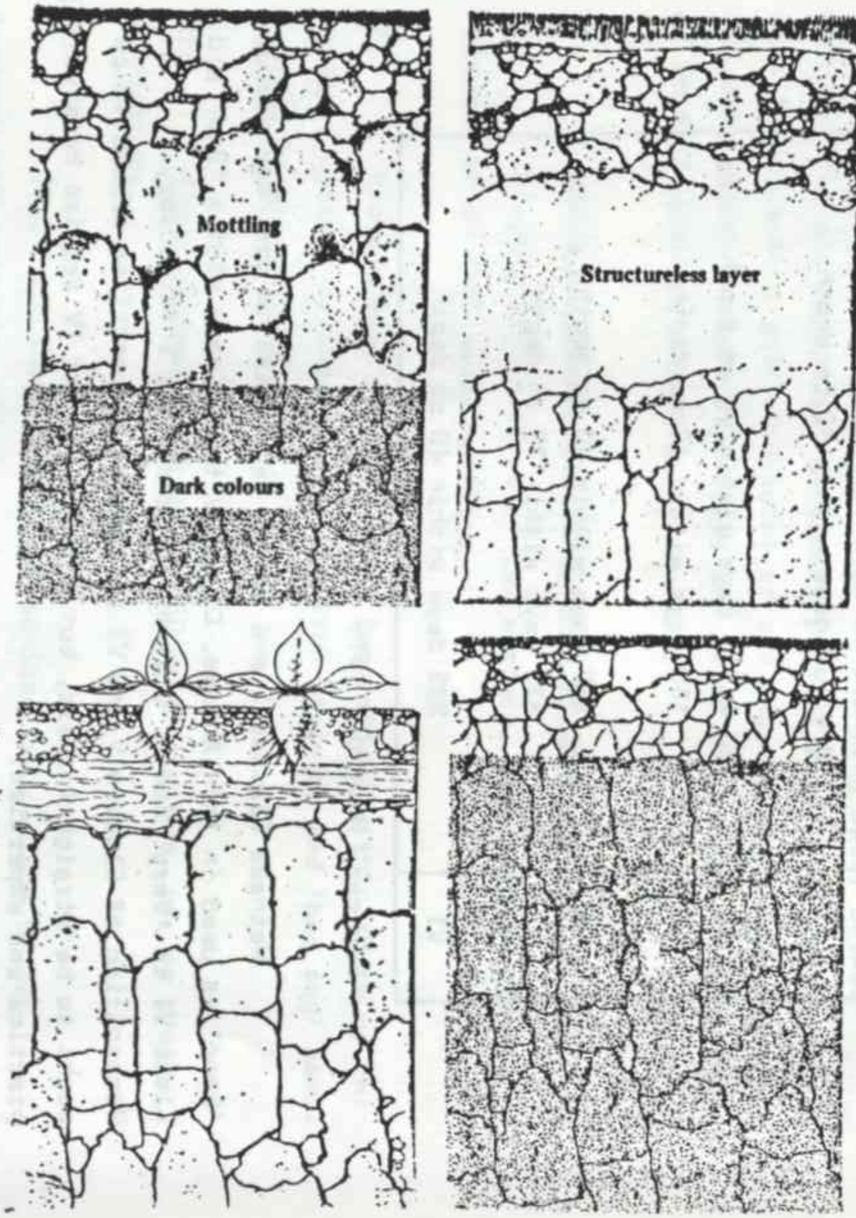
A.IV.B.2 Poaching Status

Poaching status is difficult to predict from secondary sources and is best observed in the field. Poaching has two interactive controlling factors, soil strength and the failure to remove water. Poaching susceptibility is related to clay percentage but in a complex way. Clays are generally strong in the lower

FIGURE A.IV.B.2

Subsoil Indicators of Poor Drainage

Surface conditions will indicate that a problem exists. Subsoil conditions will show whether or not this is due to poor drainage and if it is will point towards its nature and cause.
A hole about 1 metre deep is required to expose a vertical face or 'profile' of the soil.



Soil colour

As a general rule uniform brown or brownish shades throughout the depth of the profile suggests that there is no drainage problem. On the other hand dark grey, blue and blackish tones usually indicate that the soil is permanently waterlogged. Rust coloured mottling at any level within the soil profile suggests that the soil is waterlogged at certain times of the year.

Soil Structure

In a well drained soil air and water are able to move freely through the cracks and fissures which are a feature of a soil with a good structure. Where the structure is poor a drainage problem can arise.
Examine the profile for any compacted or structureless layers - for example, plough pan, a rust coloured iron pan, compaction due to poaching or a naturally structureless subsoil.

Root development

In soils with a well developed structure and good drainage root systems are able to develop to their fullest extent. On poorly structured wet land they will die back whilst a mass of fine roots at a shallow depth will indicate a barrier such as a watertable, pan or structureless layer below.

Groundwater level

The presence of water in the profile pit must be considered in conjunction with the evidence provided by the subsoil but it may indicate a watertable problem.

moisture range but can have low permeability so that if rain exceeds infiltration, the moisture content of the upper soil rises rapidly, reducing soil strength and making poaching a risk. Loams, in the middle of the clay percentage range, have better infiltration and therefore the moisture content of the upper soil remains low enough to maintain sufficient soil strength to avoid poaching (unless there is a water table high enough to wet and weaken the upper soil). Sands, at the low end of the clay percentage range, are weaker and less resistant to deformation. Compaction may lead to poor infiltration at the surface with consequent further loss of strength, making poaching a risk.

Excess water at the surface may result from slow infiltration of rainfall or from a high water table, regional or perched, which reduces both the hydraulic gradient through the unsaturated zone and the volume of soil available for storage of water above field capacity, making saturation of the surface layer more likely. Soil Survey have developed the best system for rating poaching risk (Harrod, 1979) although it is comparative and therefore difficult to relate quantitatively to utilization efficiency. Its advantage is that classes of poaching risk can be estimated even if they are not measured in a particular case. Five classes are distinguished by the Soil Survey of which the two worst and the two best can be identified with classes 'P' and 'Z' in this text; their middle class, however, is rather difficult to interpret.

Soil Survey have interpreted their data to develop grassland soil suitability classes and these indicate where poaching is a risk. A map is now available and the system is explained in Harrod (1979). The national map is on too small a scale for present purposes but may be capable of interpretation in combination with a detailed soils map, if available. Regional Bulletins shortly to be published to accompany the national soils map ought to contain this information.

Land capability classifications have been carried out in detail by Soil Survey in some areas. Sites with a wetness limitation subclass, indicated by a suffix w, can very broadly be identified with our poaching status 'P', although this should be confirmed by local observation.

Grass growth slows considerably after September (see Figure IV.9) but cattle are commonly left out into October or even November in order to save housing costs. Some grass will remain on fields not grazed in September, and a small amount of grass continues to be produced, but little liveweight gain is possible in this period without extra feed. An economic gain therefore results from the saving in housing costs, but this period is excluded from the grass production season of April to September. Loss of the opportunity to graze grass produced in September during early October due to poaching, however, is regarded as a loss in utilization. A comparison of the length of the grazing season with local well-drained sites can be used to assess poaching status. This and other indicators of poaching status are given below.

Group A: Plant-based indicators of poaching status 'Poaching'

(1) Presence of rushes or other species indicative of surface waterlogging.

(2) Bare patches of earth visible in winter between clumps of grass, indicating poaching the previous season bad enough to kill plants.

Group B: Site-based indicators of poaching status 'Poaching'

(1) Deformed soil surface.

(2) Water table less than 40 cm deep in summer, unless the soil is loamy.

(3) Autumn grazing curtailed. On all sites in the study area, if grazing ceases before October 15th because of poaching, there will be a loss in utilization of grass produced in the season April to September and the site has poaching status 'P'. For present purposes it is assumed that if poaching prevents grazing after October 15th

this does not represent a utilization loss because grass production has by then slowed sufficiently as to be regarded as negligible and by that date grass remaining from the growing season should have been consumed. Most of the STWA study area does not produce any appreciable amount of grass after September, but in the western and southern fringes of the area there is an autumn flush of growth and the assumption made above is invalid since the lack of opportunity to exploit that growth because of poaching represents a utilization loss. Figure A.IV.B.3 shows the areas affected and a note at the end of this Appendix suggests a method of assessment of this addition to annual production and of its loss if poaching prevents its exploitation.

Group C: Soil-based indicators of poaching status 'Poaching'

(1) Impermeable layer at less than 40 cm depth, unless the upper layer is loamy.

(2) Impermeable layer at less than 70 cm if the profile above is clayey.

(3) Soil classed as a surface water gley.

(4) Soil classed as a groundwater gley if it has a slowly permeable (Clay) upper horizon.

Note: Autumn Flush

Areas which have an autumn flush of growth can be identified either by a local study or by referring to Figure A.IV.B.3. The dates for the end of growing season given by MAFF (Smith, 1976) refer only to soil temperature; an autumn flush is experienced only where soil moisture deficits are low as well as the soil temperature being high enough for vigorous growth. Figure A.IV.B.3 takes account of soil moisture deficit and is therefore preferred for the purpose of identification.

The following procedure is suggested for these areas:

FIGURE A.IV.B.3

The Autumn Flush

■ = Area with autumn flush.

(1) Compare the usual end of the grazing season on the site with that given in Table A.IV.B.3 below.

(2) If grazing ends before the date given in Table A.IV.B.3 make no adjustment to UME since the autumn flush is not fully utilized.

(3) If grazing continues until the date given adjust UME by raising the AWC site class by one place.

TABLE A.IV.B.3

Date of End of Grazing Season by Agroclimatic Area

Areas which may have an autumn flush are marked thus *

Area Number	End of Grazing Season
*15 W	October 2
15 E	November 4
16	November 28
*18 N	October 24
*18 S	October 5
*19	November 9
20	November 9
21	November 19
22 W	November 16
22 E	November 28
*25 N	October 28
*25 S	October 6
*26	November 3
*30	October 24

Source: MAFF Technical Bulletin 35 (Smith, 1976)

End of grazing season = return to meteorological field capacity

The dates given in Table A.IV.B.3 are unsatisfactory in two respects. Firstly, they show an apparently large variation between adjacent areas. This makes it difficult to interpolate values for sites near the border of an area. Secondly, they refer only to meteorological data, taking no account of variation with soil type. It is partly for these reasons that the dates are not used in Group B above to classify poaching status, where a single value of October 15th is preferred as the criterion for the end of the productive grazing season on all sites in the study area, just as the single date of September 30th is preferred as the end of the grass production season. In the absence of other data though, they are suggested for use in assessing the autumn flush even though this involves something of a contradiction since for some of the areas Table A.IV.B.3 gives the end of the grazing season as occurring before October 15th.

Work is currently under way at Soil Survey to refine the prediction of the end of grazing both by smoothing the meteorological data by using a 10 km grid instead of the agroclimatic areas and by including a reference to soil type (Jones, 1983). This work will be published shortly in the Regional Bulletins accompanying the national soil map and the dates given in Table A.IV.B.3 above ought to be revised when this happens.

A.IV.2.3 Soil Survey Classifications as Guidelines to Drainage and Poaching Status

The Soil Survey have recently published a national soils map at a scale of 1:250,000. While this is too small a scale for the discrimination of soils in land drainage benefit areas it is a useful guide to the soils which may be expected and in combination with the more detailed Soils Records, where available, ought to enable a preliminary appraisal of soil/drainage status to be made. An on-site examination of soils will ultimately be necessary, however, to check whether other soils are present as well as the dominant one which is mapped, and to check the actual profile against typical profiles for that soil illustrated elsewhere. Soils vary widely and even soils of the same subgroup and series may vary sufficiently as to be agronomically important, for example, in topsoil texture or depth to any impermeable layer.

The major soil groups which are to be found in land drainage areas are described briefly below, following which subgroups likely to be found are tabulated and rated for their likely drainage and poaching status. Soil associations representing these subgroups are listed along with brief comments. This list is not intended to be comprehensive and the predictions of drainage and poaching status are only a rough guide. More details are to be found in Soil Survey's legend to the national soils map, from which the information below has been taken, in their Regional Bulletins and, of course, in local Soils Records where they are available.

(a) Major Group 3: Lithomorphic Soils

These are shallow soils with an organic or organic/mineral surface horizon over bedrock or soft, unconsolidated material within 30 cm depth. They occur mostly on upland sites.

(b) Major Group 4: Pelosols

Slowly permeable clayey soils with no prominently mottled or gleyed layer within 40 cm. They crack deeply in the dry season and have a coarse blocky or prismatic structure.

(c) Major Group 5: Brown Soils

Brownish or reddish subsurface horizons with no mottling or gleying within 40 cm. Almost all are permeable and lie on permeable materials. Found at elevations below 300 m.

(d) Major Group 6: Podzolic Soils

A black, dark brown or ochreous subsurface horizon results from accumulated iron and aluminium or organic matter. They normally result from acid weathering conditions and have an unincorporated acid organic layer at the surface. Gley podzols can occur in lowlands with periodic waterlogging. Otherwise only the stagnopodzol subgroup including ironpan soils, have drainage problems in this group but these are upland soils.

(e) Major Group 7: Surface-water Gley Soils

Seasonally waterlogged and slowly permeable. Prominently mottled within 40 cm. All have drainage problems, especially the pelo- (clayey) subgroup. Stagnogleys have a distinct topsoil and occur widely in lowland Britain.

(f) Major Group 8: Ground-water Gley Soils

Normally developed within or over permeable materials with prominently mottled or uniformly grey subsoils resulting from periodic waterlogging by a fluctuating water table. Some clayey soils with limited permeability.

(g) Major Group 10: Peat Soils

Predominantly organic soils. Periodic waterlogging common in lowland sites without groundwater control.

Likely drainage and poaching status

Where drainage status is classed 'may be bad' this depends on local water tables or, for clayey soils, on their structure and hence their permeability. Where poaching status is classed 'may poach' this implies that the subgroup has variable soil strength or possibly that a high water table is a risk. The tabulation following refers to the status of soils in undrained sites.

Note:

The following soils may be subject to poaching even with underdrainage due to surface wetness. A site examination will be necessary to establish the poaching status in any particular location.

Pelosols - Evesham, Hanslope and Worcester associations, although a high organic matter content and long-established, well-knit sward can result in sufficient surface strength to avoid poaching on drained sites, certainly on the first two associations mentioned.

Surface-water gleys - all stagnogleys are vulnerable, so that all the soil associations mentioned in the tabulation above in this major group are likely to poach even after underdrainage, namely Brockhurst, Wickham, Salop, Clifton, Beecles, Holderness, Dale, Denchworth, Crewe, Bardsey, Brickfield and Oak associations.

Ground-water gleys - soils in pelo- subgroups are vulnerable, namely Fladbury, Compton, Thames and Newchurch.

LITHOMORPHIC SOILS

Subgroup No.	Name	Association	Drainage status: Probably bad	Drainage status: May be bad	Drainage status: Probably good	Poaching status: Probably poached	Poaching status: May poach	Poaching status: Probably zero	Remarks
342	Grey rendzina	Wantage			x			x	Shallow over chalk
343	Brown rendzina	Elmton			x			x	Shallow over limestone
"	" "	Sherborne			x		x		Shallow calcareous clayey over limestone
"	" "	Andover			x			x	Shallow calcareous silty over chalk

PELOSOLS

Subgroup No.	Name	Association	Drainage status: Probably bad	Drainage status: May be bad	Drainage status: Probably good	Poaching status: Probably poached	Poaching status: May poach	Poaching status: Probably zero	Remarks
411	Typical calcareous pelosol	Evesham		x		x			Slowly permeable calcareous clayey Some seasonally waterlogged.
	"	Hanslope		x		x			As above
431	Typical argillic pelosol	Worcester		x		x			Slowly permeable non-calcareous and calcareous

BROWN SOI

Subgroup No.	Name	Association	Drainage status: Probably bad	Drainage status: May be bad	Drainage status: Probably good	Poaching status: Probably poached	Poaching status: May poach	Poaching status: Probably zero	Remarks
511		Panholes			x			x	
532		Blacktoft			x			x	
"		Romney			x			x	
541		Neath			x			x	
541		Denbigh			x			x	
"		Wick			x			x	
543		Arrow			x			x	
544		Banbury			x			x	
551		Newport			x			x	
552		Kexby			x			x	
561		Wharfe			x			x	
"		Teme			x			x	
"		Alun			x			x	
571		Sutton			x			x	
572		Whimple			x			x	
"		Dunnington Heath			x			x	
"		Flint			x			x	
"		Burlingham			x			x	

PODZOLIC SOILS

Subgroup No.	Name	Association	Drainage status: Probably bad	Drainage status: May be bad	Drainage status: Probably good	Poaching status: Probably poached	Poaching status: May poach	Poaching status: Probably zero	Remarks
641	Typical podzols	Sollom		x				x	Deep sandy, some affected by groundwater
"	"	Holme Moor		x			x		Deep fine sandy, affected by groundwater

SURFACE-WATER GLEYS

Subgroup No.	Name	Association	Drainage status: Probably bad	Drainage status: May be bad	Drainage status: Probably good	Poaching status: Probably poached	Poaching status: May poach	Poaching status: Probably zero	Remarks
711	Typical	Brockhurst	x			x			Slowly permeable
711	Stagnogley	Wickham	x			x			seasonally water-
"	"	Salop	x			x			logged fine loamy
"	"	Clifton	x			x			or fine silty soils
"	"	Beccles	x			x			over clay.
"	"	Holderness	x			x			" "
712	Pelo-stagnogley	Dale	x			x			Slowly permeable
"	" "	Denchworth	x			x			seasonally water-
"	" "	Crewe	x			x			logged ckayey
713	Cambic	Bardsey	x				x		Slowly permeable
"	Stagnogley								seasonally water-logged loamy over claye/
"	"	Brickfield	x			x			Slowly permeable seasonally waterlogged fine loamy
714	Paleo-argillic Stagnogley	Oak	x						Slowly permeable seasonally waterlogged fine loamy over clayey

GROUND-WATER GLEYS

Subgroup No.	Name	Association	Drainage status: Probably bad	Drainage status: May be bad	Drainage status: Probably good	Poaching status: Probably poached	Poaching status: May poach	Poaching status: Probably zero	Remarks
811	Typical alluvial gley	Conway		x			x		Deep fine silty and clayey soils variably affected by groundwater. Risk of flooding
812	Calcareous alluvial gley	Frome		x				x	Shallow loamy over flint gravel affected by groundwater Risk of flooding.
813	Pelo-alluvial gley	Fladbury	x			x			Clayey variably affected by groundwater Flooding.
"	"	Compton	x			x			As above
814	Pelo-calcareous alluvial gley	Thames	x			x			Calcareous clayey affected by groundwater
		Newchurch	x			x			Flooding
821	Typical sandy gley	Blackwood		x			x		Deep permeable sandy or coarse loamy. Groundwater controlled by ditches
831	Typical cambic gley	Yeolland Park		x				x	Fine loamy permeable soils
"	" "	Wigton Moor		x				x	variably affected by groundwater
851	Humic-alluvial gley	Downholland		x			x		As above. Groundwater controlled by pumps.

PEATS

Subgroup No.	Name	Association	Drainage status: Probably bad	Drainage status: May be bad	Drainage status: Probably good	Poaching status: Probably poached	Poaching status: May poach	Poaching status: Probably zero	Remarks
1022	Earthy eufibrous peat	Altcar		x			x		Groundwater controlled by pumps
1024	Earthy entro-amorphous peat	Adventurers		x			x		" "

APPENDIX IV.C

SUMMER FLOODING: ADDITIONAL FACTORS AND SPECIAL CASES

Some suggestions are offered below for cases where adjustments may be necessary to the calculated summer flood damage.

A.IV.C.1 Depth of Flooding

Deep floods sometimes have a more severe effect on yields than shallow floods in cases where the greater head results in more leaching losses. The immediate effect on the plant, however, seems to be similar in both cases. It is hard to establish whether leaching occurs but an adjustment may be made for floods over 1 m depth on permeable soils where deep percolation is anticipated by moving up one class for flood duration (Table IV.5). Generally depth of flood water does not need to be taken account of.

A.IV.C.2 Sward Species and Age

The species favoured by flooding, while they are less productive than perennial rye grass, are not necessarily less productive than species making up unimproved upland pastures. In areas of long stagnation rushes, *Agrostis* spp. and Yorkshire fog are dominant, of which only *Agrostis* is of much value at all. Many areas which are flooded regularly but more briefly, however, support more productive swards, including species such as the fescues. The energy yield of the latter type of sward is comparable with that predicted in Table IV.4 but that of the former type is much lower. Where flooding causes degeneration of the sward to the extent that rushes, *Agrostis* and Yorkshire fog predominate energy yields are reduced in the long term. To some extent this effect has been included in Table IV.5 in setting penalties according to summer flood duration but it is felt that UME output may be overestimated on these very poor swards. Unfortunately no figure can be suggested with any confidence to adjust UME in these cases.

Reseeded swards in areas subject to summer (and winter) flooding are almost certain to degenerate rapidly, with the less productive wetland species becoming dominant again in as little as two years. Reseeding without flood alleviation is therefore to be regarded as a management error. In this study the cost of reseeding has been counted separately.

A.IV.C.3 Fertilizer N Application

Summer floods may cause loss of fertilizer N, where it is applied, through leaching, denitrification or simply washing it away. Three weeks is usually allowed for the conversion of fertilizer N to grass growth after its application and flooding in this period will result in losses. One hundred percent losses are possible, certainly in the first week after application but losses thereafter are hard to predict - the flood may even just 'wash in' the fertilizer.

A.IV.C.4 Water Quality and Sediment Deposition

Water quality may have either negative or positive effects on soil fertility after flooding - negative if it is acid or contains toxins and positive if it contains nitrates, either leached or as part of returned sewage.

Some allowance is made in Table IV.6 for the effects of sediment deposition in soiling herbage, rendering it unpalatable, and delaying regrowth by burying shoots. Heavy sediment deposition, however, amounting to more than 2 cm depth, will cause a greater delay in regrowth. Sediments can be high in organic matter and will then supply significant amounts of N and other nutrients, which should be taken into account.

A.IV.C.5 Summer Flood Damage Calculation - Worked Example

Information: The flood area covers 100 ha of which about 50 ha is slightly higher than the remainder and drains faster. In winter the area floods two or three times every year, the duration ranging from one to three weeks on the lower part and less on the higher. The higher part does not lie wet in spring and fertilizer application is rarely delayed in comparison with nearby upland fields, but the lower part lies wet into spring and poaches in autumn and no fertilizer is applied to it. Summer flooding occurs roughly once a year. Interviews with farmers have revealed little agreement as to the timing of summer floods - they seem to happen during all months. There are no hydrographic data available for the estimation of flood return periods during the different parts of the summer. Summer floods seem to last for one week on the lower part but only one day on the higher part. The higher part has loamy, free-draining soil over gravel whereas the lower part is clay and only slowly permeable. The whole area is cut for hay and grazed afterwards by beef stores. Stocking rate is variable. The whole area receives farmyard manure and the higher area receives 50 kg/ha of nitrogen. Summer rainfall is 325 mm. The silt deposited by flooding is known to be high in organic matter and often contains high nitrates.

<u>Calculation</u>:

(1) Divide the flood area into Block 1, the higher part, and Block 2, the lower part.

(2) AWC site class = Average (both blocks)

(3) Soil/drainage class = GZ (Block 1)

= BP (Block 2)

(4) Assume organic N from FYM and manure of 23 kg/ha on both blocks, equivalent to a stocking rate of 1 LU/ha. An allowance of 15 kg/ha N is made for the contribution of the silt deposited in flooding.

Total N = 88 kg/ha N (Block 1)

Total N = 38 kg/ha N (Block 2)

(5) UME output = 35.0 GJ/ha (Block 1)

UME output = 19.5 GJ/ha (Block 2)

(6) Summer flood damage:-

Block 1: duration = 1 day (a)

Assume hay cut June 30th

Risk is equal through the summer. Therefore calculate the damage of a flood occurring in each month and take the mean of these.

Damage in April (conserved) = Nil

Damage in May (conserved) = Nil

Damage in June (conserved) = 2/3 x April-June production

= 15.4 GJ/ha

Damage in July-September (grazed) = Nil

<u>Average summer flood damage = 2.5 GJ/ha on Block 1</u>

Block 2: duration = 1 week (c)

Assume hay cut June 30th

Risk is equal through the summer

Damage in April (conserved) = April production

= 3.5 GJ/ha

Damage in May (conserved) = April/May production

= 9.7 GJ/ha

Damage in June (conserved) = April/May/June production

= 12.8 GJ/ha

Damage in July (grazed) = July production = 2.8 GJ/ha

Damage in August (grazed) = August production = 2.2 GJ/ha

Damage in September (grazed) = September production

= 1.7 GJ/ha

<u>Average summer flood damage = 5.5 GJ/ha on Block 2</u>

<u>Average summer flood damage over the flood area is 4 GJ/ha</u>

Estimated net UME output, after deduction of average flood damage is 32 GJ/ha on Block 1 and 14 GJ/ha on Block 2.

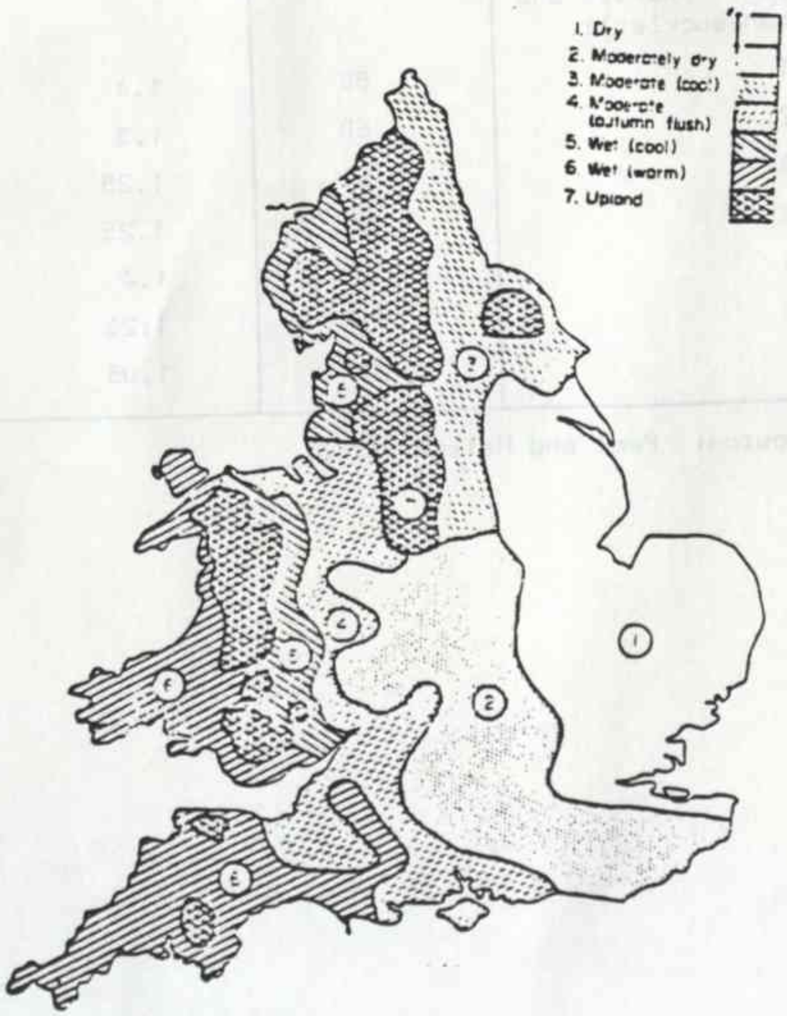
APPENDIX IV.D

FERTILIZER N USE BY FARM TYPE AND REGION

Fertilizer N use varies with climatic region as well as with farm type. Figure A.IV.D.1 shows climatic zones of England and Wales, as defined in Table A.IV.D.1 and Table A.IV.D.2 gives the fertilizer N use for each farm type in each zone. Fertilizer N use on floodplains is likely to be lower than in the zone as a whole but unfortunately there is no basis for estimating how much lower it will be.

FIGURE A.IV.D.1

Climatic Zones of England and Wales



Source: Peel and Matkin (1982)

TABLE A.IV.D.2

Fertilizer N Use for Farms in Each Zone

Zone	Fertilizer N (kg/ha)	Stocking Rate (LU/ha)
Dairy:		
1	167	1.9
2	165	1.95
3	153	1.8
4	117	1.7
5	148	1.85
6	164	1.7
7	84	1.35
Beef (suckler and non-suckler):		
1	88	1.4
2	60	1.3
3	63	1.25
4	35	1.25
5	67	1.4
6	57	1.25
7	34	1.05

Source: Peel and Matkin (1982)

ANNEXE V
THE MONETARY BENEFITS OF
IMPROVED AGRICULTURAL DRAINAGE

ANNEXE V

THE MONETARY BENEFITS OF IMPROVED AGRICULTURAL DRAINAGE

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List of Abbreviations

ADAS	Agricultural Development and Advisory Service
AHDS	Agriculture and Horticulture Development Scheme
CP	Crude Protein
DM	Dry Matter
FAO	Food and Agriculture Organization
FMS	Farm Management Service
GLU	Grazing Livestock Unit
GM	Gross Margin
hd	Head (of animals)
IBRD	International Bank for Reconstruction and Development
K	Potassium
MAFF	Ministry of Agriculture, Fisheries and Food
MLC	Meat and Livestock Commission
MJ	Megajoules
MMB	Milk Marketing Board
N	Nitrogen
NR	Net Return
NR (SFC)	Net Return after Semi-Fixed Costs
NR (TFC)	Net Return after Total Fixed Costs
P	Phosphate
STWA	Severn-Trent Water Authority
UME	Utilized Metabolizable Energy

ANNEXE V

THE MONETARY BENEFITS OF IMPROVED AGRICULTURAL DRAINAGE

V.1 INTRODUCTION AND SCOPE

The purpose of this Annexe is to describe the approach to the assessment of monetary benefits accruing to farmers and the economy following STWA land drainage investment projects. The method estimates in monetary terms the response of farmers to the new drainage opportunities afforded by a given scheme.

The 'ex post' evaluation of STWA schemes involves comparing 'before' and 'after' project situations, and estimating the net return attributable to the drainage project. Three related benefit assessment scenarios are relevant:

(i) the assessment of 'actual' net benefits (extra revenues minus extra costs at farm level) realised by farmers following the scheme. The nature of and rate at which such net benefits are realised provides the monetary measure of 'uptake', and will determine the return on the Authority's investment in drainage improvement. It is important to emphasise that this definition of 'actual' uptake is based on farmers' own perception of benefit obtained.

(ii) the assessment of 'potential' net benefits afforded by the scheme but for a variety of reasons, not necessarily taken up by farmers.

(iii) a comparison of 'actual' with 'potential' net benefits to determine the degree of benefit exploitation.

The general procedure adopted is that of a partial budgeting approach. On the basis of farmer interviews the physical inputs (eg. fertiliser use), and outputs (eg. yields), which have changed as a consequence of the drainage improvement are identified. These physical parameters are translated into financial values using standard prices. The concepts of gross margins and fixed costs are used to summarise the type and extent of either 'actual' or 'potential' benefits. The partial budgeting approach, as shown in Figure V.1, is essentially an incremental analysis. The net returns attributable to the drainage improvement are estimated at field, farm and scheme level. The nature and rate of change in net return provides a monetary measure of 'uptake'. The sum of net returns for beneficiaries within a given scheme's benefit area can be set against the incremental capital and maintenance costs of the scheme.

FIGURE V.1

The Partial Budget Approach To Scheme Appraisal

(a) Before/without project situation	(b) After/with project situation	(b)-(a) Returns attributable to project
(i) Gross Margins	(i) Gross Margins	(i) Gross Margins
(ii) Fixed Costs	(ii) Fixed Costs	(ii) Fixed Costs
(i)-(ii) Net Margin	(i)-(ii) Net Margin	(i)-(ii) Net Return
	{after deducting additional field drainage costs}	{after deducting additional field drainage costs}

The net returns attributable to the drainage improvement are estimated at field, farm and scheme level, and in accordance with the terms of reference of the study, used to assess two factors:

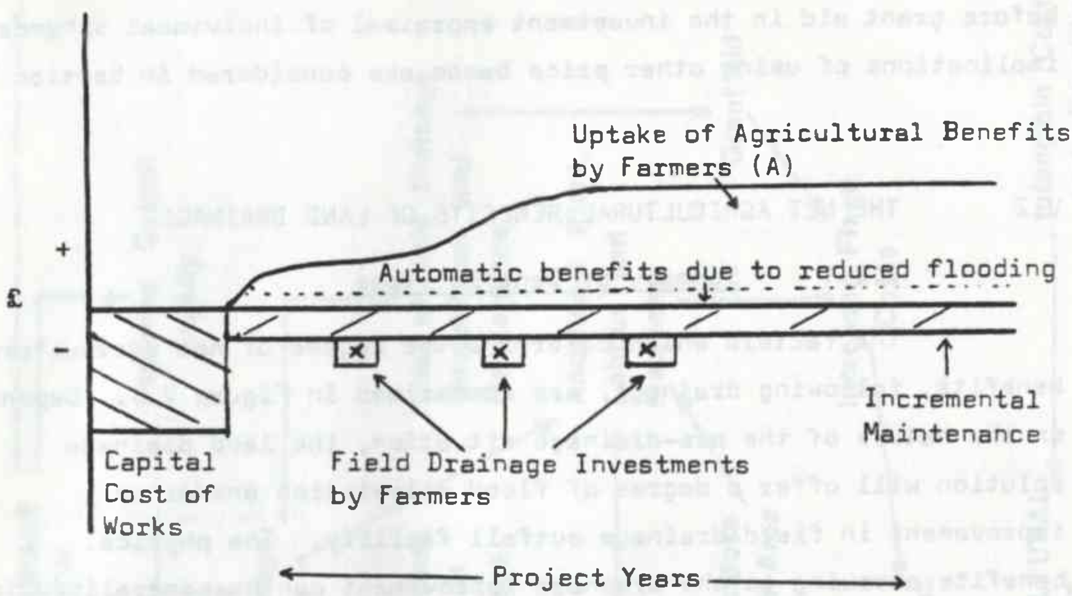
(i) the nature and rate of uptake of net agricultural benefits,

(ii) the overall return on capital invested (and therefore justification for the investment) for each STWA land drainage improvement scheme.

These 'uptake' and 'investment appraisal' estimates are separate but necessarily related. Their definition is best explained by reference to Figure V.2.

FIGURE V.2

The Components of Drainage Scheme



In financial terms 'uptake' is the extra gross margins less extra fixed costs plus other non-automatic benefits derived by farmers from the scheme (A in Figure V.2). Farmer investments in field drainage are excluded from this particular definition of uptake (see Annexe VI), as are 'automatic' benefits such as reduced flood damage which require no conscious response on the part of farmer beneficiaries. Uptake is measured for each year of scheme life up to the present time (1984). With respect to investment appraisal, for each year of project life the previously defined 'uptake' benefits are combined with automatic benefits and reductions in flood damage costs attributable to the scheme. From this is deducted the cost of field drainage and the without-project returns that would have been obtained in the benefit area in any case. The resultant stream of net benefit is termed the net agricultural cash flow which can then be set against the stream of scheme capital and recurrent costs, and discounted to derive a net present value for the scheme as a whole. A 30 year life and a discount rate of 5% is used. The procedures and results of scheme evaluation are contained in Annexe IX.

In accordance with current MAFF guidelines, the analysis adopts a quasi-financial viewpoint whereby additional inputs and outputs are measured in prevailing farm gate prices (to the base September 1982), with the exception of field drainage costs which are expressed before grant aid in the investment appraisal of individual schemes. The implications of using other price bases are considered in Section V.6.

V.2 THE NET AGRICULTURAL BENEFITS OF LAND DRAINAGE

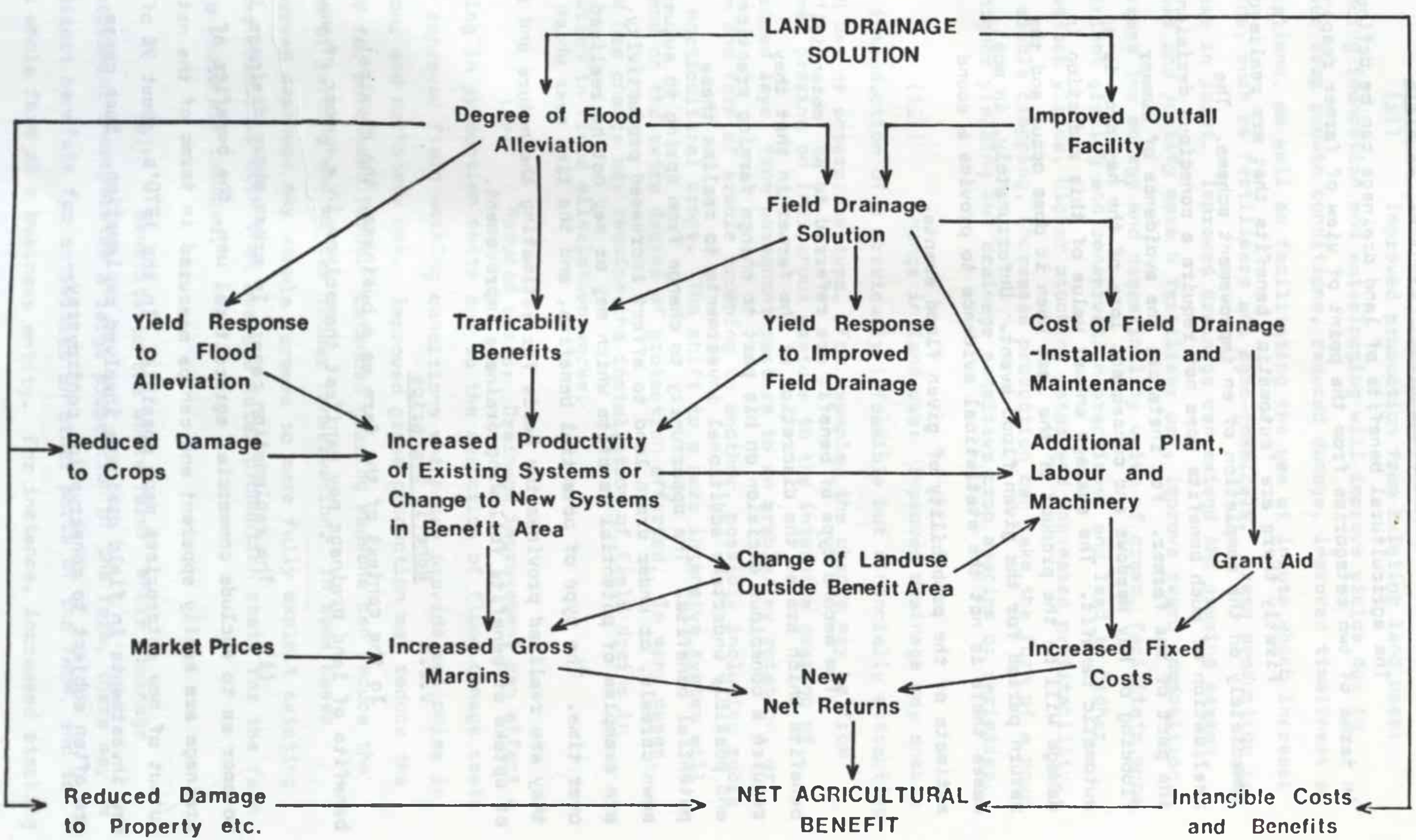
V.2.1 Summary of Benefit Types

The factors which determine the degree of net agricultural benefits, following drainage, are summarised in Figure V.3. Depending on the nature of the pre-drainage situation, the land drainage solution will offer a degree of flood alleviation and/or an improvement in field drainage outfall facility. The physical benefits accruing to the drainage improvement can be generalised in terms of a crop yield response to a better (soil/plant/water) growing environment arising from reduced flooding and/or waterlogging, a reduction in crop damage due to poor drainage, and an improvement in the 'trafficability' of soils for machines and animals, and in the workability of soils for soil-engaging implements. The nature of drainage benefits are considered in detail in Annexe II.

The resultant increase in net output (extra physical output less additional direct inputs such as fertilisers and agro-chemicals) can then be expressed in prevailing market prices to derive the addition to gross margin. To derive increased net returns it is necessary to deduct the costs of additional farm fixed costs relating to regular labour, machiney and buildings, together with the cost of field drains before grant where these have been installed.

A further consideration in the assessment of benefits at farm and scheme level are the intangible non-monetary costs and benefits of the drainage improvement. These could constitute the 'internal' benefits to local farmers of peace of mind given a reduction in the threat of flooding, or they could involve the 'external' costs accruing to the undesirable environment impacts of a scheme for other land users. The measurement of these intangibles does not fall within the terms of the present study but they are briefly enumerated in Annexe II.

Figure V.3 : DETERMINATION OF DRAINAGE BENEFITS AT FARM LEVEL



V.2.2 'Automatic' versus 'Potential' Benefits

The agricultural benefits of land drainage can be defined in terms of two categories from the point of view of farmer response.

Firstly there are 'automatic' benefits that are realised immediately on the completion of an improvement scheme. The realisation of such benefits does not require a conscious decision on the part of the farmer. For instance, the avoidance of summer flooding of hay meadows and consequent loss of the hay crop is an automatic benefit. The average annual value of this reduction in damage will be the product of the loss when it does occur and the return period for the given flood event. Unfortunately, in most cases there is not the statistical evidence to provide a sound estimate of the probability of given flood events.

The second type of benefit are referred to as 'potential' benefits which are at the discretion of the farmer in that they require a conscious decision on his part to change farming practices and possibly undertake additional investments to realise these potential benefits. The opportunity to change from spring to autumn sown cereals, or under drain land to effect increased productivity, are examples of potential benefits which may or may not be realised over time. The type of potential benefits, and the time over which they are realised provides the basis for estimating the nature and rate of uptake of benefits following drainage improvement.

V.2.3 Benefit Scenarios

In the context of the farm as a business, the physical benefits of land drainage may manifest themselves in a number of ways.

(i) The reclamation case: In areas where drainage is so poor as to exclude commercial agricultural use, the benefits of drainage are easily apparent and can be measured in terms of the net output of new enterprises made possible. In the 1970's, about 9% of new investments in field drainage involved reclamation. Such cases are often subject to conservation controversy.

(ii) Improved production from existing land uses: Reducing inundation and waterlogging will improve yields due to better crop growth conditions, reduced damage, improved timeliness of operations, as well as facilitating the use of inputs which increase yields, such as fertilisers and agro-chemicals. Grass production is a case in point. Improved drainage can extend the grazing season, enable and justify more N fertiliser use, improve sward composition, increase the energy and digestibility value of grass, facilitate more efficient grazing and conservation practices, and lead to higher livestock yields, higher stocking rates and increased profitability. For arable cropping, increased production can take the form of a move to higher yielding but drainage sensitive crop species or varieties.

(iii) Change in land use: Improved drainage may enable the introduction of a previously infeasible but financially attractive land use or enterprise type. For example, the change may be from summer grazing on indigenous pasture to the intensive grazing of improved leys, from permanent pasture to an arable/ley rotation, or from one form of arable cropping to another, possibly including roots and horticultural crops. The shift to a more intensive system will depend on the extra degree of protection afforded. In many cases, land use change may require the installation of field drains in addition to flood alleviation works.

(iv) Reduced costs: Drainage improvement can affect a saving in production costs due to the reduction of flood damage costs and improved field working conditions which can provide economies in labour and machinery use. Improved grass production may reduce the need for purchased feeds. Extended grazing seasons can reduce the cost of yarding and winter fodder conservation. In some cases improved drainage may enable farmers to more fully exploit existing fixed resources such that average total production costs for the farm as a whole are reduced.

(v) Benefits to the whole farm: Where drainage improvement incorporates a large proportion of the farm, there may be indirect benefits for activities on other parts of the farm, and to the whole farm as a business entity. For instance, increased stocking rates on improved and more accessible lowland pastures may release upland areas for arable production whilst maintaining herd size. Alternatively, increased output from previously unproductive wet land could justify (or necessitate) large capital investments and farm intensification (eg. farm machinery, buildings) previously infeasible.

The way in which benefits manifest themselves provides a framework for benefit assessment. Information collected in the course of farm interviews allows benefits to be categorised accordingly.

V.2.4 Measuring Drainage Benefits

In the course of the single visit interview, farmers are asked to recall the pre-scheme drainage situation and land use, and describe how this had changed over time since scheme completion. For reasons discussed in Annexe III, obtaining physical estimates of farming practices was both more feasible and reliable than requiring farmers to recall financial performance. In most cases farmers are not able to produce definitive estimates of financial benefit but are able to relate to changes in physical circumstances and performance.

The main physical parameters for estimating arable production are enterprise type, yields, and fertiliser use. For grassland production these relate to enterprise type, nitrogen use, length of grazing season, and conservation system and yields of conserved grass.

The methodology for benefit assessment therefore rests on deriving farmers' perception of physical parameters attributable to drainage and converting these to standardised Gross Margin, Fixed Cost and Net Margin values, all expressed in 1982 prices. Other benefits such as extended grazing seasons, are similarly converted to standardised financial values.

The concepts of Gross Margins and Fixed Costs are widely used for farm accounts analysis and planning in the U.K. They can be generalised as follows:

GROSS OUTPUT/ha	(yield t/ha x £/t)
less	
VARIABLE COSTS/ha	(direct costs which vary proportionately with the level of activity but are fairly constant per unit of activity, eg. fertiliser + seeds + sprays + concentrate feeding, per hectare)
equals	
GROSS MARGIN/ha	(the monetary return per unit of limiting/fixed resource, eg. £/ha or £/man day, consistent with the concepts of marginal revenues and marginal costs)
TOTAL FARM GROSS MARGIN	(sum of all enterprise gross margins)
less	
FARM FIXED COSTS	(the overhead/indirect/'basic' costs which are generally fixed in total and comprise regular labour, plant and machinery, buildings, rent and rates, and general expenses)
equals	
MANAGEMENT AND INVESTMENT INCOME	(a measure of farm profitability showing the net return to the farm resources and the management function)

Standardised Gross Margin/ha for specified farm enterprises, and standardised Fixed Costs/ha estimates for specified farm types and sizes are available from published sources, notably the Regional Farm Management Surveys and related Farm Management Pocket Books produced by the Departments of Agricultural Economics, ADAS, the agricultural sections of the main commercial banks, and specialist organisations like MMB and MLC.

V.2.5 The Distinction Between Semi-fixed and Fixed Costs

Given that the Gross Margin and Fixed Cost conventions have been primarily developed for the purpose of comparative accounts analysis, some of the procedures for categorising costs as either variable or fixed, reduces their validity for farm planning and evaluation purposes. The main criticism is that the definition of variable costs in the calculation of the Gross Margin is not sufficiently comprehensive and excludes such items as machinery operating costs (treated as a fixed cost) which are likely to be reasonably constant per unit of activity.

To overcome these problems of cost classification, and yet maintain a level of comparability with other farm management data sources, a distinction has been made in this study between Gross Margins, Semi-fixed Costs, Total Fixed Costs, and Net Return as follows:

GROSS OUTPUT	
less	
VARIABLE COSTS	(seeds, fertilizers, sprays, casual labour, vet and medical, packaging)
equals	
GROSS MARGIN	(according to the conventional definition)
less	
SEMI FIXED COSTS/ha	(standard estimates of direct labour requirement, machinery 'operating' expenses, crop drying/storage operating costs, building maintenance)
<u>or</u>	
TOTAL FIXED COSTS/ha	(standard estimates of total labour requirements, total ownership and operating costs of plant, machinery and buildings)
equals	
NET MARGIN	(Gross Margin minus relevant fixed costs whether SEMI or TOTAL)

'Semi-fixed costs' per unit of activity are items of recurrent expenditure associated with the use of existing fixed resources (eg. machinery fuel and repairs expenses). Total fixed costs per unit of activity combine the latter with a charge for capital investment (eg. the depreciation on plant and equipment).

In the course of interview farmers are asked whether benefit uptake has involved changes in the regular labour, fixed capital structure of the farm, or the use of contractors. If the answer is affirmative, total fixed costs are charged accordingly. Where there has been no noticeable change in fixed costs, but an increase in farming activity, the estimated increase in semi-fixed costs are changed only.

There is very little information on the behaviour of fixed costs with given changes in enterprise size, especially where these may involve enterprise substitution on the farm. Some limited data is available from Farm Management Survey sources to help derive unit rates for 'semi' and 'total fixed' costs. Table V.1, for instance, contains estimates of standard man day and standard tractor hour requirements for selected crop and livestock activities. These 'averages' can be used to estimate the likely implications for labour and machinery requirements of a given change in farming activities, and converted to monetary estimates using standard prices.

The cost of a standard tractor hour includes a charge for all machinery on the farm not just tractors. Table V.2 summarises these unit costs for different farm types and sizes, and distinguishes between semi-fixed costs (recurrent operating costs) and total fixed costs (capital and operating costs). Labour costs of £2.50 per hour for general farm labour and £3.00 per hour for stockmans time is based on 1982 standard agricultural wage rates plus employers contributions. Charges for specialist activities or services such as moling, or silage making, vegetable harvesting, have been based on prevailing contractor rates or calculated from first principles.

The procedures adopted and the data sources used for estimating these financial parameters are outlined in the following sections.

V.2.6 Labour Costs : Semi or Fixed?

The distinction between semi and total fixed costs is probably most problematic in the case of labour; should labour be regarded as a semi-fixed cost related to additional output, or as a fixed resource whose flow of services is there to be used at no extra cost up to the limit imposed by an existing labour force. In this

TABLE V.1

Standard Tractor Hour and Labour Requirements

	Tractor Hours per Hectare	Labour Hours per Hectare
Crops:		
Cereals (incl. straw)	12 (15)	14 (19)
Potatoes	50	123*
Oilseed rape	11	12
Sugar beet	45	68
Ley establishment	8	8
Hay making	12	12
Silage (per cut)	10	12
Grazing	2	3
Livestock:		
per livestock unit	7	Variable

* Depending on yields and harvesting methods.

Source: University Farm Management Surveys

TABLE V.2

Standard Tractor Hour Costs (1)

£ per hour (1982 prices)

	Total Fixed Costs (full cost (2))	Semi Fixed Costs (running costs only (3))
Mainly Dairy:		
under 50 ha	7.50	4.20
over 50 ha	6.40	3.50
Mixed Arable (95 ha average)	5.50	3.00
Arable:		
under 100 ha	7.90	4.40
over 100 ha	5.40	3.00
Mainly Sheep and Cattle (lowland):		
under 100	4.00	2.20
over 100	5.00	2.80

Notes:

(1) These costs include all machinery not just tractors.

(2) Comprising approximately 40% depreciation, 5% tax and insurance, 23% repairs, 20% fuel, 12% contract work.

(3) Excluding depreciation, tax and insurance.

Source: University of Manchester FMS 1980/81 for North West and West Midlands (based on 1980/81 inflated by 15% to give mid-1982 prices using MAFF price index).

study, additional labour requirements per unit of an activity are regarded as a semi-fixed cost and charged accordingly. Thus if moving from, say, extensive grass to intensive arable involves an extra 20 man hours per hectare this is included in the extra semi-fixed costs of such a transition.

The justification for this assumption is based on 2 main observations:

(i) For small to medium size farms, intensification usually means more work for family members, and whilst their supply is fixed, they usually have alternative activities and leisure preferences. Furthermore, a comparison of standard man day requirements and actual labour availability for farms in the benefit area, shows that theoretical labour needs exceed actual regular labour availability by a factor of 1.7. This is especially so on smaller farms.

(ii) For both small and larger farms, intensification of activity is generally occurring at times when labour, though possibly underemployed at some times of the year, is already heavily committed. Extra labour requirements at such times are likely to involve longer hours or overtime. A recent study of labour productivity on different farm sizes and systems suggested the value of labour at peak periods could exceed market wage rates by 5 to 6 times, particularly for 'peaky' arable activities (Edibo, 1983).

Thus the assumption used here is that for arable enterprises, labour inputs per unit of activity are charged as a semi-fixed cost. For livestock activities, as there are, particularly for fatstock, opportunities for labour economies of scale in herd management, on the basis of the available, admittedly limited data, only a proportion of unit labour requirements are deemed semi-fixed, unless the farmer states otherwise.

The procedures and data used for estimating fixed costs for livestock and crops are contained in sections V.3.8 and V.4.3 respectively.

V.2.7 Variation in Farming Performance in the STWA Region

The drainage projects evaluated in this study incorporate 3 Farm Management Survey Regions, namely those based at the Universities of Manchester, Nottingham, Exeter. Only one of the farmers interviewed participated in these surveys. A small number of farmers participated in enterprise recording schemes, notably provided by MMB and feed suppliers. Some farmers were willing to discuss financial data recorded in connection with MAFF AHDS schemes.

Consideration was given to the need and justification for deriving regional standards for Gross Margin and Fixed Cost estimates. After an evaluation of regional farm survey results, consultation with those involved in the latter, and an evaluation of the findings of the survey of STWA farmers, it was concluded that for given farm types the variation within regional farm survey data (particularly in relation to riverine and non riverine farmers) was probably as great as the variation between the regions. The main variations between farms relate to drainage status, soil type, farm type and farm size and it is these variables rather than regional differences, that provide the basis for estimating financial performance.

V.3 BENEFIT ASSESSMENT FOR GRASSLAND ACTIVITIES

V.3.1 Grassland Benefit Types

The benefits of improved drainage for grass production and utilisation are discussed in detail in Annexe IV. In general terms, better drainage, by providing an improved soil/plant/water regime can increase grass growth, improve sward composition, facilitate and encourage greater N fertiliser use and resultant yield response, extend the grazing season, reduce poaching and disease risk, and enable a change to more intensive and predictable grazing and conservation management systems. The overall beneficial impact is to increase the potential carrying capacity of the grassland. Achieving these potential benefits is likely to require additional expenditure on the part of the farmer, for example on extra fertiliser, breeding livestock, or plant and equipment. These additional expenditures need to be deducted from additional revenues to derive the net agricultural benefit attributable to the drainage improvement.

V.3.2 The Importance of N Fertiliser

Assessing the actual productivity of a given area of grassland requires detailed records of the kind not usually kept on most farms.

Grassland productivity can be assessed in terms of final output value (kg of liveweight gain or milk yields per hectare), or in terms of an intermediate output value (utilised metobolisable energy (UME) from grass), which in turn converts to final livestock system output.

In the majority of cases farmers do not keep the kind of records to enable a direct estimate of grassland productivity in these terms, particularly where the concern is with an individual field or group of fields rather than the farm as a whole. A proper assessment would require details of turnout dates and liveweights, liveweight gains or milk yields at grass, details of diet supplementation, numbers of livestock unit grazing days, and conservation dry matter yields and energy values. Whilst there are recording schemes providing such services (eg. MLC for fatstock, MMB for dairy), few farmers in the STWA survey were able to give reliable whole farm estimates of productivity. Even where there were, the fact that the present analysis is concerned with the productivity of individual fields subject to differential drainage/management conditions meant that field level estimates were not directly available. The problem is confounded by the necessity to recall these yields over time and in response to environmental and management changes.

The efforts of grassland researchers has shown that for given environmental and management conditions, grass production is largely a function of nitrogen application (see Annexe II). Given that farmers are more able to give reliable estimates of fertiliser inputs than physical livestock yield outputs, N is used as a proxy for grass productivity.

V.3.3 A Physical Model for Estimating Grass Productivity

The development of a physical model for estimating grass productivity is described in Annexe IV. In essence, the model estimates the utilisable metabolisable energy (UME) from grass on the basis of:

(i) Site class (soil type, rainfall).

(ii) Drainage status (flooding, waterlogging).

(iii) Poaching liability (largely soil type).

(iv) N fertiliser use.

(v) Conservation system (hay, silage, number of cuts).

A given combination of the above factors will operate a given level of UME. For instance, a 'Good' site, with good drainage, no poaching liability, 100 kg N/ha, and grazed only, will give 40530 MJ/ha. This available energy can be converted into grazing livestock units/ha at a predefined rate of exchange. In the study one grazing livestock unit requires 33,350 MJ from grass.

V.3.4 Livestock Energy Requirements and Stocking Rates

The number and type of animals that can be supported by one hectare of grass depends on the potential energy supplied from grass, the feed energy requirements per head of stock type, and the extent to which the latter is met from non-grass sources such as concentrates or purchased bulk feeds.

Estimates of total metabolisable energy requirements according to stock type, age/size, and productivity (liveweight gain and/or milk yield) are available from standard data (MAFF, 1975). (In most diets, it is energy (MJ) that is most limiting, with the satisfaction of energy requirements automatically satisfying protein (CP) needs.)

Different stock types and ages can be expressed in terms of 'livestock unit' equivalents on the basis of relative energy requirements. One livestock unit equates to 48,000 MJ/year, the total energy need of a 550 kg Friesan cow yielding 4,500 litres of milk per year. As shown in Table V.3, the relative energy needs of other stock can be also expressed in terms of livestock units.

In most cases, particularly for overwintered stock, it is likely that animals will consume other feeds besides grass. For instance, a dairy cow is usually fed in excess of 1.5 tonnes of concentrates per year. Overwintered grass beef will have their diet supplemented by purchased feeds. Given that the purpose here is to estimate stocking rates at grass, an estimate is needed of the energy requirement from grass in a representative diet for a given stock type and management system.

Representative diets to achieve stated productivity levels have been calculated in Appendix V.A. A 550 kg liveweight Friesian cow yielding 5,000 litres per year requires a total 51,500 MJ/year, of which 18,150 MJ/year comes from concentrates, leaving 33,350 MJ/year from grass. 33,350 MJ/year is used as the basis for a 'grazing livestock unit' and other stock types, ages, and performance levels are expressed in these terms as shown in Column 2 of Table V.3.

This procedure allows estimated grassland UME production to be translated into stocking rate which in turn provides a basis for estimating financial returns (see Section V.4).

V.3.5 The Cost of Grass and Energy Production

Table V.4 contains estimates of grass production variable costs per tonne of dry matter and per 100 MJ. Seventy percent utilisation efficiency and 10.5 MJ/kg dry matter are assumed. The major component is fertilizer, with reseeding and liming costs for more intensive ley systems. Fertilizer costs per hectare, based on the unit costs given in Table V.5, allow for N, P_2O_5, and K_2O, line ratio between these ingredients varying with level of N, and whether the grass is grazed or conserved.

TABLE V.3

The Relative Energy Requirements of Livestock

Livestock Units	Based on full cow equivalent (1)	Based on proportion of diet from grass (2)
Cow (4500 l)	1.0	1.0
Cow (5000 l)	1.05	1.0
Dairy follower (calving at 27 months)	1.04	1.04
Dairy cow and follower	1.27	1.29
Beef suckler (+ calf)	0.74	0.76
18 month grass/cereal	0.63	0.48
24 month grass beef	0.86	0.85
Grass fed stores:		
young stock 130-250 kg	0.17	0.24
light	0.21	0.30
medium	0.26	0.36
heavy	0.32	0.41
Ewe and lambs	0.14	0.14

Notes:

(1) Assuming 1 cow (4500 l milk) = 48000 MJ/year UME requirement.

(2) Assuming 1 cow = 33350 MJ/year from grass.

Source: Appendix V.A.

TABLE V.4

The Costs of Grass and Energy Production

Site classification : Good

Nitrogen	0	50	100	150	200	250	300	350
Theoretical (t DM/ha)	2.8	4.2	5.6	7.0	8.3	9.1	10.3	11.0
Realisable (t DM/ha)	2.0	2.9	3.9	4.9	5.8	6.7	7.2	7.7
UME ('000 MJ/ha)	20	31	41	52	61	69	76	85
Grass Production Variable Costs*								
Seeds						15	15	15
Sprays	6	8	10	12	14	16	18	20
Fertilizers		31	59	85	108	126	144	162
Lime					5	10	15	15
Total £/ha	6	39	69	97	127	167	192	212
Cost (p/'00 MJ)	3	13	17	19	21	24	25	25
Cost (£/t DM)	3	14	18	20	22	23	25	26

* Excluding hay/silage making costs

1982 prices

TABLE V.5

Fertilizer Constituents and Costs

	Active Ingredients % by Weight			£/t	p/kg of Active Ingredient		
	N	P	K		N	P	K
Compounds:							
High N	20	10	10	148	37	37	37
Low N	10	23	23	185	33	33	33
High P	10	25	15	178	36	36	36
High K	8	16	32	148	26	26	26
Straights:							
Muriate of potash	0	0	60	102	-	-	17
Triple super phosphate	0	45	0	165	-	37	-
Nitram	34.5	0	0	124	36	-	-

Grass variable costs, excluding labour and machinery for pasture management or conservation, vary according to site class and intensity of production. For the purpose of this study, they are assumed to be 22 pence per 100 MJ.

V.3.6 Grassland Benefit Scenarios

It is possible that the increased carrying capacity of grassland can manifest itself in a number of ways which in part reflect farm circumstances and farmer preferences. For instance, farmers may exploit such benefits in one or a combination of the following ways:

- increased stock numbers on same grass area; increased stocking rate; increased gm/ha,

- same stock numbers, same grass area, allowing either reduction in purchased feed, or increase in feed input; increased gm/head and gm/ha,

- same stock numbers on reduced grass area; increase in stocking rate, release of land for other uses; extra gm from released area,

- changes in or substitution of livestock enterprises: increased gm/ha.

In the main the above changes will result in increases in gross margin performance. Whether farmers incur additional fixed costs such as labour, power and machinery, and buildings will depend on the size of the change and individual farm circumstances. In the main, where farmers have recognised sizeable drainage benefits for grassland, this has involved increases in stock numbers and stocking rates.

V.3.7 Livestock Gross Margins

Grassland enterprises in STWA cover dairy, beef sucklers, beef fatstock, and sheep production. It is usual to express financial performance in terms of gross margin per head and per hectare, the relationship between the two being a function of stocking rate.

Estimates of livestock gross margins are summarised in Table V.6. , and explained in detail in Appendix V.A. Gross margins per head are derived by deducting from the value of gross output, the variable cost of bought feeds, veterinary services, and sundry items.

The procedure for estimating gross margin per hectare depends on UME from grass and grass variable costs, these latter two being related as discussed in V.3.4 above. The procedure can be explained as follows:

(i) $\dfrac{\text{Total UME from grass (MJ/ha)}}{\text{UME required from grass for given stock type (MJ/hd)}}$ = Stocking rate (hd/ha)

(ii) $\dfrac{\text{Variable cost of grass production (£/ha)}}{\text{Stocking rate (hd/ha)}}$

= Forage cost (£/hd)

(iii) (Gross margin (£/hd) - Forage cost (£/hd)) x Stocking rate (hd/ha) = Gross margin (after forage variable costs (£/ha)

The relationship between gross margins per head and per hectare is of course a complex one. For instance, higher supplement feeding may depress gross margins per head, yet, by allowing higher stocking rates, achieve higher gross margins per hectare. For most

TABLE V.6

Summary of Livestock Gross Margins

1982 prices

	£/Head Before Forage Variable Costs	£/Head (1) After Forage Variable Costs	£/ha (1)
Dairy			
Milk cows (5000 l/cow)	432	376	570
Dairy replacements	285	223	295
Milk cows and followers (per unit)	512	430	500
Beef			
Suckler herds - single suckler	191	144	250
- double suckler	207	160	280
18 month grass/cereal beef	186	157	450
Grass beef (24 month)	223	173	280
Store cattle grass feeding			
- young	88	74	425
- light	79	61	280
- medium	66	45	175
- heavy	55	31	100
Overwintering and grass finishing	122	102	330
Sheep			
Lowland fat lamb production (1.4 lambs/ewe)	34	27	265
Fat lambs sold off forage	35	28	280

Note:

(1) At average stocking rates : on 'good' site, dairy 150 kg N/ha, other cattle 125 kg N/ha, sheep 100 kg N/ha. Forage variable costs include sprays and chemical fertilizers (see Table V.4), stocking rates are based on UME requirements at grass and UME available from grass for a good site with stated chemical N applications. No additional allowance is made for organic manures; applying farmyard manure could reduce forage variable costs, or enable higher stocking rates (10-14%) at the same forage costs, thereby increasing gm/ha.

Source: Appendix V.A

progressive farmers, land is usually the limiting resource, such that maximising gross margin per hectare is the guiding criterion. The procedure used here is to convert standardised livestock gross margins/head to gross margins/hectare by reference to site-specific grass productivity, and thereby estimate the improvement in gross margin attributable to given management changes.

Figure V.4 summarises the relationship between gross margins per hectare and stocking rate, whereby given stock types/ages/performance levels are expressed in equivalent grazing livestock units (glu) as explained in Table V.3.

The gross margin improvement associated with an increase in stocking rate, or a substitution of livestock type, can be derived from Figure V.4. An increase in dairy stocking from 1 glu/hectare to 1.2 glu/hectare, for instance, would generate an expected increased gross margin of £60 per hectare. The gross margin curves assume that variable costs per head remain constant with the exception of forage costs (mainly fertiliser) which increase per head with stocking rate.

For a given site class and drainage status, gross margin per hectare will largely reflect nitrogen application as shown in Figure V.5.

V.3.B Livestock Fixed Costs

Using the method described in Section V.2, the expected average semi-fixed, and average total fixed costs per head have been calculated for different livestock systems, using data from MMB, MLC and University Farm Management Surveys. These estimates are presented in Table V.7 and explained in Appendix VI.B.

With reference to Table V.7 semi-fixed costs are the extra recurrent or operating expenses associated with an extra stock unit, whereas total average fixed costs include operating and overhead/capital expenses.

FIGURE V.4

Gross Margin per Hectare by Stocking Rate

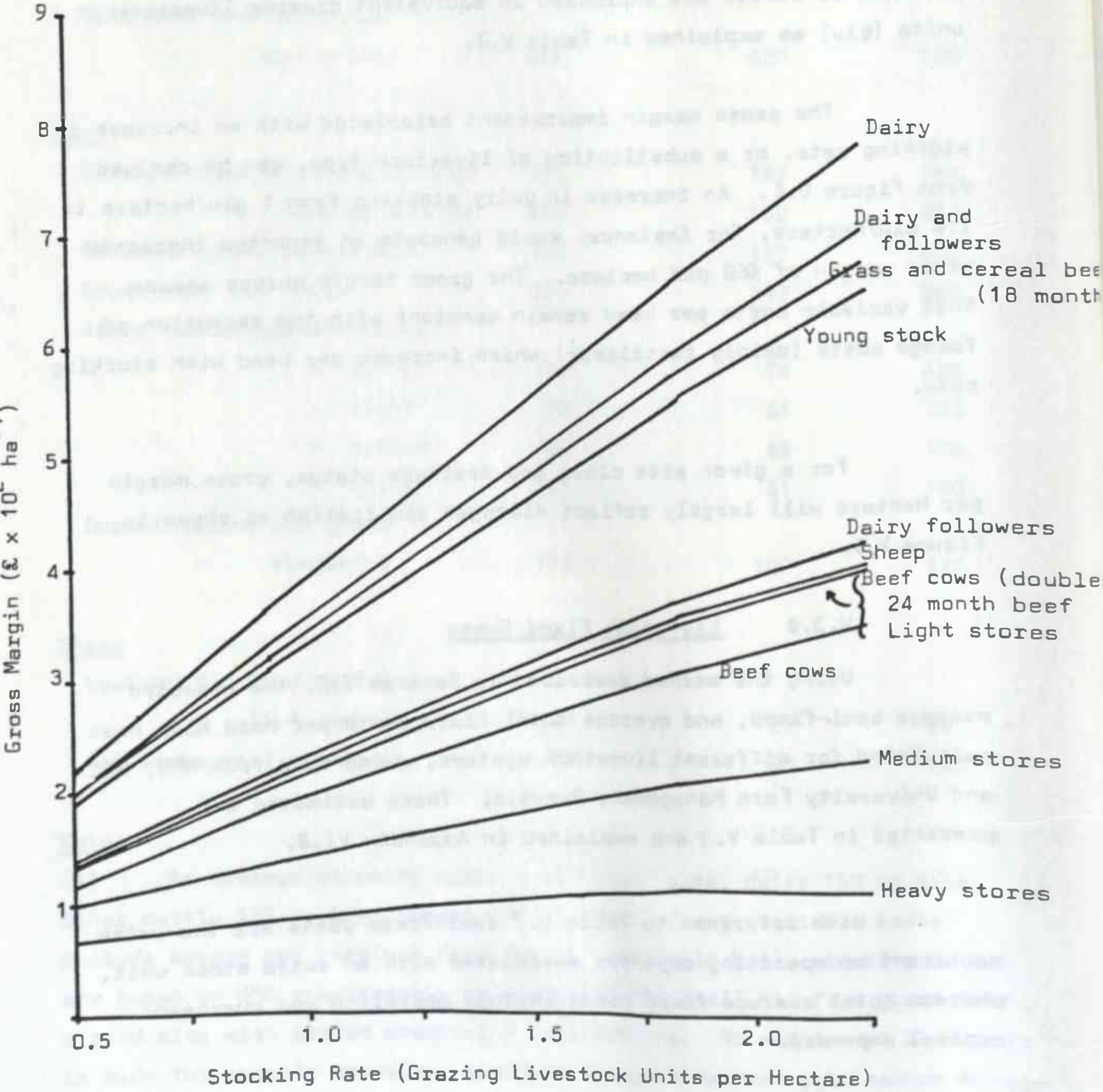
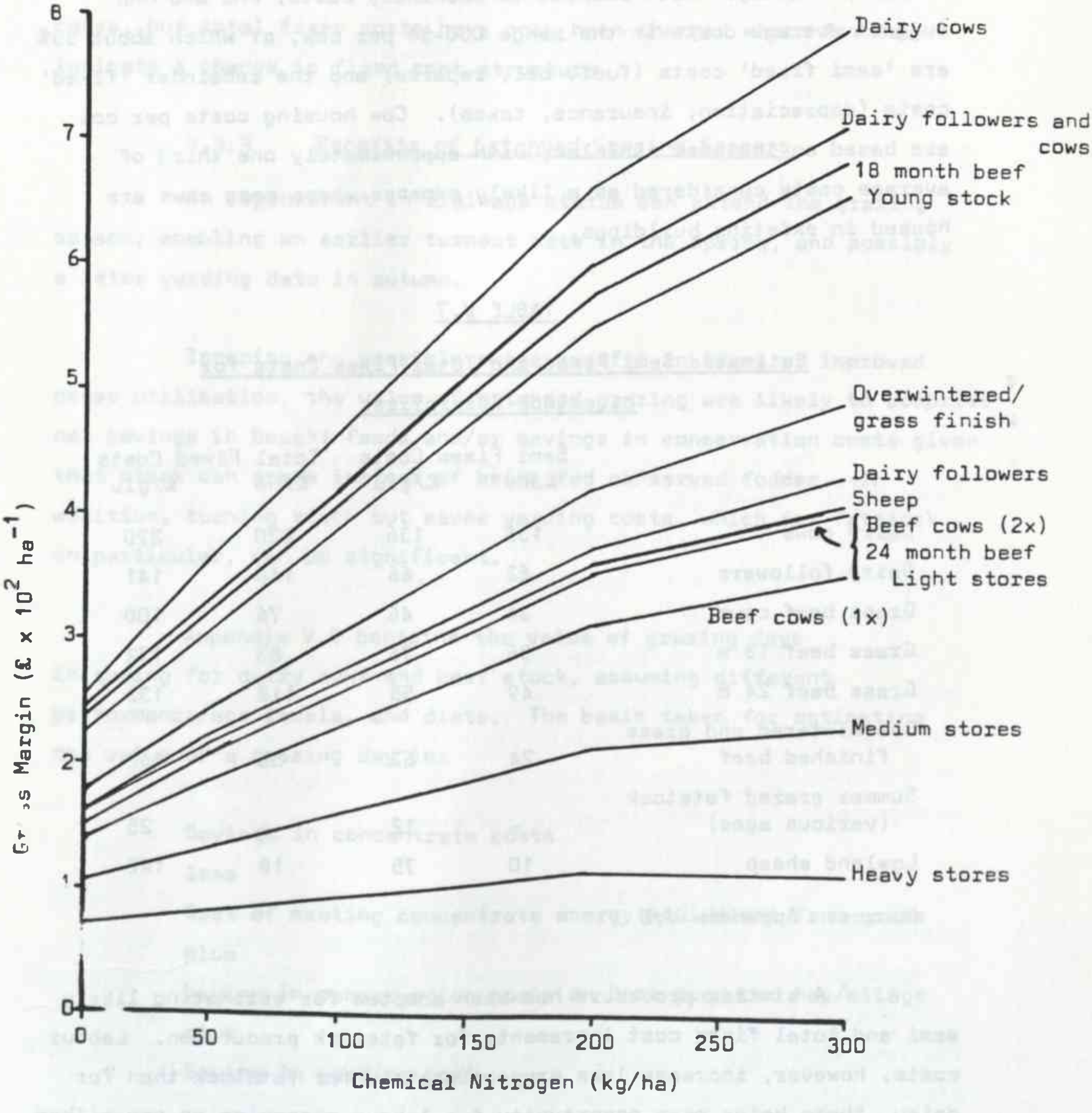


FIGURE V.5

Gross Margin per Hectare by Nitrogen Application

Site Class: "Good"

Drainage Status: "Good; Zero Poaching"



For instance, in the case of dairy production, information from MMB and Farm Management Surveys (FMS), suggests an average total labour requirement of 40 hours per cow per year, and that an addition cow would demand about 30 hours per cow. At £3.00 per hour, average total costs and semi fixed costs are therefore estimated at £120 and £90 respectively. With respect to machinery costs, FMS and MMB suggest average costs in the range £50-54 per cow, of which about 55% are 'semi fixed' costs (fuel, oil, repairs) and the remainder 'fixed' costs (depreciation, insurance, taxes). Cow housing costs per cow are based on low cost cubicles, with approximately one third of average costs considered as a likely expense where more cows are housed in existing buildings.

TABLE V.7

Estimated Semi Fixed and Total Fixed Costs for Livestock Enterprises

	Semi Fixed Costs		Total Fixed Costs	
	£/hd	£/glu	£/hd	£/glu
Dairy cows	136	136	220	220
Dairy followers	62	66	146	141
Grass beef cows	34	46	76	100
Grass beef 18 m	36	76	83	172
Grass beef 24 m	49	58	112	132
Overwintered and grass finished beef	24	62	55	142
Summer grazed fatstock (various ages)	-	12	-	25
Lowland sheep	10	75	18	142

Source: Appendix V.B

A similar procedure has been adopted for estimating likely semi and total fixed cost increments for fatstock production. Labour costs, however, increase less proportionately for fatstock than for dairy, there being more opportunity for labour economies on non-milked stock at grass. Within the limits of extremely scanty published data, and farmer guesstimates, extra stock are assumed to need about one third of average labour needs per head, mainly taken up during yarding/marketing. Machinery and buildings estimates draw mainly on MLC and FMS data according to the approach previously described for dairy.

In calculating the additional net return to livestock enterprises, additional semi fixed costs have been charged in all cases, but total fixed costs have only been charged where farmers indicate a change in fixed cost structure.

V.3.9 Benefits of Extended Grazing Seasons

An improvement in drainage status can extend the grazing season, enabling an earlier turnout date in the spring, and possibly a later yarding date in autumn.

Ignoring any possible extra benefit in terms of improved grass utilisation, the value of extended grazing are likely to comprise net savings in bought feeds and/or savings in conservation costs given that stock can graze instead of being fed conserved fodder. In addition, turning stock out saves yarding costs, which for fatstock in particular, can be significant.

Appendix V.C contains the value of grazing days in spring for dairy cows and beef stock, assuming different performance/age levels, and diets. The basis taken for estimating the value of a grazing day is:

Savings in concentrate costs
less
Cost of meeting concentrate energy equivalent from grass
plus
Saving in conservation costs on home produced hay/silage
plus
Saving in yarding cost

Extra graz ɡ days in autumn (September, October) are assumed to be worth half t › value of an early spring (March, April) day, plus yarding. Ove. intering on grass is assumed to save yarding costs only, unless values for 'agistment', particularly for sheep, are available. The resultant values (£/day/glu) used in the analysis are summarised in Table V.8.

TABLE V.8

The Value of Extra Grazing Days by Livestock Type

£/day at grass/grazing livestock unit

	Spring April/May	Autumn September/October	Winter November/March
Dairy Cows	1.13	0.65	0.24
Dairy Followers	1.05	0.64	0.24
Fatstock	0.80	0.52	0.24

V.3.10 Conservation Systems and Costs

Improved drainage can enable a move from less predictable traditional hay-making systems, to more productive and reliable silage systems. The physical performance in terms of UME of different conservation regimes is discussed in Annexe IV.

Haymaking or silage making costs vary greatly between size and type of system, area conserved, number of cuts and total tonnage. It is difficult to generalise on farm-level conservation costs because of such variations between farms and between climatic years, and because mainly farmers operate personalised, hybrid systems.

The total cost of conservation for silage making (£/UME) is higher than for haymaking, because of the greater capital investment in specialist machinery. The benefits of silage making are in terms of higher and more reliable yields, which enable grass to substitute for more expensive purchased winter feeds. The relatively high digestibility of silage compared to hay is important in grass based diets for high yielding livestock systems.

Table V.9 contains estimated costs for hay and silage making based on a typical range of systems. Hay making costs are based on a conventional baler and flat eight system. A range of silage systems were considered from large bale and bag systems, to precision chop and clamping systems. The major factor influencing costs is annual tonnage. The estimated silage costs are regarded as typical average costs and accord reasonably with other sources (Causton, 1981).

TABLE V.9

Grass Conservation Systems : Hay and Silaging Costs

	Semi Fixed Costs	Total Fixed Costs
Hay Making:		
£/ha		
Labour	42.0	42.0
Machinery	18.7	50.2
Storage	5.0	15.0
Total	65.7	107.2
£/tonne DM (at 86%)	15.3	25.0
Silage Making:		
£/ha (20 t/ha)		
Labour	17.9	17.9
Machinery	26.4	73.4
Storage	28.0	85.6
Total	72.3	176.9
£/tonne DM* (at 20%)	14.4	35.4

* Based on 2 man, flail harvester, wilted silage. Actual costs vary with annual throughput; at near full capacity the costs of different silage systems approximate to the figures above.

The farm survey revealed that where farms had changed from hay making to silage making in the benefit area due to drainage improvement, in most cases, the relevant additional costs relate to semi-fixed, rather than total fixed costs because either the move to silage had been justified in the context of the farm as a whole, or the system adopted (eg. big bale bagged silage) was not significantly different in capital investment to an equivalent hay making system. Thus in the analysis, unless farmers stated specifically otherwise, semi-fixed costs have been used to estimate additional conservation costs.

V.3.11 Pasture Management Costs

Reseeding pastures and/or applying more nitrogen doses require additional labour and machinery inputs, and these are estimated at standard rates.

Table V.10 contains semi-fixed and total costs per hectare for ley establishment and nitrogen/agro-chemic applications.

The costs of ley establishment are spread over the life of the ley. Each 80 kg of N is assumed to require one machinery application. The cost of seeds, fertilizers, and sprays is included in forage variable costs (see Table V.4).

TABLE V.10

Pasture Management Costs

First year of establishment:

Leys

£/ha	Semi-fixed costs	Total fixed costs
Labour	12.0	12.0
Machinery	27.9	53.9
	39.9	65.9

Nitrogen application and sprays on grass

£/ha for each application	Semi-fixed costs	Total fixed costs
Machinery	1.38	2.50
Labour	1.0	1.0
	2.38	3.50

V.3.12 The Cost of Grass and Silage

Table V.11 summarises the energy value and cost per unit of energy of grazed grass, silage and hay. Grass production costs and conservation are estimated at 22p and 37p per 100 MJ respectively, giving a total 59p per 100 MJ conserved. The study estimates are consistent with estimates from other sources. By comparison purchased feeds range between 87p and 127p per 100 MJ for hay and concentrates respectively.

V.3.13 Comparative Benefits of Improved Grass

Grass productivity benefits can manifest themselves in a variety of ways as discussed in V.3

Table V.12 compares the financial implications of benefit patterns for a given improvement in drainage status from 'bad' to 'good', at a given N level.

TABLE V.11

The Cost of Grass and Silage (1982 prices)

	GRI/ICI Estimates (a)				Silsoe Estimate Feed cost p/'000 MJ
	Dry matter yield t/ha	Feed cost £/t DM	Energy MJ/kg DM	Feed costs p/'00 MJ	
Grazed grass (forage variable costs)	6.7-10.2	24-26 (1)	11.8	20-27	22 (b)
Silage making only	6.3-11.0	29-38	10	29-38	37 (c)
Silage (forage variable costs + silage making)	6.3-11.0	50-64 (2)	9.8-10.7	50-64	59

Notes:

(1) Excluding overhead costs.

(2) Excluding overhead costs and value of aftermath grazing.

Sources: (a) Thomas and Young (ed), Milk from Grass.

(b) Table V.4

(c) Table V.9

TABLE V.12

Benefits of Drainage Improvement for Grass Production (1)

£'s, 1982 prices

	gm/ha	£/'00 MJ	Net (2) Revenue/ha	£/'00 MJ
Savings in bought: Barley	23	0.56	23	0.56
: Hay	20	0.50	20	0.50
Increase in stocking and more stock:				
Dairy	33	0.87	19	0.47
Fatstock (24 m)	19	0.47	13	0.33
Increase in gross output (3)				
Dairy (milk)	-	-	105.6	2.64
Fatstock (liveweight) 24 m	-	-	46	1.15
Land release (4)				
Spring barley	33	0.81	25	0.63
Winter wheat	44	1.10	35	0.88
Potatoes	107	2.68	55	1.38

Notes:

(1) Assuming good site, drainage improving from BZ to GZ, with constant 100 N applied. Extra UME = 4000 MJ/ha, 1.23 glu/ha increased to 1.35 glu/ha.

(2) After semi fixed costs.

(3) Assuming all 4000 MJ converted to extra milk output at 5.3 MJ/kg of milk, or fatstock yield at 59 MJ/day for average liveweight of 300 kg gaining 0.67 kg liveweight/day.

(4) Assuming an increase in carrying capacity releases

$\left\{1 - \frac{1.23}{1.35}\right\}$ ha/ha of grass = 0.09 ha.

Predictably, where extra energy can be converted into extra gross output, the benefits are considerable, but the scope for doing so within existing enterprises may be limited without other changes in management practice, such as conservation or pasture management improvement. Alternatively extra energy from grass can substitute for relatively expensive purchased feeds. This option is often attractive to farmers who, for a variety of reasons, are not able or do not wish to intensify or expand production. Improved reliability of grass supply, as it affects the need for purchased feed, is important in reducing annual fluctuations in net income, in some situations, providing the confidence for intensification or expansion.

Where the benefits of grass have not been associated with major changes in feeding regimes or yields per animal, and this would appear to be the majority of cases, the benefits have been in terms of an increase in stock numbers on a given area of grass. In such situations, management practices remain fairly constant (eg. diet composition, milk yields, liveweight gains) but stocking rates increase. The financial benefits of increased stocking rates are more modest than those associated with changes in the system of livestock management itself, but more readily achievable particularly for moderate improvements in grass production and increases in animal numbers that can be accommodated within the existing fixed cost structure. In a number of cases farmers indicate that benefits have involved a combination of yield, bought feed, and stocking rate factors, but have not been able to quantify these relative benefits.

Table V.12 also identifies the benefits associated with land released to arable, which for the example chosen fall between livestock gross output and stocking rate benefits.

V.3.14 Uptake of Nitrogen on Grass

Pre-scheme nitrogen use on permanent grass was low at an overall average of 89 kg/ha. This had increased to 131 kg/ha by 1983/4. Some 13% of the benefit areas in grass received no nitrogen post-scheme.

With fertilizer as the major basis for estimating productivity improvements on grassland the build-up of fertilizer use over time is an important determinant of the estimated rate of benefit uptake. At interview, farmers were able to report pre-scheme and present (1983/4) nitrogen use. Where nitrogen use had increased after the scheme, farmers in most cases reported that it had done so steadily each year, unless there had been a change in grassland management usually linked to drainage, reseeding, the introduction of leys, or silage making which occurred at a particular time. On the older schemes, farmers reported that fertilizer rates had remained reasonably constant (allowing for climatic year variations) since 1979/80. This appears consistent with the annual Rothamsted fertilizer survey (Church, 1984), which shows a continuous, almost linear, trend of increased use of N fertilizer (for those using it) on grass up until the late 1970's.

Where specific information is not available on the annual change in fertilizer use over time, but pre-scheme and present post-scheme N uses are known, assumptions have been necessary regarding estimated use during intervening years, based on farm survey data and secondary information. For instance, it is assumed that, unless information exists to the contrary, the increment in fertilizer use post-scheme has followed a linear increase during the 1970's up 'til 1979 after which time it has been constant. These assumptions are listed in Appendix V.D, together with a review of the national fertilizer survey.

V.4 DRAINAGE BENEFITS FROM ARABLE PRODUCTION

V.4.1 Benefit Types

The potential benefits of improved drainage for arable production are discussed in Annexe II. They relate to a better soil/plant/water growing environment, reduced damage due to excess water, and to the benefits of improved timeliness of field operations.

Compared to grassland systems, where the crop is converted to final output in a livestock complex, the benefits of drainage to arable production are more direct and easy to identify (although they may remain difficult to fully explain). In the main, drainage benefits to arable cropping will manifest themselves in terms of:

(i) an improvement in the physical input:output performance of existing crops,

(ii) a switch to new crops and/or crop rotations, such as a change from grass to arable, a change in the type of crops grown (eg. spring to autumn sown cereals), or a change in the cropping pattern (eg. a change in the type and relative frequency of crops and grass in a rotation, eg. years of cereals, length of leys).

To assess the actual benefits of such changes information is obtained from farmer interview and other local sources about the physical parameters relating to the 'before' and 'after' improvement situations, namely, enterprise type, input levels, yields, dates of change (see Annexe III). The physical estimates are then translated into standardised gross margins and relevant fixed cost estimates.

V.4.2 Arable Crop Gross Margins

Table V.13 summarises main types of arable gross margins used in the study. Their derivation is more fully explained in Appendix V.E. In the course of benefit assessment, field level arable gross margins are calculated according to farmer estimates of realised yields, and variable costs are adjusted where practices (eg. fertiliser use) are significantly different from 'standard'.

V.4.3 Arable Crop Fixed Costs

Changes in cropping intensity and patterns may, depending on farm circumstances, require additional expenditure and/or investment in 'fixed' resources, namely labour, machinery, buildings and storage.

In accordance with the assumptions discussed in Section V.2 estimates are made of the likely extra semi-fixed and total fixed costs per hectare of a given cropping activity. The estimates draw mainly on regional Farm Management Survey data. Semi-fixed costs reflect the likely extra recurrent expenditure (labour, machinery operating costs, drier operating costs), whilst total fixed costs

TABLE V.13

Arable Crop Gross Margins

1982 prices

	£/ha
Winter wheat (5.5 t/ha - 6.5 t/ha)	480 - 600
Spring wheat (4.3 t/ha - 5.0 t/ha)	390 - 470
Winter barley (4.75 t/ha - 5.0 t/ha)	394 - 421
Spring barley (4.3 t/ha - 5.0 t/ha)	370 - 444
Oilseed rape (2.0 t/ha - 2.5 t/ha)	340 - 473
Sugar beet (35 t/ha - 45 t/ha)	570 - 810
Potatoes, main crop (30 t/ha - 40 t/ha)	834 - 1139
Red beet (36 t/ha)	824
Strawberries (5 t/ha - 7 t/ha)	985 - 1545
Broad beans (2.8 t/ha)	310
Vining peas (4.5 t/ha)	290

Source: Appendix V.E

TABLE V.14

Semi and Fixed Costs for Arable Crops

£/ha 1982 prices

	Semi Fixed Costs	Total Fixed Costs
Cereals (5 t/ha crop)	89	181
Sugar beet	305	418
Potatoes	577	970 (1)
Oilseed rape (2 t/ha)	106	162
Red beet	290	390
Strawberries	420	520
Broad beans	72	104
Kale	39	56
Vining peas	119	161

Source: Appendix V.F

Notes:

(1) Including extra on-farm storage where relevant

include a component for extra capital investment (machinery, plant and buildings depreciation).

Table V.14 contains a summary of standardised semi and fixed costs assumptions for arable enterprises.

Semi-fixed costs have been assumed to apply in all cases. Total fixed costs are assumed relevant only where farmers have indicated that changes in farm fixed cost structure have been a consequence of drainage. For instance, where new crop rotations in the benefit area include enterprises such as potatoes, previously grown on other parts of the farm, then there has been no increase in the fixed costs of this particular enterprise. Extra semi or fixed costs may however have been increased for the farm as a whole.

V.4.4 Land Use Substitution

In some cases the improvements in productivity in the benefit area may not fully reflect the benefits to the farm as a whole. This arises particularly where improved drainage allows land to be released on other parts of the farm for more productive uses. This type of benefit scenario was referred to in section V.2.3 and Table V.12. In most instances this involved retaining the same livestock herd on a smaller area of grass, and releasing 'upland' areas to arable. Where the farm survey indicated that this had taken place, the benefit assessment has been adjusted accordingly.

V.5 PRICE AND PRODUCTIVITY ASSUMPTIONS OVER TIME

V.5.1 Price Relationships

All prices in the analysis are in mid 1982 constant prices. The analysis therefore ignores the differential effect of inflation on inputs and outputs over the time horizon concerned, and implies that 1982 price relativities provide a good overall estimate of (real) (inflation adjusted) price relationships. Fifteen of the 16 schemes examined relate to the period 1971 to 1984, a time of unprecedented inflation and considerable changes in price relativities.

Constant 1982 prices have been used for a number of reasons:

(i) 1982 was the year in which the study began.

(ii) Adjusting annual benefit estimates for real price changes over the 1970-84 period would be cumbersome, and would make the results difficult to present and interpret.

(iii) There is evidence that real price changes have been compensated for by productivity improvements, such that gross margins (and to a lesser extent) net revenues have changed proportionately less than real prices.

(iv) The implications of taking a constant price base can be tested by sensitivity analysis.

Table V.15 contains the main price indices used in this study. As discussed in Annexe VII, agricultural aggregate input and output prices have declined in real terms, but the former less than the latter, such that enterprise and farm margins have generally been squeezed. During the same period, however, productivity improvements have continued unabated with average unit yields of cereals and milk per cow rising at the rate of some 2-3% per year (see Annexe VII), and these improvements have helped to counteract the declining terms of trade of agriculture. Thus, for the 1970-84 period, lower real prices in the later years have partly been offset by higher yields.

Figure V.6 shows the relationship between gross margins (which incorporate yield and price effects) at current prices and at constant 1982 prices for wheat and dairy cows. These particular estimates, based on Nix, do involve a predictive element for the year in which they were published, but are considered adequate for the purpose intended here, which is to argue that changing enterprise relativities can be handled in the sensitivity analysis.

Figure V.7 contains comparative trends in major livestock and arable enterprises. Figure V.8 shows the change in real terms of major fixed cost items over the relevant period. The possible effects of these real price movements on benefit estimation are considered in the sensitivity analysis, section V.7.

TABLE V.15

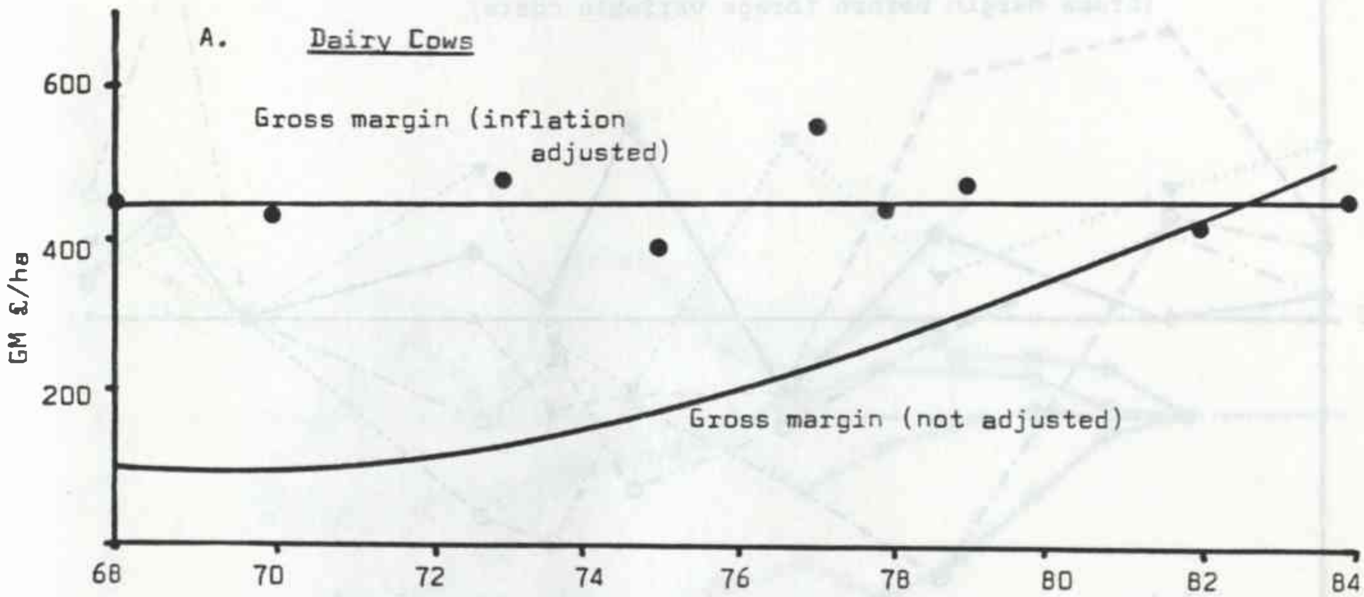
Price Indices Used in the Study

	Retail Price Indices	Public Works Non-Roads	Agricultural Inputs Current	Agricultural Inputs Capital	Agricultural Produce
1966	18.8	15.6			
1967	19.3	16.0			
1968	20.2	16.7			
1969	21.3	17.1			
1970	22.7	19.3			
1971	24.7	21.9			
1972	26.5	27.2			
1973	28.0	38.2			
1974	33.5	44.7			
1975	41.7	43.9	46.4	39.9	52.6
1976	48.6	44.7	57.6	48.1	67.7
1977	56.3	51.3	66.5	57.7	70.3
1978	61.0	61.4	68.0	65.0	72.5
1979	69.0	76.8	75.8	73.4	80.1
1980	81.6	91.7	84.9	85.7	84.5
1981	91.3	87.7	93.3	92.6	97.7
1982	100.0	100.0	100.0	100.0	100.0
1983	107.2	n/a	1.07	1.06	1.04
1984	113.6*	n/a	1.13*	1.11*	1.10*

* Estimated upon basis of first five months.

FIGURE V.6

The Relationship Between Gross Margins at Current Prices and Constant 1982 Prices



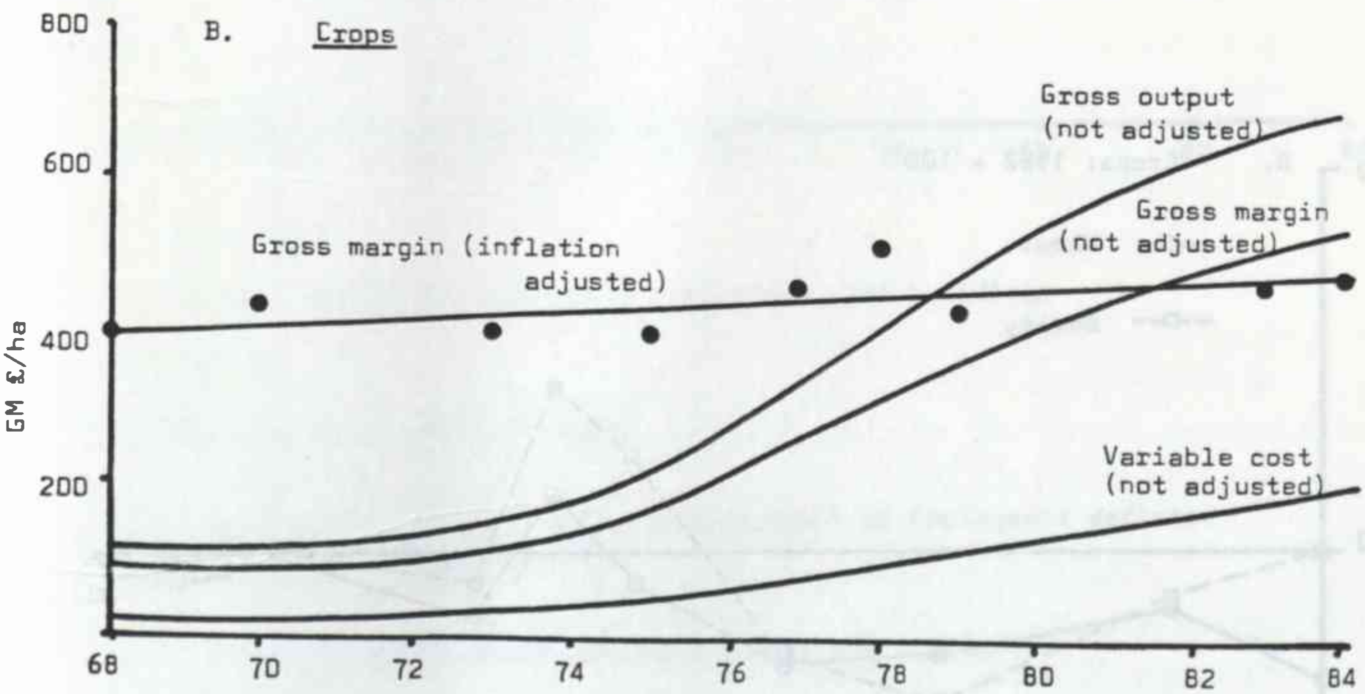


FIGURE V.7

Trends in Gross Margins 1968-84

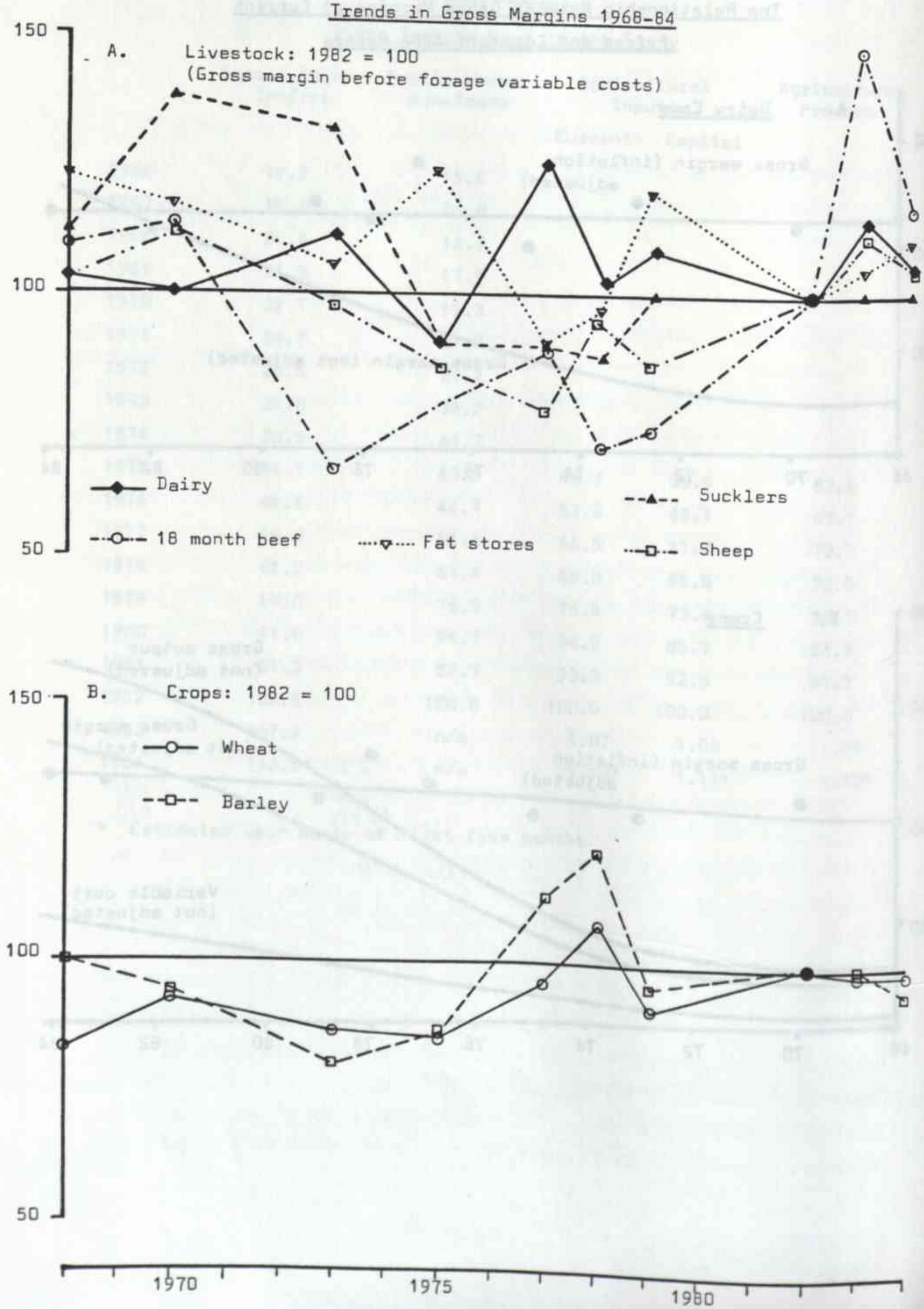
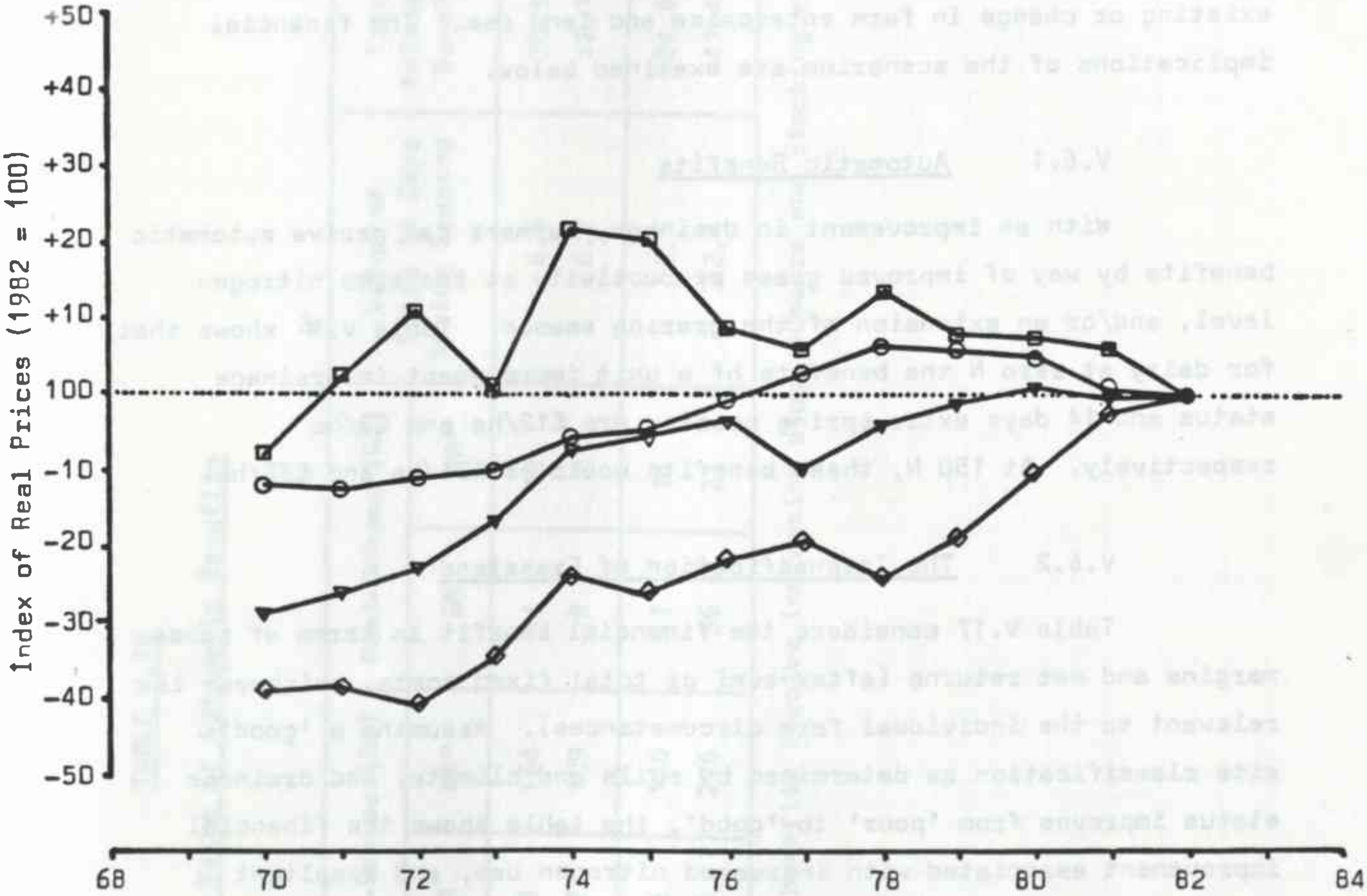


FIGURE V.8

Real, Inflation Adjusted Input Prices 1970-82



□ Fertilizers

○ Agricultural investment goods : machinery and buildings

▽ Labour

◇ Energy : Fuels and lubricants

(1) Actual Indices from MAFF and Department of Employment deflated by Retail Prices Index.

Possible weights for sensitivity analysis : 1972-79

Labour	0.9 x 1982 value	
Fertilizer	1. x "	"
Energy	0.8 x "	"
Investment goods	1.0 x "	"

V.6 FINANCIAL BENEFIT SCENARIOS

The main types of benefit scenarios were identified in section V.2.3 above, and involved either an intensification of existing or change in farm enterprise and land use. The financial implications of the scenarios are examined below.

V.6.1 Automatic Benefits

With an improvement in drainage, farmers can derive automatic benefits by way of improved grass productivity at the same nitrogen level, and/or an extension of the grazing season. Table V.16 shows that for dairy at zero N the benefits of a unit improvement in drainage status and 14 days extra spring grazing are £12/ha and £9/ha respectively. At 150 N, these benefits would be £21/ha and £22/ha.

V.6.2 The Intensification of Grassland

Table V.17 considers the financial benefit in terms of gross margins and net returns (after semi or total fixed costs, whichever is relevant to the individual farm circumstances). Assuming a 'good' site classification as determined by soils and climate, and drainage status improves from 'poor' to 'good', the table shows the financial improvement associated with increased nitrogen use, and resultant increased stocking rates.

For dairy and follower systems gross margins (GM), net returns after semi fixed costs NR (SFC) and net returns after total fixed costs NR (TFC)* increased by £274, £153 and £69/ha respectively following an increase in nitrogen from 0 to 150 kg/ha. In most cases of moderate intensification NR (SFC) will apply.

The application of 300 kg N/ha would achieve increases per hectare of £485 (GM), £271 NR (SFC) and £124 NR (TFC). Reseeding and silage making is likely to be required to sustain this intensified

* NR (SFC) = GM - semi fixed costs and apply where the change has not required new capital expenditure on the farm. If capital expenditure has been required to take up benefits NR (TFC) = GM - total fixed costs applies.

TABLE V.16

The Value of Automatic Benefits

£/ha

	N kg/ha	Pre-Scheme (BZ)		Post-Scheme (GZ)		Value of Extra 14 Days Spring Grazing	Total Automatic Benefit
		GM	NR*	GM	NR*		
Dairy and Followers	0	228	164	14	12	8.8	20.8
24 m Beef	0	142	109	8	6	6.7	12.7
24 m Beef	100	236	166	17	11	13.6	24.6
Dairy and Followers	150	466	296	36	21	22.4	43.4

* After semi fixed costs, assuming benefits involve increasing stock numbers and stocking rates.

TABLE V.17

Benefit Scenarios for Improved Grassland Productivity

Enterprise	Pre-Scheme (BZ)				Post-Scheme (GZ)												Remarks
	N	GM	NR(SFC)	NR(TFC)	(i)				(ii)				(iii)				
					N kg/ha	Δ GM £	Δ NR (SFC) £	Δ NR (TFC) £	N kg/ha	Δ GM £	Δ NR (SFC) £	Δ NR (TFC) £	N kg/ha	Δ GM £	Δ NR (SFC) £	Δ NR (TFC) £	
Dairy	0	231	157	111	75	172	96	51	150	326	185	100	300	575	328	178	Silage operating costs 1 cut, cost £54 on 300 n, £85 for 2 cuts. 1 cut, cost £36 on 200 N.
Dairy & Follower	0	228	164	118	75	144	79	35	150	274	153	69	300	485	271	124	
Over-wintered Stores	0	171	137	94	75	112	75	31	150	211	143	62	200	278	191	85	Value of extra grazing days at 150 kg/N: £1.6/day dairy £1.2/day fatstock
Beef Cows (x 2)	0	142	116	87	75	85	58	27	150	162	111	55	200	213	148	75	
24 m Beef	0	142	110	69	75	85	51	11	150	162	98	24	200	213	132	34	
Medium Stores	0	106	100	93	75	38	27	18	150	73	54	38	200	96	73	53	

BZ : bad drainage, GZ : good drainage

N : nitrogen kg/ha

GM : Gross Margin, NR(SFC) : Net Return after semi fixed costs

NR(TFC) : Net Return after total fixed costs

Δ : extra

system. Silage operating costs would be £54 for one cut at 300 kg N/ha.

Medium weight stores summer fattened at grass was the most common pre-scheme beef enterprise. Improvements from adding 75 kg N/ha are £38 (GM), £27 NR (SFC) and £18 NR (TFC). Those farmers taking up benefits and staying in livestock generally move out of store fattening into more intensive systems, such as 18-24 m beef, or overwintering and grass fattening. The low level of most pre-scheme fattening systems means that the potential for financial improvement whether for livestock or arable is considerable.

V.6.3 Grass to Arable Ley

Table V.18 considers the switch from grass to arable/ley systems, where the latter involves a typical 3 year ley, 3 cereal rotation. Moving from a pre-scheme poorly drained site with zero nitrogen, to a well drained site with 150 kg N/ha on grass, increases GM, NR(SFC) and NR(TFC) by some £280, £200 and £135 per hectare respectively. Extra conservation operating costs on grass, if relevant, would reduce net returns by about £36/ha. The more intensive the pre-drainage livestock system, the lower the increment in financial return.

V.6.4 Grass to Arable

Table V.19 considers examples of the swtich from grass to arable. Assuming a pre-scheme situation of low intensity dairying, moving to a post-scheme cropping of continuous wheat at 5 t/ha generates an extra £201/ha GM, £176/ha NR(SFC) and £131 NR(TFC). Arable rotations including root and oil seed break crops can increase GM by over £330/ha, and NR(SFC) and NR(TFC) by over £300 and £250 respectively.

Where the pre-scheme situation is good drainage with moderately intensive grass production (150 kg N/ha), reliably good yields of cereals, or intensive arable rotations are needed to make the switch worthwhile. In such situations gross margins may fall or remain constant, but savings in fixed costs achieve overall increases in net returns after fixed costs of £100-£150/ha.

TABLE V.18

Benefit Scenarios for Grass to Arable Ley Systems

Good Site Class : £/ha

Pre-Scheme (BZ)					Post-Scheme (GZ)								
					(i) 3 year ley, 150 N, 2 WW (6.25 t), 1 SB (5 t)				(ii) 3 year ley, 300 N, 2 W (7 t), 1 SB (5.5 t)				
Enterprise	N	GM	NR(SFC)	NR(TFC)		ΔGM	ΔNR (SFC)	ΔNR (TFC)		ΔGM	ΔNR (SFC)	ΔNR (TFC)	
Dairy and Follower	0	228	164	118	Dairy and Follower	288	207	132	Dairy and Follower	431	282	192	Less silage making costs 300 N, 1 cut, £54, 2 cuts £85/ha.
Overwintered Stores	0	171	137	94	Overwintered Stores	285	211	141					
24 month beef	0	142	110	69	24 month beef	275	202	134	18 month beef	526	385	276	
Medium stores	0	106	100	93	Overwintered Stores	350	248	142					
Dairy and Follower	75	372	243	153	Dairy and Follower	144	128	97					
24 month beef	75	227	161	80	24 month beef	190	151	123					
Dairy and Follower	150	557	342	211	Dairy and Follower	-41	29	39	Dairy and Follower	102	104	99	
18 month beef	150	507	384	234	18 month beef	11	16	40	18 month beef	161	111	111	

BZ : bad drainage, GZ : good drainage

N : nitrogen kg/ha

GM : Gross Margin, NR(SFC) : Net Return after semi fixed costs

NR(TFC) : Net Return after total fixed costs

Δ : extra

WW : winter wheat, W : wheat

TABLE V.19

Benefit Scenarios for Grass to Arable Systems and Intensified Arable Systems

(a) Grass to Arable : Good Site

Pre-Scheme (BZ)					Post-Scheme															
					(i)				(ii)				(iii)				(iv)			
Enterprise	N	GM	NR(SFC)	NR(TFC)	Cropping	ΔGM	ΔNR (SFC)	ΔNR (TFC)	Cropping	ΔGM	ΔNR (SFC)	ΔNR (TFC)	Cropping	ΔGM	ΔNR (SFC)	ΔNR (TFC)	Cropping	ΔGM	ΔNR (SFC)	ΔNR* (TFC)
Dairy and Follower	0	228	164	118	Continuous WW 6.25 t/ha	345	316	259	WW 5.0 t/ha	201	176	131	Arable rotation 2 W, 6.25 t 1 WB, 5.5 t 1 OSR, 3.2 t	336	303	247	Arable rotation and roots 2W, 6.25 t 1 Pot, 40 t 1 S.Bt, 40 t	525	324	207
24 month beef	0	142	110	69		431	370	304		287	230	180		422	557	296		611	378	256
Medium stores	0	106	100	93		467	380	280		323	240	156		458	567	272		647	388	232
Dairy	150	557	342	210	Continuous WW 6.25 t/ha	16	138	163	WW 5.0 t/ha	-128	-2	39	Arable rotation 2 W, 6.25 t 1 WB, 5.5 t 1 OSR, 3.2 t	7	125	155	Arable rotation and roots 2 W, 6.25 t 1 Pot, 40 t 1 S.Bt, 40 t	196	146	115
18 month beef	150	507	384	234		66	96	139		-78	-44	15		57	83	131		246	104	91

(b) Intensified Arable

* Excluding extra storage investment

Spring barley	5 t/ha	444	355	263	WW 6.25 t	129	125	110
Winter wheat	5 t/ha	429	340	249	Arable and roots	324	148	76

BZ : bad drainage, GZ : good drainage

N : nitrogen kg/ha

GM : Gross Margin, NR(SFC) : Net Return after semi fixed costs

NR(TFC) : Net Return after total fixed costs

Δ : extra

WW : winter wheat, WB : winter barley

W : wheat, Pot : potatoes

S.Bt. : sugar beet, OSR : oil seed rape

V.6.5 Intensification of Arable

Improved drainage particularly reduced flooding, may enable a move to autumn sown cereals with increases in gross margins of about £130/ha. The financial attractiveness of introducing roots into the rotation will partly depend on the existing availability of fixed resources, labour, machinery and storage. Where these do exist and roots and field vegetables can be grown, their inclusion can increase the gross margin by upwards of £300/ha. The amount of extra net return derived will depend on whether additional investments in capital structure are needed.

Where reduced flooding enables horticultural production, additional gross margins and net returns can exceed £1500 and £800 respectively.

V.7 SENSITIVITY ANALYSIS

This section considers the sensitivity of the estimates of net benefits to the main physical and financial variables.

V.7.1 Crop Yields

Table V.21 contains the sensitivity of gross margin, and net revenue estimates to a ±1% variation is yield about the means observed in the farm survey. Predictably, yield variation have a much greater effect on net revenue estimates (after fixed costs) than on gross margins, particularly for high fixed cost enterprises such as roots.

V.7.2 Grass Utilisation

It is assumed that farmers utilise 70% of theoretically available energy from grass, except on poaching liable soils where utilisation is 60%. Table V.20 considers the effect on estimates of gross margins and net revenues of a 50% utilisation for both pre- and post-scheme situations, with the effect that a smaller proportion of potential benefit is taken up. Takeup at 50% utilisation would be 71% of that at 70%.

TABLE V.20

Effect of Grass Utilisation on Financial Net Benefit

Dairy cows and followers : 'Good' site class

					Increment		
					(a)	(b)	(b/a)
Drainage status	BZ		GZ				
Nitrogen kg N/ha	0		100				
Utilisation %	70	50	70	50	70%	50%	
Stocking rate glu/ha	0.55	0.39	1.22	0.87	0.67	0.48	0.72
Gross margin	228	184	416	318	188	134	0.71
Net return (SFC)(1)	163	137	268	211	105	74	0.71
Net return (TFC)(2)	118	105	166	137	48	32	0.67

Notes:

(1) After semi fixed costs.

(2) After total fixed costs.

In a number of cases, however, post-scheme utilisation is likely to be higher than pre-scheme such that incremental benefit could be underestimated. Moving from 50% pre-scheme to 70% utilisation post-scheme would increase financial benefits by a factor of 1.23 over their present estimated levels. On balance, errors on utilisation estimation are expected to cancel out.

V.7.3 Financial Crop Prices

Table V.22 considers the sensitivity of financial estimates to a ±1% change in output prices about the assumed level. Crops with higher input costs are most critically effected.

Consideration was given in section V.5. to the changing real prices of output and input prices during the relevant period. It was suggested that 1982 price relativities overestimate the gross margin of wheat, 18 m beef and sheep by a factor of 1.1 for the 1972-79 period. Furthermore, labour and machinery costs were on average about 0.90 and 0.96 of their 1982 real price level during the 1970's. This order of variation would result in an overestimation of fixed costs of about 6%-8% depending on enterprise. This possible variation in gross margin and net revenues is not considered critical in view of the general sensitivity of these values to standard price estimates and farmers yield estimates.

TABLE V.21

Sensitivity of Financial Estimates to Yields

% change due to ±1% in yield*

	Gross Margin/ ha	Net Revenue/ha after semi fixed costs	Net Revenue/ha after total fixed costs
Winter wheat	1.2	1.5	1.6
Spring barley	1.2	1.5	1.8
Winter barley	1.3	1.6	1.9
Potatoes	1.3	1.2	5.6*
Sugar beet	1.5	2.5	3.8
Oil seed rape	1.3	1.6	1.7

* At mean yield levels.

TABLE V.22

Sensitivity to Prices

	Yield t/ha	Gross Margin/ ha	Net Revenue/ha after semi fixed costs	Net Revenue/ha after total fixed costs
Winter wheat	6.25	1.2	1.5	1.9
Spring barley	5.00	1.2	1.5	2.0
Winter barley	5.00	1.3	1.6	2.2
Potatoes	40.00	2.0	3.9	11.2
Sugar beet	40.00	1.4	2.5	3.5
Oil seed rape	3.125	1.3	1.6	1.7
Dairy (milk price)	N200	1.9	3.0	4.9
Fatstock (18 m beef)		2.4	2.8	3.5

% change due to ±1% change in price

V.7.4 Economic Prices and Analysis

For the purpose of farmer uptake analysis, agricultural net benefits have been measured at financial farmgate prices. For the purpose of appraising public sector investments in land drainage schemes, it is necessary to adopt the viewpoint of the national economy, measuring a scheme's extra outputs and inputs in terms of the extra value a society places on the production of an extra unit of commodity, or the use of an extra unit of a resource. Where prevailing market prices are a good indicator of social values, then financial profitability will equal social profitability, and any 'economic' assessment can use financial prices. However, where financial prices reflect imperfect or artificial market conditions, such as the effects of taxation, subsidies, import tariffs, and Government intervention, then adjustments are required to remove these effects and derive economic prices which reflect the real value of producing or using more of a particular commodity or resource.

It is argued (Black and Bowers, 1981; Body, 1982) that agricultural commodity prices, particularly since European CAP, have been supported at artificially high prices, whilst the sector has been the recipient of direct and indirect production subsidies (see Annexe VII).

One method of deriving 'economic' prices commonly applied to agricultural projects in developing countries is to value internationally traded commodities at import/export parity, that is at their world market values. This procedure is an attempt to remove the effect of domestic market imperfections and Government policies. Whilst widely used, the method is not without its critics, particularly concerning the relevance of a residual world market. However, it does provide an alternative measure for guiding economic investment.

Table V.23 summarizes the financial and economic prices for the internationally traded commodities relevant to the present study. The economic prices are based on FAO/IBRD (1984) sources covering the years 1975-82 adjusted to 1982 prices using the International Inflation Index. Their derivation is explained in

Appendix V.G. Economic prices for the period 1975-82 were lower than the 1982 financial prices used in the scheme investment appraisal (Annexe IX).

TABLE V.23

Financial and Economic Prices

	(a) Financial	(b) Economic	(b/a)
Wheat (£/t)	115	75.7	.66
Barley (£/t)	108	54.5	.51
Sugar beet (16%) (£/t)	26.5	26.5	1.00
Beef (p/kg	95	61	.64
Milk (p/l)	14	10.5	.75
Fertilizer (p/kg):			
Urea (55% N)	36	15	.41
Trip. Sup. Phosphate (45% P)	36	28	.77
Potassium chloride (60% K)	17	12	.70

It is possible using the prices in Table V.23 to undertake a partial economic analysis to consider the likely impact on the estimated net agricultural benefits of using economic rather than financial prices. (A full analysis, which would need to isolate the effect of all production grants, subsidies, and taxation, and value the use of resources such as labour and capital at 'shadow' rather than financial rates, is not within the terms of this study.)

Economic gross margins for wheat, barley, sugar beet, beef, and milk and are contained in Appendix V.G. In the main they are some 25-30% lower than the financial estimates. Fixed costs have not been adjusted to economic values, because of the reasons stated above.

Using economic prices for agricultural produce and fertilizer reduces the increment in gross margins attributable to a given improvement as shown in Table V.24 for specified benefit scenarios. Using world market prices, the economic increment in gross margin from intensifying dairy production is about 72% of its financial value. On the same basis, the economic value of moving from dairy to cereal production would appear to have been about 54% of its financial value. Whilst economic fixed cost estimates are not available, given the relative senstivity of gross margin and net returns aluded to in Tables V.18 and V.19 , these reductions in gross margins would have a proportionately greater reducing effect on net returns after fixed costs, unless, of course, the adoption of economic prices, particularly for labour, resulted in some equivalent 'savings' in fixed costs.

This order of reduced incremental benefit needs to be put in the context of the scheme analysis and the estimated 'switching values' which indicate the amount by which net agricultural benefits need to increase or decrease to reduce scheme profitability to zero. These are presented in Annexe IX and summarized in Table IX.6.

Using world market prices for valuing agricultural production has been rejected by MAFF and Treasury as being unnecessarily pessimistic. The world market is a residual market, subject to wild fluctuations, and at present is particularly depressed (partly due to domestic pricing policies which encourage surpluses which are dumped onto the world market). It is argued by some that the U.K. should be seen in the context of European CAP.

An alternative price basis would be prevailing prices less the cost to the U.K. Exchequer, after CAP refund, of market regulation, but this measure is not compatible with the concept of a common market. Another price basis would be the cost within CAP of market regulation, eg. the net expenditure by the U.K. Intervention Board on cereal sector management could be deducted from average market prices to derive adjusted prices for cereal commodities. These alternative measures, which have not been calculated here, are likely to fall somewhere between prevailing support market prices and world market prices.

TABLE V.24

Benefit Scenarios Using Financial and Economic Prices

	Pre-Scheme		Post-Scheme		Increment (a)	(b)	(b/a)
Drainage status	BZ		GZ				
Nitrogen	0		200				
Enterprise type	Dairy		Dairy				
Price base	F*	E*	F	E	F	E	
Gross margin	231	180	659	492	428	312	0.72
Net return (SFC)(1)	157	106	402	236	245	130	0.53
Net return (TFC)(2)	111	60	246	80	135	20	0.15
Drainage status	BZ		GZ				
Nitrogen or yield	0		Y = 6.25				
Enterprise type	Dairy		Wheat				
Price base	F	E	F	E	F	E	
Gross margin	231	180	572	365	341	185	0.54
Net return (SFC)	157	106	480	273	323	167	0.52
Net return (TC	111	60	373	165	262	105	0.40
Drainage status	BZ		GZ				
Nitrogen	0		100				
Enterprise type	Med. stores		18 m beef				
Price base	F	E	F	E	F	E	
Gross margin	106	54	598	454	492	400	81%
Net return (SFC)	100	48	452	308	352	260	74%
Net return (TFC)	93	41	273	130	180	89	50%

1982 constant prices.

'Good' site classification.

*F = financial, E = economic (see Appendix V.G)

Notes:

(1) Net return after meeting semi fixed costs.

(2) Net return after meeting total fixed costs. Fixed costs have not been adjusted to economic prices.

Using the same data base which ignores the influence of agro-climatic conditions, Figure V.7 shows the trends in gross margins for the period 1968 to 1984 for wheat, barley, dairy, fat stores, sucklers, 18 month beef, and sheep. In very general terms, relative real gross margins would appear to have been lower than 1982 levels during the period 1972-1979 for wheat and sheep (by about 10%), and 18 month beef (by about 20%), whereas for other enterprises the annual fluctuations averaged around the 1982 gross margin value. This assessment is carried forward to the sensitivity analysis in Section V.6.

V.8 CRITIQUE OF THE METHODOLOGY

The method for assessing the monetary value of drainage benefits has been based on single visit interview whereby farmers recall the changes in farming practice, productivity, and capital items which they perceive have been directly attributable to a change in drainage status. Because of limitations imposed by the interview situation (see Annexe III), and the lack of reliable field and farm specific financial data, the assessment has been undertaken in mainly physical terms, supported where necessary both by farmers' and researchers' value judgements, and converted to financial values using standardised enterprise budgets at constant prices. The main criticisms that can be levelled at the financial assessment approach is that it relies heavily on farmer recall, and where data is lacking, both physical and financial, involves the use of a number of simplifying assumptions and procedures.

The method has been selected because for the purpose of identifying factors which explain uptake, a single visit survey was the most appropriate method of obtaining a reasonably detailed and comprehensive, mainly physical, data base which was satisfactory for statistical analysis. The method has inevitably meant a compromise on detail, particularly concerning farm business management data which is not accessible in a single visit interview. In many cases, the data needed for site specific estimates of the financial benefits attributable to improved drainage, whether potential or actual, can only be collected by on-going monitoring, requiring frequent visit survey methods.

The following paragraphs address the main criticisms of the approach, and largely point to the need for further work.

The details of the farm survey method are discussed in Annexe III. The main criticism relates to the reliance on farmer recall. Secondary sources, however, such as parish statistics, aerial photographs, did not prove useful. Financial memories were particularly blurred, except for major investments like field drainage or dairy parlours. With respect to physical data, much of the field level data needed to allow a definitive estimate of benefit was not available for the present situation let alone for an earlier time period, particularly for grassland where physical output improvement is especially difficult to isolate. In most cases single fields are not viewed independently but within the grazing and conservation complex of the farm as a whole. The situation is further complicated by unrecorded grazing by different stock types and ages, different levels of supplementary and variable conservation practice. Seasonal and annual weather variations confound things further. The analysis is necessarily reduced to one of simplified averages, based on general principles and 'best-fit scenarios'. In terms of estimates of physical performance, the room for error is considerable, but probably self cancelling. Some solace is taken in that the analysis is essentially an incremental one concerned with 'extra' inputs and outputs, and providing the estimates of the extent of benefit offered and taken up are reasonably reliable, errors due to over or under estimating the baseline situation are less important.

Perhaps the most critical assumption in the procedure is that N fertilizer is a good proxy for stocking rate. It is assumed that farmers achieve grass utilisation efficiencies (and related stocking rates) of 60% to 70% of total grass energy, and that they would achieve this order of benefit from a given improvement. If lower utilisation levels are achieved, say, of 50% for both before and after drainage improvement, a given improvement in potential stocking is likely to result in a lower absolute take-up of benefit, albeit a similar relative order of improvement. The data needs for reliable estimates of grassland productivity are considerable, but there are recording schemes now available to farmers for this purpose. The implication of an error in estimating pre-scheme and post-scheme exploitation of potential stocking rates for benefit assessment is considered in the sensitivity analysis.

Another criticism, following on from the previous point, is the assumption that where field drainage status has improved, the benefits of all subsequent changes in field and farm management are attributable to the improved drainage status, eg. this would apply to the amount of fertilizer used, the type of livestock management system operated, the conservation methods employed. In many cases, some of the changes could have happened without the drainage improvement, in other cases a substantial part of the benefit is attributable to non-drainage factors. The approach adopted in this study is that where drainage has been seen to facilitate improvement, the resultant benefits can be attributed to the drainage improvement providing the extra costs in exploiting these benefits are charged accordingly. To draw a parallel, if the study had been looking at the uptake of benefits associated with, say, the adoption of intensive silage making systems, it is likely that the benefits from field drainage improvements needed to sustain intensive grass production would be attributed to the silage making systems themselves providing that the costs of field drainage were included in the assessment.

The improvement in cereal yields, largely due to improved varieties is another case where all yield increments in benefit areas have been attributed to drainage improvements. This, however, is justified because in the majority of benefit areas, cereals could not be grown before the scheme, and therefore the ability to exploit varietal improvements is a benefit attributable to drainage.

The benefits of the arterial and field drainage investment are partly weather determined. In wet years drainage pays off, in dry years it makes little contribution. The method here deals only with averages without reference to annual agro-climatic conditions, which will dictate the actual response to drainage. If site specific data were available, there are ways of simulating weather dependent drainage benefits (see Annexe II and Annexe VI), but these have not been in the terms of reference for this study.

The remaining major criticisms of the benefit assessment method relate to the use of standardised gross margin and fixed cost estimates. The approach is justified by the lack of usable farm level data accessible by survey. Its use is made difficult however by the lack of standard data, particularly on fixed costs, for evaluating marginal changes in farming activities such as the extra costs of dairy herd expansion. The method used overcomes the shortcomings of the gross margin by charging semi fixed costs for all marginal changes and total fixed costs for major changes which involve the capital structure of the farm.

Throughout the analysis labour costs have been charged as a semi fixed cost. It could be argued that charging for additional family labour where apparent surplus exists, or additional hired workers where there is local unemployment, overstates the real economic cost of employing such labour, because they are not being drawn from active employment, and therefore there is no output loss. In the case of family workers, it often transpires that there are off-farm activities to consider, such as contracting or cattle trading, or even a display of leisure preference. In the case of hiring extra workers drawn from the ranks of the unemployed, the real costs of employment will be less than market wage rates. Todate, however, the Department of Employment has avoided using 'shadow' prices of labour for project appraisal purposes, inspite of persistent unemployment.

Where benefit uptake allows better use of existing hired workers, charging for labour as a semi fixed cost could overestimate extra costs, for instance where one hired stockman may be able to, say, manage an extra 5 cows in a 50 head herd without significant reduction in standards of herd management. On balance, however, charging for labour was justified because for the farms surveyed family and regular hired labour was some 40% less than the standard man day requirements of the systems operated, suggesting a need to work harder or longer than 'average' and the need to hire casual labour at peak times.

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APPENDIX V.A

LIVESTOCK ENTERPRISE DATA

V.A.1 INTRODUCTION

This Appendix contains a brief description of livestock systems found within STWA benefit areas and presents and explains the estimates of 'standardised' gross margins and fixed costs used in the benefit assessment procedure.

The general approach has been to estimate standard Gross Margins per head of livestock (before deducting forage variable costs), and on the basis of observed N fertiliser application rates, to estimate likely stocking rates by matching estimated energy supply from grass with the energy needed per head of stock. In this way, an estimate of gross margin per hectare (after deducting forage variable costs) can be derived which reflects site conditions and management practices.

V.A.2 GRAZING LIVESTOCK SYSTEMS AND GROSS MARGINS

This section contains a brief outline of the major grazing livestock systems found in STWA benefit areas supported by gross margin estimates which for convenience are presented at the end of this section.

V.A.2.1 Dairy

Estimates of dairy gross margins for Friesian cows are contained in Table V.A.1. Two aspects are important; gross margin per cow, and gross margin per hectare. Important determinants of gross margin per cow are milk yield and concentrate use. For a given gross margin per cow, gross margins per forage hectare are determined by overall stocking rate in cows per hectare. Stocking rates are determined by grassland management factors; intrinsic quality of site, sward composition, nitrogen levels, conservation/grazing practices.

According to MMB 1980/81 returns, the top 25% of herds (by gross margin performance) were larger, had higher yields per cow, higher stocking rates, and used more nitrogen than the bottom 25%. Whilst concentrate usage per cow was generally higher for high yielding cows, lower concentrate feeding per litre of milk was often evident. In the main, the better herds were on the better land, although these applied 45% more nitrogen to achieve 45% higher stocking rates, and as a result nitrogen use per cow was similar between top and bottom 25% performers.

V.A.2.2 Dairy Followers

For self-contained dairy herds, assuming a 20% depreciation rate, every four cows requires one calf, yearling, and heifer to serve as replacements. This implies that about one hectare in every four is given to carrying replacements. Gross margins for dairy replacements are lower than for dairy (Table V.A.2). The gross margin for a self-contained herd including followers is likely to be reduced by about 20% compared to that of a 'flying herd' where replacements are bought in (Table V.A.3).

Separate gross margins for dairy followers are identified because their grazing and land type requirements differ from those of milking cows. In some cases STWA farmers rear dairy replacements on contract or for sale in the absence of a dairy herd.

V.A.2.3 Beef

The main types of beef rearing and fattening systems of relevance to lowland flood plains are single and multiple suckling, eighteen and twenty-four month grass (and grass/cereal) beef, and a variety of store cattle fattening and/or finishing systems.

(i) Suckler Herds

Table V.A.4 contains estimated gross margins for single and double suckler herds.

According to MLC returns, the most important factor determining suckler success was stocking rate, mainly achieved through higher nitrogen use per hectare. MLC recommend 120-150 kg N per hectare to achieve two cows per hectare (depending on calving pattern).

(ii) Dairy Beef

Two basic systems are commonly practiced to produce beef using dairy bred calves from the peak autumn/winter calvings. These are (eighteen month) grass/cereal fed beef and (twenty-two to twenty-four month) grass beef. Many variations on these systems exist to accommodate particular dairy herd and farm circumstances.

(a) Eighteen month grass/cereal beef:

Early-weaned autumn-born (usually Friesian or Friesian x Hereford) calves are reared on a forage/concentrate diet until spring turnout at about 180 kg liveweight. Summer grazing is supplemented by concentrates as required. Cattle are yarded at about 325 kg, finished on a forage/barley diet, and slaughtered at 16 to 20 months at 420-520 kg liveweight. For autumn-born calves finished during the second winter, two conservation cuts are usually needed; two-thirds of the area in late May, one-third in August. Estimated gross margins for this system are given in Table V.A.5.

According to MLC returns, producers achieving the top third of gross margins per hectare did so mainly through improved stocking rates. A second major factor was lower concentrate use largely achieved through quality silage conservation. MLC results suggest fertiliser rates at 125 kg N and 150 kg N per hectare for stocking rates of 0.4 ha, and 0.33 ha per head respectively. A 'target' of 0.25 ha per head would need about 200 kg N.

(b) Grass beef:

Grass beef production involves the early weaning of late autumn to late winter (November to February) born calves. Early maturing Friesian x Hereford crosses are preferred. They are put out to grass as soon as possible with concentrates to supplement their limited appetite for grass in order to obtain liveweight gains of

0.7 kg/day. (These young cattle are generally grazed ahead of the previous year's cattle now ready for grass finishing.) The young stock are housed in the autumn at about 250 kg and fed on a silage/ concentrate ration to achieve liveweight gains of about 0.5 kg/day.

At spring turnout, the lean cattle can achieve liveweight gains of about 1.0 kg/day, giving a good return to grass. As grass supply diminishes, cattle are slaughtered between July and October at 450–550 kg. Some cattle may need to be yarded and winter finished. MLC records for 1980/81 showed overall liveweight gains of 0.7 kg per day. With winter born calves finished on grass, it is usual to take a single conservation cut on half the grass area. A representative gross margin for grass beef is given in Table V.A.6.

MLC's returns for grass beef show that grassland management and resultant higher stocking rates are responsible for about two-thirds of the extra gross margin achieved by the top third units. A second important factor is that of lower concentrate arising largely from better silage conservation and grazing systems. High stocking rates require higher nitrogen application. MLC survey results show an average application of 125 kg N to achieve stocking rates of two cattle per hectare, and an extra 60 kg N to achieve three cattle per hectare. Leader follower grazing systems are advocated to exploit grazing potential. This involves rotational paddock grazing with youngest stock getting first access to higher quality and infection-free herbage. The system requires a greater management input and investment in fencing.

(c) Grass finishing of stores:

The purchase of store cattle for winter feeding or grazing, and the subsequent sale of these as more advanced stores or finished cattle, accounts for the greater part of beef production in Britain. The cattle may be yearlings from suckler herds, or dairy bred stores.

Grass finishing requires its own brand of grazing management. Cattle of the same age are put to grass in batches. There is usually no conservation and cattle numbers are adjusted through the season, by means of buying and selling in accordance with grass supply. With early maturing breeds, two overlapping batches will exploit all the grass grown (or one batch for late maturing crosses). Cattle are sent to slaughter as grass production falls. Late maturing stock, eg. Charolais, may require concentrate supplements. Representative gross margins are given in Table V.A.7.

The most important factor influencing gross margin per hectare success is total liveweight gain. Trader margins (the difference between purchase and sale price per kg) are also important, particularly in heavy cattle, emphasising the need for marketing skill. Stocking rate is also a major contributor to high gross margins.

For management reasons, nitrogen application is lower on non-conserved grazing areas. MLC results suggest an average rate of 100 kg N per hectare to support 4 x 330 kg stores at turnout, ie. about 7 kg N per 100 kg liveweight. A target of 140 kg N per hectare and a total turnout weight of 2000 kg per hectare is recommended.

(d) Overwintering and grass finishing:

Suckled calves and stores are overwintered on a low cost diet comprising conserved forage, arable crop residues (particularly straw) and protein concentrates. Winter liveweight gains are restricted to 0.4 kg per day to allow for subsequent high gains during grass finishing. Representative gross margins are given in Table V.A.8.

V.A.2.4 Sheep

A number of sheep production systems are followed by flood plain farmers: early (winter) lambing flocks, spring lambing flocks selling fat lambs off grass in summer and autumn, and fat lambs and hoggets (first wintered) sold off forage. In some cases, dairy farmers may buy a 'flying' flock of pregnant ewes to utilize grass in the late autumn/early spring, selling off ewe and progeny as couples in the spring. Lowland farmers may also act as winter hosts for upland replacement ewe flocks.

(i) Lowland Fat Lamb Production

Representative gross margins are contained in Table V.A.9.

The two main factors influencing gross margin performance are the stocking rate and the number of lambs reared per ewe tupped. MLC returns show that increased stocking often means lighter lambs, a greater proportion of which cannot be finished on grass. Higher stocking rates can be achieved by earlier lambing and improved grass management, particularly attention to fertiliser use, pest control and forage conservation for lamb finishing. MLC records suggest 150 kg N/hectare is needed to carry 12 ewes and their lambs (2.2 Lu/ha).

ADAS recommends a target production of 1000 kg of lamb liveweight per hectare, obtainable from stocking about 1000 kg ewe liveweight per hectare. This translates to an overall 14 ewes per hectare of 70 kg ewes. This level of stocking requires about 200 kg N assuming good sites with adequate rainfall.

(ii) Lambs Sold Off Forage Crops

Two systems are practiced. The selling of fat lambs off forage in late autumn/early winter, and the production of hoggets for sale in late winter/early spring. Gross margins for these systems are given in Table V.A.10.

Finished fat lamb production generally shows a 10% higher gross margin per ewe than store lamb production, but higher stocking rates in store lamb production reduce the relative advantage of finished lambs in terms of gross margin per hectare. Grassland flocks give higher gross margins than arable/forage flocks due to lower feed costs. Whilst differences are apparent in gross margins per ewe between sheep varieties according to lambing rates, fleece and carcass values, and feeding and depreciation costs, variations in stocking rate in accordance with sheep size mean that varietal type does not greatly affect gross margins per hectare.

TABLE V.A.1

Dairy Enterprise Gross Margins (1982 prices)

(a) Per Head:

	Low	Medium	High	MMB[6]
Performance				
Milk yield (1)	4300	5000	5700	5272
Concentrate use (kg/l)[1]	0.30	0.33	0.36	0.33
Output per Cow				
Milk price (p/l)	14	14	14	
Milk sales (£)	602	700	798	708
Calf sales (£)[2]	70	70	70	54
Less: herd depreciation (£)[3]	45	45	45	28
Total Output (£)	627	725	823	733
Variable Costs (£/cow)				
Concentrates[4]	194	248	308	242
Sundries[5]	40	45	50	44
Total Variable Costs (£) (before forage)	234	293	358	286
Margin over Concentrates (£)	408	452	490	466
Gross Margin per Cow Before Forage Costs (£)	393	432	465	447

Notes:

(1) Yields are assumed responsive to concentrate use. However, in practice, the more efficient producers often use less concentrates per litre at higher yields per cow.

(2) Allowing calving index 1.08, and 7% mortality.

(3) 22½% depreciation, replacement £550, cull £350.

Table V.A.1 continued:

(4) At £150/t, 1.65 t for medium performance.

(5) Vet and med £12, A.I. £11, straw £7, consumables £10-20.

(6) MMB costed farmers 1981/2; Average results for 1130 herds - forage costs averaged £113/ha, £56.5/cow, 246 kg N/ha, £0.46/kg N, including FYM.

(b) Per Hectare of Grass:

Assuming a 550 kg liveweight cow yielding 5000 litres with 1.65 tonnes of concentrate as feed,

Utilisable Metabolisable Energy (UME) requirement/cow/year
= 25000 MJ + 5.3 MJ/l milk
= 51500 MJ

UME from grass = 51500 - (11.0 MJ/kg conc. as fed)
= 33350 MJ/cow/year

One livestock unit is defined as a 550 kg cow yielding 4500 l/year equalling 48000 MJ/year, fed 1.33 tonnes of concentrate = 33350 MJ from grass

Assuming 'Good' site classification and gross margin/head at £432:

N	'000 MJ/ha	hd/ha	Forage £/hd	gm £/hd	gm £/ha	lu/ha*
0	20	0.60	10.0	422	253	0.60
50	31	0.93	41.9	390	363	0.93
100	41	1.23	56.1	376	462	1.23
200	61	1.83	69.4	363	664	1.83
300	76	2.28	84.2	348	793	2.28

* assuming 1 cow = 1 livestock unit = 33350 MJ from grass

TABLE V.A.2

Dairy Followers : Gross Margin (1982 prices)

(a) Per Head:

	Average
Performance Level	
Output	
Value of friesian heifer (1)	530
Less: value of calf	70
Total Output	460
Variable Costs	
Concentrate	150
Sundries	25
Total Variable Costs (before forage)	175
Gross Margin per Heifer (before forage)	285

Notes:

(1) Down calving heifer at 27 months

(2) Concentrates at £140/t.

Table V.A.2 continued:

(b) **Per Hectare of Grass:**

Assuming down calving heifer at 27 months*

UME requirement, birth to calving = 50150 MJ

UME from non grass = 1.07 t conc. at 11 MJ/kg as fed = 11770 MJ

0.75 t straw at 5 MJ/kg as fed = 3750 MJ

15520

UME from grass = 34630 MJ

Assuming 'Good' site:

N	'000 MJ/ha	hd/ha	Forage £/hd	gm £/hd	gm £/ha	lu/ha**
0	20	0.58	10.3	274.7	159	0.60
50	31	0.90	41.1	243.9	220	0.93
100	41	1.18	58.5	226.5	267	1.23
200	61	1.76	72.2	212.8	375	1.83
300	76	2.19	87.7	197.3	432	2.27

* 30 months calving UME requirement = 53539 MJ

24 months calving UME requirement = 40539 MJ

** 1 replacement = 1.04 of a cow equivalent at grass

TABLE V.A.3

Dairy and Followers : Gross Margins (1982 prices)

Per Hectare of Grass:

1 cow + 0.28 of a replacement unit/year.

Gross margin before forage costs = 432 + 0.28 x 285 = £511.8 per cow + replacement unit

UME needed from grass = 33350 + (0.28 x 34630) = 43050 MJ*

Site class 'Good':

N	'000 MJ/ha	Units /ha	Forage £/unit	gm/hd	gm/ha	lu/ha
0	20	0.46	13.0	499	230	0.60
50	31	0.72	54.0	458	330	0.93
100	41	0.95	72.6	439	417	1.23
200	61	1.42	89.4	422	600	1.83
300	76	1.77	108.5	403	714	2.28

* Equivalent to 1.3 cow equivalents at grass

TABLE V.A.4

Suckler Herd Gross Margins (1982 prices)

(a) **Per Head:**

	Single Suckling Autumn calving	Single Suckling Spring calving	Double Suckling
Output			
Sales:			
Weight (kg)	280	240	2 at 240
Price (p/kg)	100	100	100
Revenue (1)	280	240	440
Subsidy	12	12	12
Less: depreciation (2)	26	26	125
Total Output	266	226	327
Variable Costs			
Concentrate (3) and bought feed	58	44	100
Sundries	17	15	20
Total Variable Costs	75	59	120
Gross Margin per Cow (before forage costs)	191	167	207

Notes:

(1) Assuming 94% calving.

(2) Cow purchase minus cull value over 6 years (£500-360), plus 5% calf mortality at £70. Additional calf purchase for double sucklers.

(3) Concentrates at £140, autumn 300 kg, spring 200 kg, 540 kg double sucklers, plus bulk feeds straw/potatoes at £16/t.

Table V.A.4 continued:

(b) **Per Hectare of Grass:**

Beef Cows : single sucklers, autumn calving

Beef cow and calf UME requirement = 35656 MJ

UME from non-grass =	300 kg of conc. at 11 MJ/kg as fed =	3300 MJ
	0.5 t of barley straw at 6.4 MJ/kg =	3268 MJ
	1.0 t of pots/brewers grains at 2.6 MJ/kg =	2600 MJ
		9168 MJ

UME from grass = 35656 - 9460 = 26488 MJ

Gross margin before forage costs = £191

N	'000 MJ/ha	hd/ha	Forage £/hd	gm £/hd	gm £/ha	lu/ha
0	20	0.76	7.9	183	139	0.60
50	31	1.17	33.3	158	185	0.93
100	41	1.55	44.5	147	227	1.23
200	61	2.30	55.2	136	312	1.83
300	76	2.87	66.2	124	356	2.28

* 1 beef cow + cow = 0.79 of a cow equivalent at grass

Table V.A.4 (b) continued:

Double Sucklers:

2 calves finished to 240 kg each : liveweight gain (240-40 kg x 2 = 400 kg)

UME needed =	22000 MJ
Single suckled calf to 300 kg, UME needed =	15600 MJ
∴ additional UME requirement =	6400 MJ
Additional UME available from non-grass diet 9168 MJ x $\left(\frac{£100}{£58} - 1\right)$ =	6600 MJ
Total UME from grass for double suckler	26288 MJ

Gross margin before forage costs = £207/cow

N	'000 MJ	hd/ha	Forage £/hd	gm £/hd	gm £/ha	lu/ha
0	20	0.76	7.9	199	151	0.60
50	31	1.18	33.1	174	205	0.93
100	41	1.56	44.2	163	254	1.23
200	61	2.32	54.7	152	353	1.83
300	76	2.89	66.4	141	406	2.28

TABLE V.A.5

Eighteen Month Grass/Cereal Beef Gross Margin (1982 prices)

(a) **Per Head:**

		Autumn Born		Spring Born
Output				
Sale:				
Weight (kg)		475		450
Price (p/kg)		100		95
Revenue (£)		475		428
Less: calf purchase (£)[1]		96		91
Total Output (£)		379		337
Variable Costs (£)				
Calf rearing[2]		70		70
Concentrates:				
grazing supplement[3]	13		16	
finishing concentrates[4]	77		59	
Total concentrates		90		75
Miscellaneous (including straw)		21		18
Total Variable Costs (£)		181		163
Gross Margin per Head (£) (before forage costs)		198		174

Notes:

(1) Autumn born £90, spring born £85, plus 7% mortality.

(2) Milk substitute £10, weaner and rearing nuts £60.

(3) Autumn born 100 kg at £130/t, spring born 125 kg at £130/t.

(4) Autumn born 550 kg at £140/t, spring born 420 kg at £140/t.

Table V.A.5 continued:

(b) **Per Hectare of Grass:**

Autumn Born:

UME requirement = 30300 MJ/finished animal

Non-grass UME source:		
milk	13 kg	
weaner units	400 kg	
grazing supplement	100 kg	
concentrates	550 kg	
Total concentrates	1063 kg at 11 MJ/kg as fed	11693
Straw and other bulk feed, 500 kg at 5 MJ/kg =		2500
Total non-grass UME		14200

∴ UME from grass = 16100 MJ/finished animal

Gross margin before forage variable costs = £186 /head average

'Good' site:

N	'000 MJ	hd/ha	Forage £/hd	gm/hd	gm/ha	lu/ha
0	20	1.24	4.8	181.2	225	0.60
50	31	1.93	20.2	165.8	320	0.93
100	41	2.55	27.1	158.9	405	1.23
200	61	3.79	33.5	152.5	578	1.83
300	76	4.72	40.7	145.3	686	2.28

TABLE V.A.6

Grass Beef* (24 month) Gross Margins (1982 prices)

(a) **Per Head:**

Output		
Sale:		
Weight (kg)		510
Price (p/kg)		95
Revenue (£)		485
Less: calf purchase (£)(1)		96
Total Output (£)		389
Variable Costs (£)		
Calf rearing(2)		55
Concentrate:		
grazing supplement(3)	26	
winter concentrate(4)	60	
Total concentrates		86
Miscellaneous (including straw)		25
Total Variable Costs (£)		166
Gross Margin per Head (£) (before forage costs)		223

Notes:

* Average of autumn and spring born calves.

(1) £90 + 7% mortality.

(2) Milk powder £10, weaner and rearing nuts £45.

(3) 200 kg at £130/t.

(4) 430 kg at £140/t.

Table V.A.6 continued:

(b) **Per Hectare of Grass:**

UME needed 41050 MJ for 24 month finished animal : 510 kg liveweight.

UME for non-grass:

milk powder	13 kg		
concentrate rearing	300 kg		
concentrates	630 kg		
	943 kg at 11 MJ/kg as fed	=	10373 MJ
500 kg straw and other bulk feeds at 5 MJ/kg		=	2500 MJ
			12873 MJ

∴ UME from grass at, say = 28200 MJ

Gross margin before forage variable costs £223/head.

'Good' site:

N	'000 MJ/ha	Forage £/ha	hd/ha	£/head for costs	gm/hd	gm/ha	lu/ha equiv.
0	20	6	0.71	8.5	214.5	152	lu/ha (at 0.9 lu/hc)
50	31	39	1.10	35.5	187.5	206	0.93
100	41	69	1.45	47.6	175.4	254	1.23
200	61	127	2.15	58.8	164.2	355	1.83
300	76	192	2.70	71.1	151.9	410	2.28

TABLE V.A.7

Grass Feeding of Store Cattle

(a) **Per Head:**

	Young Stock	Light Stores	Medium Stores	Heavy Stores
Output				
Sale:				
Weight (kg)	250	340	450	550
Price (p/kg)	100	95	95	95
Revenue (£)	250	323	428	523
Less: store purchase(1)	151	233	349	455
Total Output (£/head)	99	90	79	68
Variable Costs (£/head)				
Concentrates	3	3	5	5
Sundries	8	8	8	8
Total Variable Costs	11	11	13	13
Gross Margin per Head (£) (before forage variable costs)	88	79	66	55

Notes:

(1) Purchases, young 130 kg at 115 p + 1% mortality, light 220 kg, medium 330 kg, heavy 430 kg, at 105 p, plus 0.8% mortality.

Table V.A.7 continued:

(b) **Per Hectare of Grass:**

Young Stock : turnout 130 kg, sale weight 250 kg, 120 kg gain

180 days at grass : 0.67 kg/day gain

UME requirement = 45 MJ/day/head x 180 days = 8100 MJ

Non-grass UME = 220 MJ (20 kg of concentrate)

UME from grass = 7880 MJ/head

Gross margin before forage variable costs £88/head

'Good' site:

N	'000 MJ	hd/ha	Forage £/hd	gm/hd	gm/ha
0	20	2.54	1.53	86.5	220
50	31	3.93	9.9	78.1	307
100	41	5.20	13.3	74.7	388
200	61	7.74	16.4	71.6	554
300	76	9.64	19.9	68.1	657

Light Stores : turnout 220 kg, sale weight 350 kg, gain 120 kg

180 days at grass : 0.67 kg/day gain

UME requirement = 57 MJ/day/head x 180 days = 10260 MJ/head

Non-grass UME = 220 MJ (20 kg of concentrates)

UME from grass = 10040 MJ/head

Gross margin before forage variable costs £79

'Good' site:

N	'000 MJ	hd/ha	Forage £/hd	gm/hd	gm/ha	lu/ha
0	20	1.99	3.0	76.0	151	0.6
50	31	3.09	12.6	66.4	205	0.93
100	41	4.08	16.9	62.1	253	1.23
200	61	6.08	20.9	56.1	353	1.83
300	76	7.57	25.4	53.6	406	2.28

Table V.A.7 (b) continued:

Medium Stores : turnout 330 kg, sale weight 450 kg, 120 kg gain

180 days at grass : 0.67 kg/day gain

UME requirement = 68 MJ/head/day x 180 days = 12240 MJ

Non-grass UME = 390 MJ (36 kg concentrates)

UME from grass = 11850 MJ/head

Gross margin before forage variable costs £66

'Good' site:

N	'000 MJ	hd/ha	Forage £/hd	gm/hd	gm/ha	lu/ha
0	20	1.69	3.55	62.5	106	0.60
50	31	2.62	14.9	51.1	134	0.93
100	41	3.46	19.9	46.1	160	1.23
200	61	5.15	24.7	41.3	213	1.83
300	76	6.41	30.0	36.0	231	2.28

Heavy Stores : turnout 430 kg, sale weight 550 kg, 120 kg gain

180 days at grass : 0.67 kg/day gain

UME requirement = 84 MJ/head/day x 180 days = 15120 MJ

Non-grass UME = 390 MJ (36 kg concentrates)

UME from grass = 13730 MJ/head

Gross margin before forage variable costs £55

'Good' site:

N	'000 MJ	hd/ha	Forage £/hd	gm/hd	gm/ha	lu/ha
0	20	1.46	4.1	50.9	74.3	0.60
50	31	2.26	17.3	37.7	85.3	0.93
100	41	2.99	23.0	31.9	95.5	1.23
200	61	4.44	28.6	28.6	117.0	1.83
300	76	5.54	34.7	20.3	113.0	2.28

TABLE V.A.8

Overwintering and Grass Finishing of Spring Born Suckle Calves

Gross Margins (1982 prices)

(a) **Per Head:**

Output

Sale:

Weight (kg)	440
Prices (p/kg)	95
Revenue (£)	418
Less: purchase(1)	233
Total Output (£)	185
Variable Costs (£)	
Concentrates(2)	52
Miscellaneous(3)	11
Total Variable Costs(5)	63
Gross Margin per Head (before forage variable costs)	122

Notes:

(1) Sold in late summer/autumn at 18-20 months, bought at 220 kg at 105 p, plus 0.8% mortality.

(2) Winter 220 kg at £140/t, grazing supplement 40 kg at £130/t, plus 1 t bulk feed at £16.

(3) Vet and med £5, other £6.

Table V.A.8 continued:

(b) **Per Hectare of Grass:**

Purchase weight 220 kg, sale weight 440 kg, 220 kg gain over 335 days

165 days yarded at 0.5 kg/day gain = 82.5 kg

170 days at grass at 0.81 kg/day gain = 137.5 kg

220.0 kg

UME required:

165 days yarded liveweight 220-302.5 kg at av. 47.5 MJ/day = 7450

170 days at grass liveweight 302.5-440 kg at av. 76 MJ/day = 12920

Total UME requirement over 335 days = 20760 MJ/head

Non grass UME:

260 kg concentrate 2860 MJ

1 tonne straw and bulk feeds 5000 MJ

7860 MJ

∴ UME from grass = 12900 MJ/head

Gross margin before forage variable costs = £122

N	'000 MJ	hd/ha	Forage £/hd	gm/hd	gm/ha	lu/ha
0	20	1.55	3.9	118.1	183.0	0.60
50	31	2.40	16.3	105.8	254.0	0.93
100	41	3.18	21.7	100.3	319.0	1.23
200	61	4.73	26.9	95.2	450.0	1.83
300	76	5.89	32.6	89.4	527.0	2.28

TABLE V.A.9

Lowland Fat Lamb Production Gross Margins (1982 prices)

(a) **Per Head:**

	Low	Average	High
Output/Ewe			
Lambs reared per ewe	1.2	1.4	1.6
Average lamb price (£)[1]	37	36	35
Lamb revenue (£)	44.4	50.4	56.0
Ewe premium[2]	1.5	1.5	1.5
Wool[3]	3.5	3.5	3.5
Less: depreciation[4]	10.0	10.0	10.0
Total Output	39.4	45.4	51.0
Variable Costs			
Concentrates[5]	8.0	8.0	8.0
Sundries	3.0	3.0	3.0
Total Variable Costs	11.0	11.0	11.0
Gross Margin per Ewe (before forage variable costs)	28.4	34.4	40.0

Notes:

(1) 200 p/kg dead weight, 18 kg average dead weight, according to stocking rate.

(2) Annual compensatory premium under CAP.

(3) 115 p/kg x 3 kg.

(4) 22% replacement, cull ewes and rams £30, 25% of ewes purchased at £60, rams at £175, plus mortality.

(5) 50 kg at £140/t, plus bought forage at £1.

Table V.A.9 continued:

(b) **Per Hectare of Grass:**

UME need:

60-70 kg ewe = 4328 MJ

0-40 kg fat lamb = 188/MJ x 1.4 lambs

UME needed/ewe = 6961 MJ

Less concentrates:

50 kg at 12.5 MJ/kg as fed = 625

Other forage crop including straw = 2000

4336 MJ

Gross margin per ewe before forage variable costs = £34.4

UME from grass

N	'000 MJ	Ewes/ha	Forage costs /ewe	gm/ewe	gm/ha	lu/ha
0	20	4.6	1.3	33.1	152	0.60
50	31	7.2	5.4	29.0	217	0.93
100	41	9.5	7.3	27.1	258	1.23
200	61	14.1	9.0	25.4	358	1.83
300	76	17.5	11.0	23.4	410	2.28

Fat lambs sold off forage.

TABLE V.A.10

Fat Lambs Sold Off Forage Gross Margins

(a) **Per Head:**

	Mainly Autumn/ Winter Sales	Mainly Winter/ Spring (hoggets) Sales
Output/ewe		
Lambs reared per ewe tupped	1.4	1.4
Average price per lamb/hogget	37.0[1]	39.0[2]
Lamb revenue (£)	51.8	54.6
Wool	3.5	3.5
Ewe premium	1.5	1.5
Less: depreciation	10.0	10.0
Total Output	46.8	49.6
Variable Costs/ewe		
Concentrates[3]	8.7	11.7
Sundries	3.0	3.0
Total Variable Costs	11.7	14.7
Gross Margin per Ewe (before forage variable costs)	35.1	34.9

Notes:

(1) 50% sold in summer/autumn at 18 kg, 50% sold in autumn/winter at 20 kg at 200 p/kg, plus 3% losses.

(2) 35% sold in summer/autumn at 17 kg at 200 p, 65% sold in winter/spring at 21 kg at 205 p plus 3% losses.

(3) 55 kg and 65 kg per ewe at £140/t, plus purchased forage at £1.

APPENDIX V.B

LIVESTOCK SEMI AND TOTAL FIXED COSTS

This Appendix contains the estimates of livestock semi fixed and total fixed costs using the method described in section V.2.4. The Tables are supported by notes explaining the data sources and assumptions.

TABLE V.B.1

Semi Fixed and Total Fixed Costs for Dairy Cows

£'s 1982 prices	Semi Fixed Costs per head	Total Fixed Costs per head
Dairy cows (£/cow)		
Labour [(1)]	90.0	120.0
Machinery and power [(2)]	29.5	52.5
Buildings [(3)]	15.8	47.7
Total per head	135.3	220.2
Total per livestock unit	136	220

Notes:

(1) Based on MMB Analysis of Costed Farms 1980/81, and S.J. Amies 1978, and FMS estimates of 40 hours/cow (excluding field work) at £3.00/hour. For herds of 50-70 head additional cows within this range would need 26 to 30 hours extra per head.

(2) FMS: 7 tractor hours at £4.20 running costs only, £7.50 total costs. MMB 1980/81 machinery and equipment costs = £54/cow in 1982 prices.

(3) Cow housing: low cost cubicle house: £300/cow space over 20 years at 12% plus 1½% maintenance. Parlour costs are excluded.

TABLE V.B.2

Semi Fixed and Total Fixed Costs for Dairy Followers

£'s 1982 prices	Semi Fixed Costs	Total Fixed Costs
Dairy Followers (£ per replacement unit)[(1)]		
Labour	33.6	88.5
Machinery	22.8	41.0
Buildings	5.4	16.4
Total	61.8	145.9
Total £/g lu	60	141

Note:

(1) A replacement unit comprises a calf, a yearling and a down-calving heifer.

TABLE V.B.3

Semi Fixed and Total Fixed Costs for Beef Cows

1982 prices, £/beef cow and suckler

	Semi Fixed Costs	Total Fixed Costs
Labour	10.1	26.9
Machinery	20.3	36.9
Buildings	4.0	12.0
Total £/head	34.4	75.8*
Livestock unit/head g lu	0.76	0.76
Total £/g lu	46	100

Sources of data:

Labour:

MLC - average annual labour cost £26.9/head, assume 38% variable.

FMS - 12 h/year x £2.5/h = £30.

Machinery:

MLC - average annual m/c cost £36.89, assumed 55% variable.

FMS - 5.25 tractor hours x £2.5/h operating costs = £13.1

5.25 tractor hours x £4.5/h total costs = £23.63

Buildings:

MLC - £13.80/year, approximates to £93/beef cow amortized over 20 years at 12% plus 1½% maintenance.

***Total fixed costs:**

MLC - £132/beef cow including rent and rates and other general expenses.

TABLE V.B.4

Semi Fixed and Total Fixed Costs for Grass Beef

1982 prices, £/finished animal

	18 month beef		24 month beef	
	Semi Fixed Costs	Total Fixed Costs	Semi Fixed Costs	Total Fixed Costs
Labour	13.3	35.0	19.0	50.0
Machinery	18.2	33.1	23.8	42.8
Buildings	4.8	14.4	6.4	19.2
Total £/head	36.3	82.5*	49.2	112.0
Grazing livestock unit/head	0.48	0.48	0.85	0.85
£/grazing livestock unit	76	172	58	132

Sources of data:

18 month beef

Labour:

MLC - average £33.2/head, 18 m beef, assume 38% variable.

FMS - 11-20 hours/finished steer depending on whether 1 or 2 yardings, £27.50 to £50.

Machinery:

MLC - 'tractor' operating £10.95, depreciation £22.13, total £33.1 of which 55% assumed variable.

FMS - average 7 tractor hours at £2.50/h (av. for lowland cattle) = £17.50 operating costs, total machinery costs/head £31.50.

Buildings:

Based on MLC records.

Approximates to £55/head space over 20 years at 15% = £9.6/year, av. 1.5 spaces per finished store, including 1½%/year maintenance.

Table V.B.4 continued:

***Total fixed costs:**

MLC - £125/head 18 month beef including rent and rates, and other general expenses.

24 month beef

Labour:

FMS - twice yarded 20 hours at £2.50.

Machinery:

FMS - 9.5 tractor hours/head at £2.50/hour operation costs, £4.50 total costs.

Buildings:

£9.6/year/space x 2 years.

TABLE V.B.5

Semi and Total Fixed Costs for Overwintered and Grass Finished Stores

£/finished animal	Semi Fixed Costs	Total Fixed Costs
Labour (1)	8.9	23.5
Machinery	12.2	22.2
Buildings	3.2	9.7
Total £/head	24.3	55.4
Grazing livestock units/head	0.39	0.39
Total £/g lu	62.3	142.1

Note:

Estimates based on 18 month beef (Table V.B.4) with fixed costs at approximately two-thirds of the latter, given that these animals will be once rather than one and a half times yarded on average.

TABLE V.B.6

Semi and Total Fixed Costs for Fatstock at Grass

15-21 month cattle (av. 18 month) grazed over 6 months

£/head	Semi Fixed Costs	Total Fixed Costs
Labour (1)	1.5	4.0
Machinery (2)	4.3	7.9
Buildings	-	-
Total £/head	5.8	11.9
Total £/glu	12.1	24.8

Notes:

(1) FMS - 0.27 h/head/month x 6 months at £2.5/h.

(2) FMS - 1.75 h/head x £4.50/h, 55% of which are operating costs.

TABLE V.B.7

Semi and Total Fixed Costs for Lowland Sheep

1982 prices, £/ewe	Semi Fixed Costs	Total Fixed Costs
Labour	5.3	10.5
Machinery	3.9	7.1
Buildings	0.3	0.8
Total £/head	9.5	18.4*
Livestock unit/ewe	0.13	0.13
£/livestock unit	73	142

Sources of data:

Labour:

MLC - £10.5 total.

FMS - 0.5 man days/head = £10.00, 50% for lambing, dipping and shearing.

Machinery:

MLC - total £7.1, 55% of total assumed variable.

FMS - 1.5 tractor hours/head x £2.50/h = £3.8 operating costs

1.5 tractor hours/head x £4.50/h = £6.8 total machinery costs

Buildings

MLC - £0.60/ewe.

*Total fixed costs:

MLC - £24/ewe including rent, rates and other general expenses.

APPENDIX V.C

THE VALUE OF GRAZING DAYS

TABLE V.C.1

Opportunity Cost of Grazing Days

Dairy Cows:

(1) Dairy Cows: 5500 litres, Average Dairy ME Requirement at 150 MJ

Alternative	Concentrate		Hay		or Silage instead of hay		Feed cost		Yarding Costs £/day	Total cost assuming feed cost (b) £/cow/day
	kg as fed	MJ	kg as fed	MJ	kg as fed	MJ	(a)	(b)		
(i)	10	110	5.3	40	15.3	40	1.42	1.30	0.24	1.54
(ii)	5	55	12.7	95	36.2	95	1.20	0.89	0.24	1.13

(2) Dairy Cows: Daily ME Requirements for 25 kg milk/day during first 30 weeks of lactation at 180 MJ/day

(i)	10	110	9.3	70	26.7	70	1.61	1.39	0.24	1.63
(ii)	6	66	15.2	114	43.4	114	1.43	1.07	0.24	1.31

Beef Stock:

(1) Diet (i)

Liveweight	ME required MJ/day for 0.67 kg/day liveweight gain	Feeding				Feeding cost £/head		Livestock Units/head	Cost assuming feed cost (b) £/lu/day	Yarding Cost £/lu/day	Average Cost £/lu/day
		Barley		Silage		(a)	(b)				
		Kg	MJ	Kg	MJ						
450	80	2.0	38.5	15.8	41.5	0.61	0.48	.6	0.80		
300	62	2.0	38.5	9.0	23.5	0.49	0.42	.5	0.84	0.24	1.10
225	52	2.0	38.5	5.2	13.5	0.43	0.38	.4	0.95		

(2) Diet (ii)

450	80	0.5	9.6	26.8	70.4	0.54	0.33	.6	0.55		
300	62	0.5	9.6	20.0	52.4	0.43	0.27	.5	0.54	0.24	0.80
225	52	0.5	9.6	16.2	42.4	0.36	0.24	.4	0.60		

Notes:

(i) Diets assume maximum 18 kg DM/day intake, and automatic satisfaction of protein needs.

(ii) Feed values

	Concentrates	Hay	Silage
DM %	88.0	85.0	25.0
MJ/kg DM	12.5	8.8	10.5

(iii) Prices and Costs

Purchase feeds: Concentrates: £140/tonne WM, £1.27/100 MJ

Barley: £140/tonne WM, £1.10/100 MJ

Hay: £65/tonne WM, £0.87/100 MJ

Silage valuation: £20-25/tonne WM, £0.86/100 MJ

Hay costs: Variable forage costs: £22/t DM

Baling, handling, storage: £25/t DM

Total cost: £47/t DM, £0.54/100 MJ

Silage costs: Variable forage costs: £22/t DM

Silage making & clamp: £35/t DM

Total cost: £57/t DM, £0.55/100 MJ

(iv) Feed Costs/Head/Day

Savings in purchased feeds (net of additional costs of meeting equivalent energy requirement from grass at 22p/100 MJ) plus savings in conservation costs where relevant.

(a) Net savings in bought feeds at

concentrates: £1.27/100 MJ

hay/silage: £0.90/100 MJ

(saving in concentrate costs) + (saving in bought forage) - (cost of meeting energy need from grass)

(b) Net savings in bought feeds, and savings in conservation costs on silage/hay component of yarded diet.

(saving in concentrate costs) - (cost of meeting concentrate energy equivalent from grass) + (saving from conservation costs on home produced hay/silage)

(v) Yarding Costs

£0.24/lu/day including straw.

APPENDIX V.D

FERTILIZER USE ON GRASS

TABLE V.D.1

N Fertilizer Use Assumptions on Grassland

Pre-Scheme Land Use	Post-Scheme Land Use	N Levels on Grass		Field Drainage 0 = none 1 = new or old	Assumption on Timing of Change of Fertilizer Use
		Pre-Scheme	Post-Scheme		
Grass*	Grass	0	+ve	0	1
"	"	+ve	+ve	0	1
"	"	0	+ve	1	2
"	"	+ve	+ve	1	2
"	Arable	0	–	0, 1	3
"	"	+ve	–	0, 1	3
"	Arable/ley	0	+ve	0	1
"	Arable/ley	+ve	+ve	0	1
"	Arable/ley	0	+ve	1	4
"	Arable/ley	+ve	+ve	1	4

* Including grass in arable/leys.

Working Assumptions in situations where field specific details are not known:

(1) A linear increase in N fertilizer use is assumed up to 1979 after which existing applications apply.

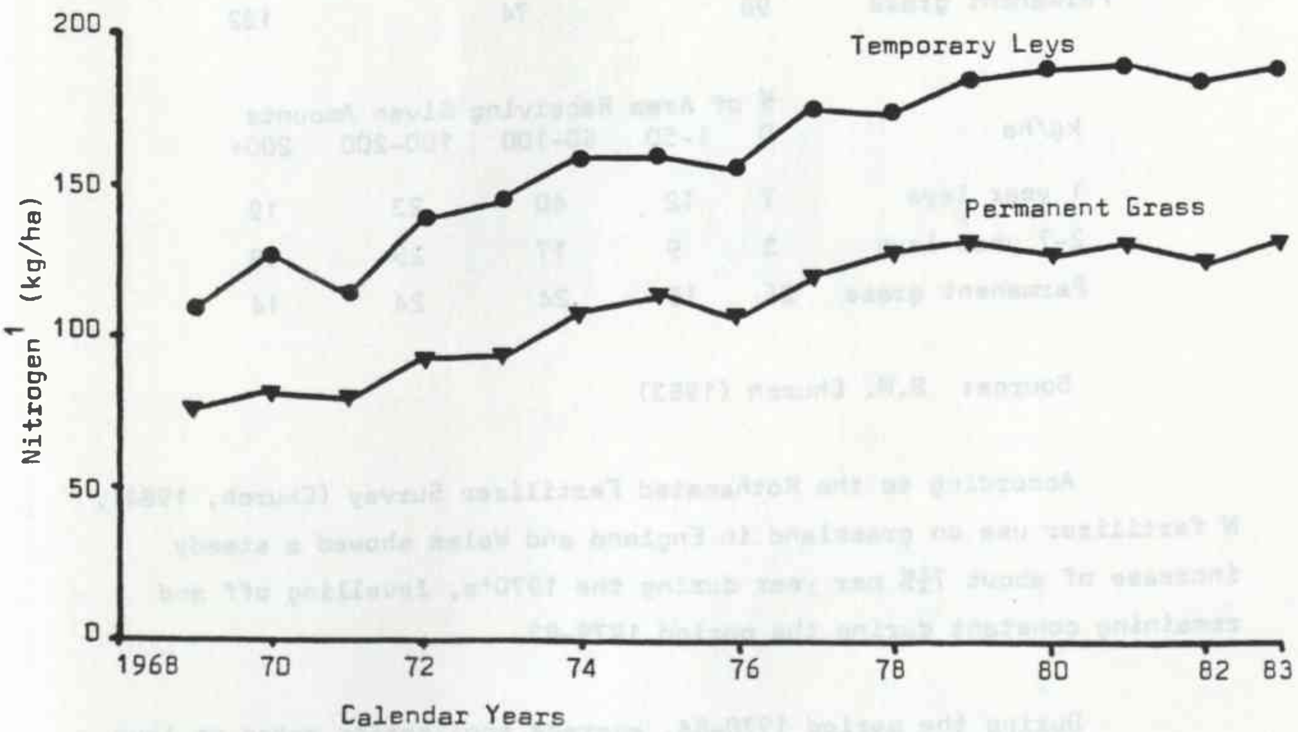
(2) N rates are assumed constant before drainage, after point of drainage assumption 1 applies.

(3) Assume N as constant before land use change.

(4) Assume N as constant before drainage or land use change which ever occurs first, after which assumption 1 applies.

FIGURE V.D.1

Rate of 'N' Fertilizer Application on Grass 1969-1983



1. Actual rates for areas receiving 'N'.

Source: Rothamsted Fertilizer Survey (Church, 1984)

TABLE V.D.2

N Fertilizer Use in England and Wales, 1983

kg/ha

	Average Application Rates Overall	% of Area Receiving	Actual
1 year leys	116	93	124
2-7 year leys	181	95	191
Permanent grass	98	74	132

kg/ha	% of Area Receiving Given Amounts 0	1-50	50-100	100-200	200+
1 year leys	7	12	40	23	19
2-7 year leys	5	9	17	29	39
Permanent grass	26	15	24	24	14

Source: B.M. Church (1983)

According to the Rothamsted Fertilizer Survey (Church, 1984), N fertilizer use on grassland in England and Wales showed a steady increase of about 7½% per year during the 1970's, levelling off and remaining constant during the period 1979-83.

During the period 1970-84, average application rates on leys were about 50% higher than for permanent grass. A larger percentage of the total ley area received nitrogen compared to permanent grass.

APPENDIX V.E

ARABLE CROP GROSS MARGINS

This Appendix contains the basic commodity price and variable cost assumptions used to define arable enterprise gross margins. Estimates of gross margins at individual farm level have been adjusted according to reported yields, or where actual farming practice such as fertilizer use, vary significantly from standard.

TABLE V.E.1

Winter Wheat Gross Margin

1982 prices

OUTPUT				
Grain yield (t/ha)	4.5	5.5	6.5	7.5
Price (£/t)		115		
Grain revenue	518	633	748	863
Straw(1)	38	38	38	38
Total Output	556	671	786	901
VARIABLE COSTS				
Seeds(2)		39		
Sprays		60		
Fertilizer(3)		65		
Other(4)		20		
Total Variable Costs		184		
GROSS MARGIN PER HECTARE	372	487	602	717

Notes:

(1) Assuming 2½ t/ha at £15.

(2) 175 kg at £220/t.

(3) 200 kg of low N compound (10.20.20 , at £180/t plus 80 kg N at 36p.

(4) Straw baling costs at £8/t.

TABLE V.E.2

Spring Wheat Gross Margin per Hectare

1982 prices, £

OUTPUT			
Grain yield (t/ha)	3.5	4.3	5.0
Price (£/t)		115	
Grain revenue	403	495	575
Straw(1)	38	38	38
Total Output	441	533	613
VARIABLE COSTS			
Seeds(2)		42	
Sprays		25	
Fertilizers(3)		56	
Other(4)		20	
Total Variable Costs		143	
GROSS MARGIN PER HECTARE	298	390	470

Notes:

(1) 2½ t/ha at £15/t.

(2) 190 kg at £220/t.

(3) 350 kg of high N compound at £160/t.

(4) Straw baling at £8/t.

TABLE V.E.3

Winter Barley Gross Margins per Hectare

1982 prices, £

OUTPUT			
Grain yield (t/ha)	4.0	4.75	5.0
Price (£/t)		108	
Grain revenue	432	513	540
Straw(1)	30	30	30
Total Output	462	543	570
VARIABLE COSTS			
Seed(2)		35	
Fertilizers(3)		58	
Spray		40	
Other(4)		16	
Total Variable Costs		149	
GROSS MARGIN PER HECTARE	313	394	421

Notes:

(1) 2 t/ha at £15/t.

(2) 170 kg at £220/t.

(3) 200 kg of low N compound plus 60 kg N at 36p.

(4) Straw baling at £8/t.

TABLE V.E.4

Spring Barley Gross Margin per Hectare

1982 prices, £

OUTPUT			
Grain yield (t/ha)	3.5	4.3	5.0
Price (£/t)		108	
Grain revenue (£/ha)	378	464	540
Straw(1)	30	30	30
Total Output	408	494	570
VARIABLE COSTS			
Seed(2)		37	
Sprays		25	
Fertilizer(3)		48	
Other(4)		16	
Total Variable Costs		126	
GROSS MARGIN PER HECTARE	282	368	444

Notes:

(1) 2 t/ha at £15/t.

(2) 170 kg at £220/t.

(3) 300 kg of (25.10.20) high N fertilizer at 160/t.

(4) Straw baling at £8/t.

TABLE V.E.5

Oil Seed Rape Gross Margin

1982 prices, £

OUTPUT				
Yield (t/ha)	1.5	2.0	2.5	3.0
Price (£/t)		265		
Total Output	398	530	663	795
VARIABLE COSTS				
Seed (1)		28		
Fertilizer (2)		127		
Sprays		35		
Total Variable Costs		190		
GROSS MARGIN PER HECTARE	208	340	473	605

Notes:

(1) 10 kg.

(2) 325 kg of NPK compound at £180/t + 190 kg N at 36p.

TABLE V.E.6

Sugar Beet Gross Margin

1982 prices, £

OUTPUT			
Yield (t/ha)	25	35	45
Price (£/t)		27	
Total Output	675	945	1215
VARIABLE COSTS			
Seed (1)		45	
Fertilizer (2)		135	
Sprays (3)		90	
Transport (4)	75	105	135
Total Variable Costs	345	375	405
GROSS MARGIN PER HECTARE	330	570	810

Notes:

(1) 6.5 kg at £6.9/kg.

(2) 850 kg N, K compound at £160/t.

(3) Herbicide £60, fungicide £5, pesticide £25.

(4) £3/t net.

TABLE V.E.7

Main Crop Potatoes Gross Margin

1982 prices, £

OUTPUT				
Ware yield (t/ha) (1)	20	30*	40	50
Price (£/t)		60		
Total Output	1200	1800	2400	3000
VARIABLE COSTS				
Seed	253 (2)		403 (3)	
Fertilizer (4)	208		208	
Sprays	90	130	160	190
Casual Labour (5)	105	155	210	260
Sundries (6)	155	220	280	340
Total Variable Costs	811	966	1261	1401
GROSS MARGIN PER HECTARE	389	834	1139	1599

* PMB standard yield estimate

Notes:

(1) 92% ware at £63.50, 8% chats at £20.

(2) 2.5 t/ha; 75% certified at £710, 25% once grown at £75/t.

(3) 4.0 t/ha.

(4) 1.3 t compound at £160/t.

(5) For hand picking behind digger, £90/ha if harvester used.

(6) PMB levy (£37/ha), bags, chitting, storage.

TABLE V.E.8

Strawberries Gross Margin

1982 prices, £

OUTPUT			
Yield (t/ha)	5		7
Price (£/t)		700	
Total Output	3500		4900
VARIABLE COSTS			
Fertilizers (75 N, 75 P, 125 K)		75	
Sprays		175	
Plants		175	
Packaging/marketing	840		1180
Casual labour	1250		1750
Total Variable Costs	2515		3355
GROSS MARGIN PER HECTARE	985		1545

TABLE V.E.9

Beetroot (grown on contract) Gross Margins per Hectare

1982 prices, £

OUTPUT	
Ware (30 t/ha at £40/t)	1200
Baby beet (6 t/ha at £50/t)	300
Total Output (for lifted beet in field)	1500 (1)
VARIABLE COSTS	
Seed (2)	150
Fertilizer (3)	170
Sprays	140
Grading (4)	216
Total Variable Costs	676
GROSS MARGIN PER HECTARE	824

Notes:

(1) Transport costs deducted.

(2) 15 kg.

(3) Fertilizer N 250 kg, P_2O_5 120 kg, K_2O 220 kg.

(4) £6/t.

TABLE V.E. 10

Broad Beans (combined) Gross Margin per Hectare

1982 prices, £

OUTPUT		
Yield (t/ha)		2.8
Price (£/t)		150
Total Output		420
VARIABLE COSTS		
Seed	52	
Fertilizer	18	
Sprays	40	
Total Variable Costs		110
GROSS MARGIN PER HECTARE		310

TABLE V.E.11

Vining Peas Gross Margin per Hectare

1982 prices, £

OUTPUT		
Yield (t/ha)		4.5
Price (£/t)		150
Total Output		675
VARIABLE COSTS		
Seeds	55	
Sprays	15	
Fertilizer	45	
Vining and transport charges*	270	
Total Variable Costs		385
GORSS MARGIN PER HECTARE		290

* £60/tonne.

TABLE V.E.12

Grass Drying and Pelleting Gross Margins, Fixed Costs and Net Return

		£/t DM (100% DM)	£/ha at 12.5 t DM (100%) per ha
GROSS OUTPUT		100	1250
VARIABLE COSTS			
Fertilizers and chemicals	16.0		
Fuel for drier	18.9		
Bags	2.6		
Total Variable Costs		37.5	469
GROSS MARGIN		62.5	781

FIXED COSTS*

	Semi Fixed Costs	Total Fixed Costs		
Labour	6.1	6.1		
Electricity	10.0	10.0		
Field m/c and transport	14.4	20.6		
Plant repairs	5.4	5.4		
Plant depreciation	0.0	8.9		
Total	35.9	51.0	449	638
NET RETURN			332	143

* Based on representative plant costs.

APPENDIX V.F

ARABLE SEMI AND TOTAL FIXED COSTS

This Appendix contains the data and assumptions for estimating the semi fixed and total fixed costs of arable enterprises. With reference to section V.2, semi fixed costs are those items of recurrent expenditure such as direct labour and machinery operating costs which are usually left out of the conventional calculation of the enterprise gross margin.

The total fixed costs incorporate both these recurrent expenditure items and a charge for capital costs relating to depreciation and interest and other strictly indirect expenses.

TABLE V.F.1

Semi and Total Fixed Costs for Wheat and Barley

	Semi Fixed Costs	Total Fixed Costs
Labour (£/ha)[1]	35.0	35.0
Machinery (£/ha)[2]	39.0	71.5
Drying (£/t dried)[3]	4.0	8.0
Storage (£/t)[4]	1.0	11.0
Total for 5 t/ha crop (£/ha)	89.0	181.5

Notes:

(1) 14 h at £2.50.

(2) 13 h at £3 operating, £5.50 full.

(3) Fuel and repairs £4, depreciation and interest £4: approx. ½ crop would be dried.

(4) Operating £1, depreciation and interest £10.

TABLE V.F.2

Semi and Total Fixed Costs for Sugar Beet

	Semi Fixed Costs	Total Fixed Costs
Labour (£/ha)[1]	170.0	170.0
Machinery (£/ha)[2]	135.0	247.5
Total	305.0	417.5

Notes:

(1) 68 h at £2.50.

(2) 45 h at £3 operating, £5.50 full.

TABLE V.F.3

Semi and Total Fixed Costs for Potatoes

1982 prices

	Semi Fixed Costs	Total Fixed Costs
Labour (£/ha)[1]	307.5	307.5
Machinery (£/ha)[2]	150.0	275.0
Storage (£/t)[3]	3.0	9.7
Total for 40 t/ha crop	577.0	970.0
Total for 30 t/ha crop	466.0	772.0

Notes:

(1) 123 h at £2.50 excluding casual labour on 40 t/ha crop, including riddling. About 100 h for 30 t/ha crop.

(2) 50 h at £3 operating costs, £5.50 full costs for 40 t/ha crop. about 45 h for 30 t crop.

(3) Fuel and repairs on the floor storage in existing buildings £3/t, pallet storage in insulated ventilated building £50/t over 20 years at 12% = £13.4/t.

TABLE V.F.4

Semi and Total Fixed Costs for Oil Seed Rape

1982 prices

	Semi Fixed Costs	Total Fixed Costs
Labour (£/ha)[(1)]	30	30
Machinery (£/ha)[(2)]	62	90
Drying (£/t dried)[(3)]	6	10
Storage (£/t stored)[(4)]	1	11
Total £/ha for 2 t/ha crop	106	162

Notes:

(1) 12 h at £2.5.

(2) 11 h at £3 operating and £29/ha contract windrowing, £5.50/h full costs and £29/ha.

(3) All crop dried to 8% moisture content.

(4) Operating expenses £1, depreciation and interest £10.

TABLE V.F.5

Semi and Fixed Costs for Red Beet*

1982 prices

	Semi Fixed Costs	Total Fixed Costs
Labour[(1)]	170	170
Machinery[(2)]	120	220
Total	290	390

* Grown on contract.

Notes:

(1) 68 hours at £2.50.

(2) 40 hours at £3 operating, £5.5 full costs.

TABLE V.F.6

Semi and Fixed Costs for Strawberries

1982 prices

	1st Year of Establishment Semi Fixed Costs	1st Year of Establishment Total Fixed Costs	2nd + Years Semi Fixed Costs	2nd + Years Total Fixed Costs
Labour[(1)]	300	300	150	150
Machinery[(2)]	120	220	60	110
Total per Hectare	420	520	210	260

Notes:

(1) 120 h, 60 h.

(2) 40 h, 20 h.

TABLE V.F.7

Semi and Fixed Costs for Broad Beans

£/ha

	Semi Fixed Costs	Total Fixed Costs
Labour[(1)]	32.5	32.5
Machinery[(2)]	39.0	71.5
Total per hectare	71.5	104.0

Notes:

(1) 13 hours at £2.5.

(2) 13 hours at £3 operating, £5.5 full costs.

TABLE V.F.8

Semi and Fixed Costs for Vining Peas

£/ha

	Semi Fixed Costs	Total Fixed Costs
Labour[(1)]	67.5	67.5
Machinery[(2)]	51.0	93.5
Total	118.5	161.0

Notes:

(1) 27 hours at £2.50.

(2) 17 hours at £3 operating, £5.5 full costs.

APPENDIX V.G

ECONOMIC PRICES FOR AGRICULTURAL COMMODITIES

The following Tables explain the derivation of economic prices and gross margins based on world market prices over the period 1975-82, and expressed in 1982 prices.

TABLE V.G.1

Economic Prices for Agricultural Commodities

1982 constant prices, 1975-82

	Export Parity			Import Parity			
	Wheat (1)	Barley (2)	Urea (3)	Meat (4)	Sugar (5)	TSP (6)	Pot.Chl. (7)
Fob $	168.6	123.8	192.2		351.8	197.6	88.3
Freight, insurance					65.0	19.0	20.0
Liverpool Cif $				2363	416.8	216.6	108.3
Liverpool Fob $	168.6	123.8	192.2				
Liverpool Cif/Fob 5 £ (8)	85.2	62.5	97.1	1193.4	210.5	109.4	54.7
Port charges	4.5	3.5	8	30	15	9	8
Port gate	80.7	59.0	89.1	1223.4	225.5	118.4	62.7
Port gate to central store	2.0	1.5	4	15	5	5	4
Value at central store	78.7	57.5	85.1	1238.4	230.5	123.4	66.7
Delivery to project	3.0	3.0	3.0	10.0 (9)	5.0 (9)	3.0	3.0
Farmgate Value (£/t)	75.7	54.5	82.1	1228.4	225.5	126.4	69.7

Notes:

(1) Canadian no. 1 (WRS) Thunder Bay, less 10% quality/variety premium.

(2) Feed no. 1 Thunder Bay.

(3) Fob Europe bagged.

(4) Argentine boneless.

(5) World Int. Sugar Agreement Daily price, Fob Caribbean ports.

(6) Triple Super Phosphate, Fob U.S. Gulf.

(7) Potassium Chloride, Muriate of Potash, Fob Vancouver.

(8) Average annual exchange rate 1975-82, US $ 1.98 = 5 £1.

(9) Transport costs are deducted to give an equivalent price at central store.

TABLE V.G.2

Economic Price for Milk

1982 constant prices for 1975-82 period

	Skimmed Milk Powder(1)	Butter(2)
Liverpool Fob US $	2240.0	
Liverpool Cif US $		1687.3
Liverpool Fob/Cif S £(3)	1131.9	852.2
Port charges	9.0	20.0
Port gate value	1122.9	872.2
Delivery to project	3.0	8.0
Farmgate price £/t	1119.9	864.2

1 tonne milk (1030 litres) at 3.7% butter fat, 8.6% solid non-fat

= 0.037 t butter fat x £864.2/t = £31.98

+ 0.086 t skimmed milk x £119.9/t = £96.31

1030 litres of milk = £128.29

1 litre of milk = £0.125

less 2p/litre processing = £0.105/litre

Notes:

(1) US wholesale.

(2) New Zealand butter Cif U.K. port.

(3) Average annual exchange rate, 1975-82, US $1.98 = S £1.

TABLE V.G.3

Economic Price for Liveweight Fatstock

Price/tonne carcase meat = £1228.4 (Table V.G.1)

Killing out % = 50.0

Equivalent liveweight price = £614.2/tonne, 61p/kg.

TABLE V.G.4

Economic Price for Sugar Beet

Economic price of raw sugar (£/tonne) = £225.5 (from Table V.G.1)

Processing costs to produce 1 tonne = £120.0

Net value £105.5

	£
Value of 1 tonne sugar beet:	
Sugar at 16% = £105.5 x .16 =	16.88
pulp at 100 kg at £85/t =	8.50
Molasses at 25 kg at £50/t =	1.20
	£26.58

TABLE V.G.5

Financial versus Economic Gross Margins for Wheat

1982 prices

	Economic		Financial	
OUTPUT				
Yield (t/ha)	5.5	6.25	5.5	6.25
Price (£/t)	75.7	75.7	115.0	115.0
Straw (£/ha)(1)	38.0	38.0	38.0	38.0
Gross Output per Hectare	454.3	511.1	671.0	756.8
VARIABLE COSTS/HA				
Seeds(2)	25.4		39	
Sprays	60.0		60	
Fertilizer(3)	40.5		65	
Other	20.0		20	
Total Variable Costs	145.9	145.9	184	184
GROSS MARGIN PER HECTARE	308.4	365.2	487	572

Economic/Fiancial Gross Margins = 0.63

Notes:

(1) Straw 2½ t at £15.

(2) 175 kg at £220 x .66

(3) N110 x 25p, P60 x 28p, K60 x 12p.

TABLE V.G.6

Financial and Economic Gross Margins for Barley

1982 prices

	Economic		Financial	
OUTPUT				
Yield (t/ha)	4.3	5.0	4.3	5.0
Price (£/t)	108		54.5	
Straw (£/ha)	30		30.0	
Gross Output per Hectare	494.4	570	264.4	302.5
VARIABLE COSTS (£/ha)				
Seeds	37.0		18.8	
Sprays	25.0		25.0	
Fertilizer	48.0		23.3	
Other	16.0		16.0	
Total Variable Costs	126.0		83.1	
GROSS MARGIN (£/HECTARE)	368.4	444.0	181.3	219.4

Economic/Financial Gross Margins = 0.49

TABLE V.G.7

Financial and Economic Gross Margins for Dairy Cows

	Financial	Economic
OUTPUT/cow		
Yield (l/cow)	5000	5000
Price/l	14	10.5
Milk sales	700	525
Calf sales (1)	70	45.5
less: herd depreciation (1)	45	29.3
Total Output	725	541.2
VARIABLE COSTS (£/cow)		
Concentrates (2)	248	186
Sundries	45	45
Total Variable Costs	293	231
GROSS MARGIN (£/COW)	432	310.2

Dairy followers: adjusting for fatstock and feed prices, dairy followers economic gross margin is 75% of financial gross margin. Dairy and followers would show an overall economic gross margin of 73% of financial value.

Economic/Financial Gross Margin/hd = 0.72, /ha at 200 N = 0.75.

Notes:

(1) Assuming economic fatstock prices.

(2) Assuming economic cereal feed prices.

TABLE V.G.8

Financial and Economic Gross Margins for 18 Month Beef

Per finished head

	Autumn Born			
		Financial		Economic
OUTPUT				
Weight (kg)		475		475
Price (p/kg)		100		61
Revenue (£)		475		289.8
less: calf (£)		96		62.4
Total Output (£)		379		227.4
VARIABLE COSTS/HEAD*				
Calf rearing		70		56.0
Concentrate:				
grazing supplement	13		9.8	
finishing	77		57.8	
		90		67.6
Miscellaneous		20		20.0
Total Variable Costs		180		87.6
GROSS MARGIN PER HEAD		199		139.8

* Incorporate economic cattle feed prices.

Allowing for economic prices of fertilizer: economic gross margin per hectare for 18 m beef stocked at 3.8 head/ha (200 N) = £455, 78% of financial value.

Financial/Economic Gross Margin = 0.7

ANNEXE VI

UNDERDRAINAGE DESIGN AND COSTING

ANNEXE VI

UNDERDRAINAGE DESIGN AND COSTING

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Abbreviations Used in Annexe VI

AHDS	Agriculture and Horticulture Development Scheme
AHGS	Agriculture and Horticulture Grant Scheme
AII	Agricultural Inputs Index
CNCI	Cost of New Construction Index
FCGS	Farm Capital Grant Scheme
FDEU	Field Drainage Experimental Unit
FHDS	Farm and Horticulture Development Scheme
MAFF	Ministry of Agriculture, Fisheries and Food
RPI	Retail Price Index
SPSS	Statistical Package for the Social Sciences

ANNEXE VI

UNDERDRAINAGE DESIGN AND COSTING

VI.1 INTRODUCTION

One objective of this study was to examine the design and costing of underdrainage systems. This was necessary as part of ex-post evaluations so that drainage costs could be estimated on fields which were known to have been drained but for which no detailed costs came to light during farmer interviews or examination of the Ministry drainage files. In addition it was thought useful to develop a system for estimating underdrainage cost which could be used by River Engineers for cost-benefit studies.

The method originally conceived relied on drainage theory to predict a drainage design according to soil and climatic variables. It was thought that a cost could then be calculated according to the length of pipework required. This theoretical method is described in Appendix VI.A to this Annexe. It became apparent during the course of the study, however, that drainage designs are based on tradition rather than theory (see section VI.3). In particular, where drainage theory suggests a rather wide or a rather close spacing due to high or low soil permeability respectively, drainage practice reveals a much more modest variation around the mean spacing found in this study, 17.77 m. Moreover it was found that reliable estimates of some physical variables needed to calculate the theoretical spacing were not available since they could only be established from detailed site surveys. Two variables: in particular were difficult to estimate: the soil's hydraulic conductivity and the depth of the unconfined aquifer (ie. the depth to the impermeable layer). An alternative system for estimating underdrainage costs was therefore developed using regression analysis and relying on more readily available variables.

VI.2 BACKGROUND TO UNDERDRAINAGE ACTIVITY IN BRITAIN : POST-WAR TRENDS

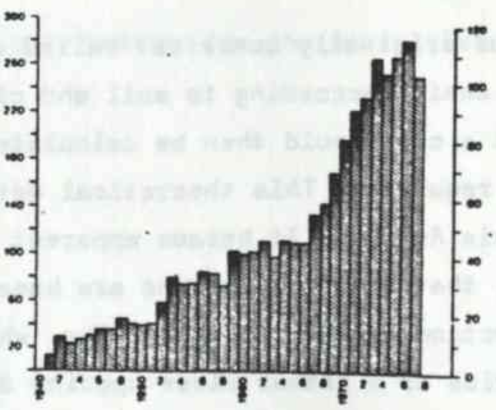
VI.2.1 The Rate of Drainage

Drainage activity increased 1940-70, peaked in 1972-4 due to the introduction of the FCGS grant scheme and withdrawal of the high rate of grant (60%) and has now levelled at c.100,000 ha/annum (Figures VI.1 and VI.2).

FIGURE VI.1

Acreage Drained Annually by Grant-aided Underdrainage in England and Wales

Data gathered from grant payments on work completed.



Source: Armstrong (1978)

FIGURE VI.2

Quarterly Rate of Drainage Activity (Thousand Hectares) For the Period 1/4/71 to 31/3/80

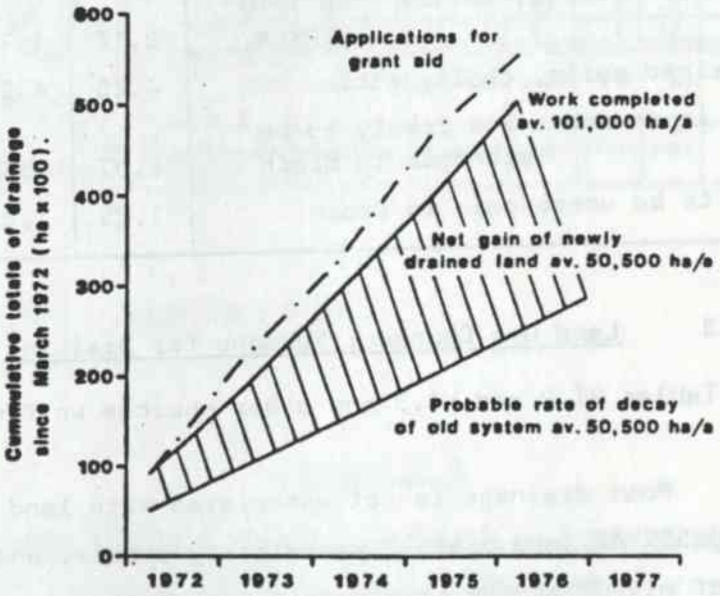
Source: Armstrong (1981)

VI.2.2 The Need for Drainage

A great deal of agricultural land was drained in the 19th Century. Old systems are now failing at c. 50,000 ha/annum. At the current rate of progress the backlog will not be eliminated for 50 years (Figure VI.3).

FIGURE VI.3

Drainage Applications, Works, and Estimated Need



Source: Trafford (1977)

Table VI.1 suggests that two-thirds of drainage activity takes place on land with old drainage systems, ie. land which had already been deemed worthy of improvement at some time in the past.

TABLE VI.1

Changes in the Field Drainage Situation 1968/9 to 1976

Classification	Estimated Areas in Millions ha		
	1969	1976	Change
Post 1940 grant-aided work	0.69	1.34	+0.65
Old drains still working, mainly from 19th Century	2.14	1.74	-0.41
Naturally drained soils, chalk, etc.	4.25	4.25	-
Land needing improvement and likely to be economic to drain	2.87	2.63	-0.24
Areas likely to be uneconomic to drain	1.05	1.05	-

VI.2.3 Land Use Change : Reasons for Draining

From Tables VI.2 and VI.3 and other sources we find that:

(a) Most drainage is not associated with land use change (= 59%). Nearly 50% of land drained was already arable, and remains so. Three-quarters of mixed farming area remains so, some going to arable.

(b) Of the 6.5% which was intensive grass (= dairy), around half stays as grass.

(c) The two classes whose land use mostly changes are extensive grass (= livestock) and rough grazing, comprising only 27% of the area drained. Rough grazing almost all goes to arable; extensive grassland goes largely to mixed cropping or arable.

(d) Only 9% of land drainage constitutes reclamation: classes 8 and 9 (rough grazing and 'other'). Some of this (about 1% of the total area drained) goes to arable use; this 1% is likely to have been affected by major arterial improvements.

TABLE VI.2

Land Use Change Following Drainage in England and Wales (1971-80). Percentage Area

Land use after drainage \ Land use before drainage	1	2	3	4	5	6	7	8	9	Area in this class after drainage (%)	Area in this class after drainage (ha)
1. Intensive arable	97.7	2.2	1.8	.7	.4	.2	.3	.4	4.5	1.67	12 576
2. Orchards/soft fruit	.7	76.6	.4	.4	.5	.4	.4	.4	1.5	0.81	6 122
3. Arable with roots	.2	9.1	97.2	28.4	6.3	2.4	4.6	4.8	13.2	26.52	200 135
4. Arable	.3	10.6	.3	69.3	17.7	9.0	19.8	10.0	36.1	31.21	235 548
5. Mixed farming	.4	1.0	.1	1.0	74.4	27.9	37.9	17.4	16.2	23.03	173 795
6. Pasture (Intensive)	.5	.5	0	.1	.5	59.6	19.3	18.2	7.5	9.08	68 512
7. Pasture (Extensive)	.2	0	0	.1	.2	.5	17.6	48.3	14.4	7.58	57 175
8. Rough grazing	0	0	0	0	0	.1	.1	.4	.3	.07	563
9. Other	0	0	.1	0	0	0	0	.1	5.8	.04	345
Area in this class before drainage (%)	1.01	.48	14.96	33.21	16.86	6.50	17.67	8.95	.35		
Area in this class before drainage (ha)	7 642	3 636	112 894	250 666	127 286	49 074	13 337	67 539	2 665		754 773

Source: Armstrong (1981)

TABLE VI.3

Land Use Change Following Drainage in England and Wales (1971-80). Area in Hectares

Land use after drainage \ Land use before drainage	1	2	3	4	5	6	7	8	9	Area in this class after drainage (%)
1. Intensive arable	7 649	79	2 080	1 659	482	75	340	271	121	12 577
2. Orchards/soft fruit	54	2 787	483	1 083	599	182	593	301	40	6 122
3. Arable with roots	13	30	109 731	71 206	7 996	1 165	6 119	3 223	352	200 135
4. Arable	24	385	308	173 720	22 522	4 423	26 466	6 723	977	235 548
5. Mixed farming	27	38	163	2 463	94 753	13 676	50 508	11 737	431	173 795
6. Pasture (Intensive)	37	17	26	331	653	29 258	25 688	12 304	200	68 513
7. Pasture (Extensive)	14	1	9	166	252	258	23 454	32 639	383	57 175
8. Rough grazing	0	0	15	11	25	34	183	287	8	564
9. Other	3	0	79	28	4	4	20	54	154	345
Area in this class before drainage (ha)	7 642	3 636	112 894	250 666	127 286	49 074	133 371	67 539	2 665	754 773

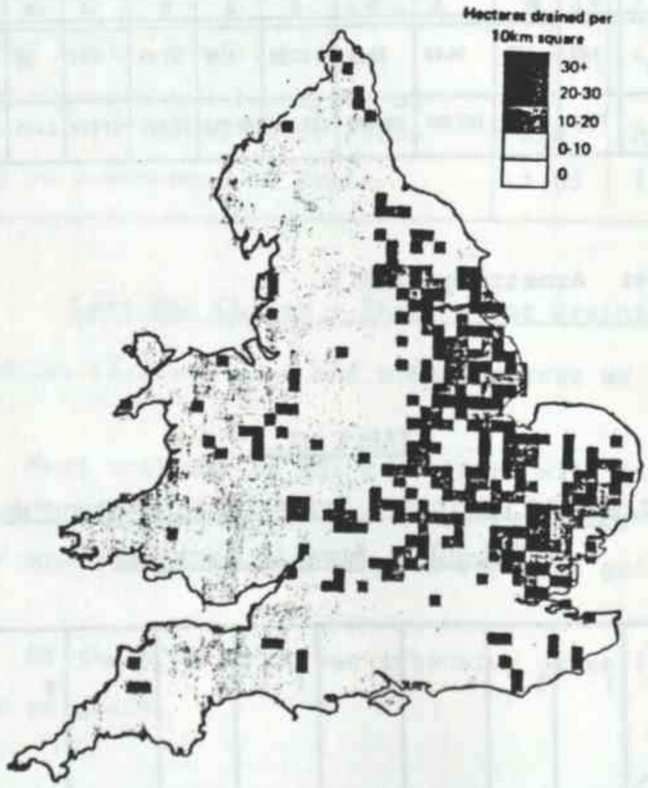
Source: Armstrong (1981)

VI.2.4 Regional Distribution

Drainage activity takes place predominantly in the East and is concentrated on improving arable land. In the West it is more often associated with a change of land use, usually into cereals from grass or mixed farming.

FIGURE VI.4

Location of Drainage Activity (1/4/78 to 31/3/79)



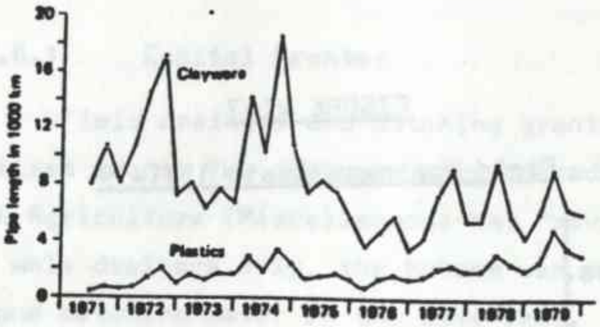
Source: Armstrong (1981)

VI.2.5 Use of Drainage Materials

There is a gradual switch over to plastics, although the oil crises have temporarily reversed trends.

FIGURE VI.5

Use of Drain Materials, Quarterly Length of Pipes Used, Clayware and Plastics, 1/4/71 to 31/3/79



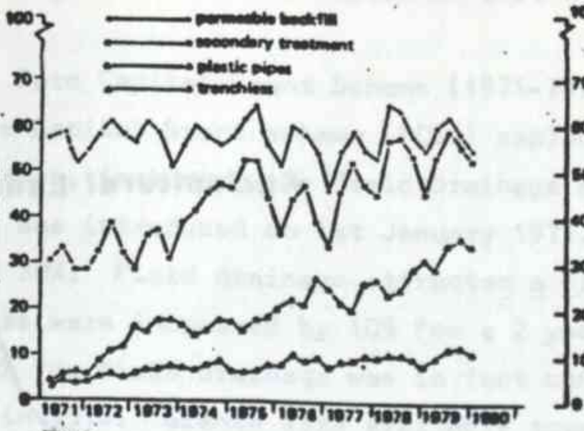
Source: Armstrong (1981)

VI.2.6 Use of Permeable Backfill

Rising fuel prices have made transport of permeable backfill much more expensive. It is now used only where strictly necessary, ie. where secondary treatments are also used or for the interception of springliness.

FIGURE VI.6

Drainage Techniques 1/4/71 to 31/3/80. Percentage of Schemes Using Permeable Backfill, Secondary Treatments, Plastics Pipes, and Trenchless Drain-laying Machinery



Source: Armstrong (1981)

VI.2.7 Field Drainage Costs

The development of drainage machiney in the 1950's and 1960's, and latterly the introduction of the trenchless machine, kept down drainage costs. The fuel crises of the 1970's increased costs (Figures VI.7 and VI.8).

FIGURE VI.7

Field Drainage Costs 1971-79

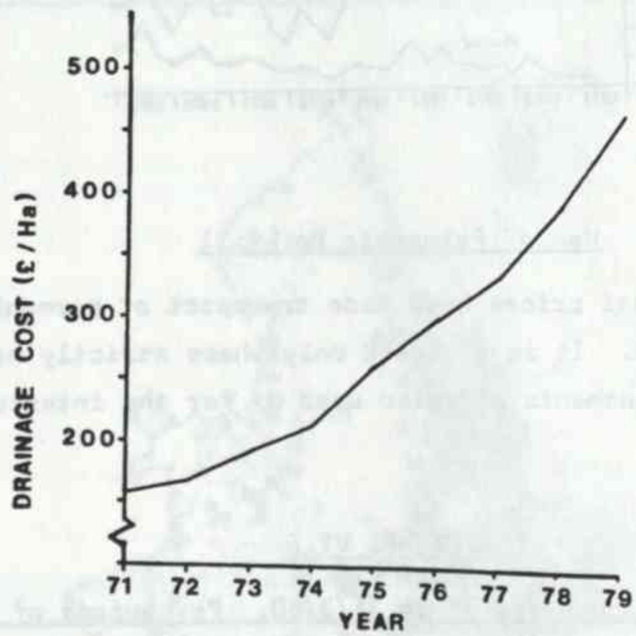
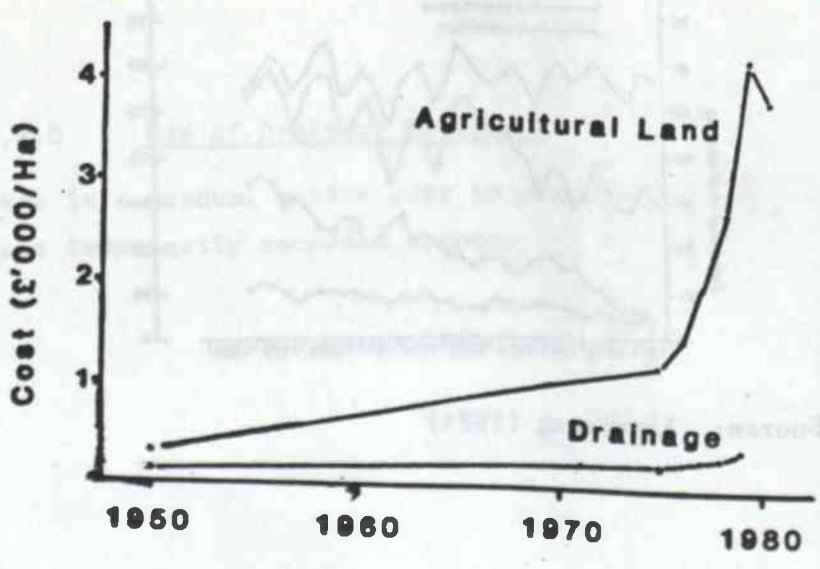


FIGURE VI.8

Costs of Agricultural Land and Drainage 1950-80



VI.2.8 The System of Grant Support for Underdrainage

Source: Bingham, S.P. (1983). 'A Guide to the Development of Grants for Agriculture and Horticulture in England and Wales - 1940-82'. Economics Division III, Ministry of Agriculture, Fisheries and Food.

VI.2.8.1 Capital Grants:

(a) Field drainage and ditching grants (1940-70):

The first grants for drainage were introduced on 1st January 1940, under the Agriculture (Miscellaneous War Provisions) Act of 1940. Originally for mole drainage only, the scheme was extended to cover tile drainage and ditching later in the same year. Grant was paid at a rate of 50% of approved expenditure up to a maximum sum per hectare (until 1952), given the prior approval of the Local Agricultural Executive Committee. Approval was only likely to be given in cases where the scheme was expected to lead to increased food production in the near future at a reasonable cost. Improvements to the main ditches were not eligible as these were the responsibility of the Local Drainage Authority or County or Borough Council. Subsoiling became eligible for grant aid at the same rate in 1969 provided it was carried out as part of an approved tile drainage scheme.

The rate of grant was increased to 60% for the period March 1970 to March 1972 provided that applications were in by 31st December 1970 and work was completed within 3 years. The Field Drainage and Ditching Grants scheme closed on 31st December 1970.

(b) Farm Capital Grant Scheme (1971-74):

The Farm Capital Grant scheme (FCGS) replaced a number of earlier grant schemes, including the Field Drainage and Ditching of Grants above, and was introduced on 1st January 1971. The standard rate of grant was 30%. Field drainage attracted a higher rate of 50% although both rates were increased by 10% for a 2 year period. The higher rate of 60% for field drainage was in fact continued until the FCGS was amended in 1974. Grants were available towards capital expenditure and included ancillary items such as ditching, pumps, culverts, and secondary treatments, provided that prior approval had been obtained from the Ministry that the scheme was technically sound.

(c) Farm Capital Grant Scheme (1974-80):

The Farm Capital Grant scheme was modified in accordance with an EEC directive and the amended version came into operation on the 1st January 1974. The standard rate of grant was set at 20%. Field drainage had a maximum of 55%, but to meet an EEC requirement, it was calculated as a 25% grant in respect of the combined cost of the field drainage and of all other capital investment 'of a type eligible for assistance under the FHDS' (see below) over the preceding 2 years; it was, however, not less than 25% of the drainage work. This was replaced by a flat rate 50% grant for field drainage on 1st June 1976.

On 1st February 1980, the standard rate of grant under FCGS was set at 22½% except for field drainage which was aided at 37½%. This was a temporary measure prior to the replacement of FCGS by the Agriculture and Horticulture Grant scheme on 1st October 1980.

(d) Agriculture and Horticulture Grant Scheme (1980-85):

The Agriculture and Horticulture Grant scheme (AHGS) replaced the FCGS and provides grants payable to anyone incurring expenditure of a capital nature in connection with an agricultural business. The standard rate of grant is 22½% although field drainage attracts a grant rate of 37½%.[1] Prior approval is not necessary. The scheme is due to end on 31st December 1985.

VI.2.8.2 Development Grants:

(a) Farm and Horticulture Development Scheme (1974-1980):

The Farm and Horticulture Development scheme (FHDS) was partly financed by EEC funds and was designed to enable farmers with a low income to achieve an income comparable with the average in non-agricultural industry. Grants were available on a wide range of items for which the standard rate was 25% for agriculture generally and 60% for field drainage. Applicants had to put forward a development plan showing that at the end of the plan their agricultural business would be able to support at least one man putting in a full year's work. There were maximum and minimum qualifying expenditures and prior approval had to be obtained from the Ministry. On 1st February 1980 the general rate was reduced to 32½%, and that for field drainage

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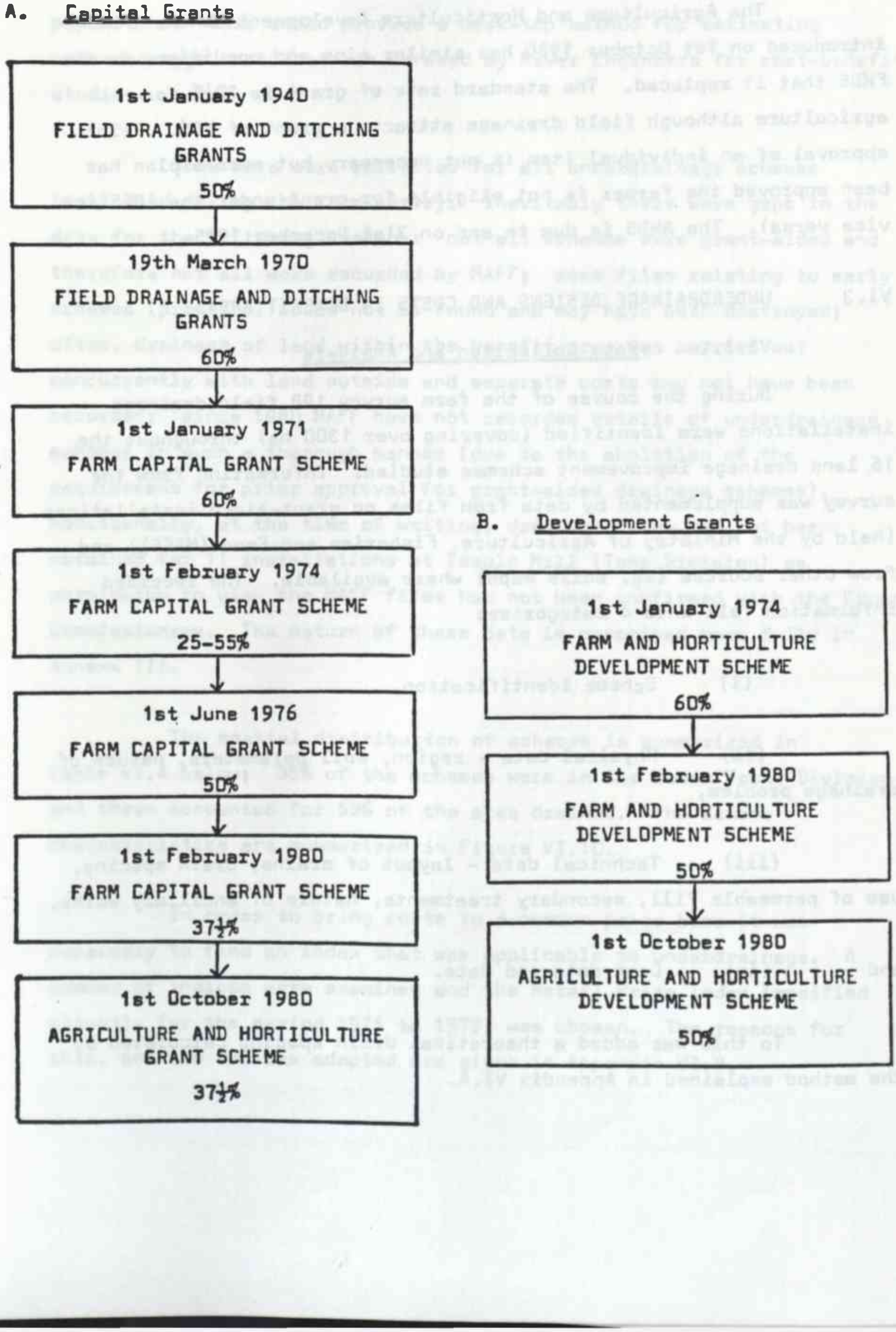
1. The current (1984) rate of grant for field drainage is 30 %.

FIGURE VI.9

Summary of Grant Systems and Rate of Grants for Field Drainage (1940-1983)



to 50%, pending the replacement of the FHDS by the Agriculture and Horticulture Development scheme.

(b) Agriculture and Horticulture Development Scheme (1980-85):

The Agriculture and Horticulture Development scheme (AHDS) introduced on 1st October 1980 has similar aims and conditions to the FHDS that it replaced. The standard rate of grant is 32½% for agriculture although field drainage attracts a grant of 50%. Prior approval of an individual item is not necessary but once a plan has been approved the farmer is not eligible for grant under the AHGS (or vice versa). The AHDS is due to end on 31st December 1985.

VI.3 UNDERDRAINAGE DESIGNS AND COSTS IN BENEFIT AREAS

VI.3.1 Data Collection and Analysis

During the course of the farm survey 198 field drainage installations were identified (covering over 1300 ha) throughout the 16 land drainage improvement schemes studied. Information from the survey was supplemented by data from files on grant-aided installations (held by the Ministry of Agriculture, Fisheries and Food (MAFF)) and from other sources (eg. soils maps) where available. The recorded information fell into 4 categories:

(i) Scheme identification,

(ii) Physical data - region, soil parameters, nature of drainage problem,

(iii) Technical data - layout of drains, drain spacing, use of permeable fill, secondary treatments, nature of ancillary works,

and (iv) Cost data and date.

To this was added a theoretical drain spacing calculated by the method explained in Appendix VI.A.

The aim of this section of the study was to examine the relationships between (i) physical data and drain spacing, (ii) actual and theoretical drain spacing, and (iii) physical data and cost, with the objective of devising an empirically based system for estimating the likely cost of an underdrainage scheme based on readily available parameters. This would provide a desk-top method for estimating underdrainage cost that can be used by River Engineers for cost-benefit studies.

Some data were collected for all underdrainage schemes identified during the farm survey. Inevitably there were gaps in the data for the following reasons: not all schemes were grant-aided and therefore not all were recorded by MAFF; some files relating to early schemes (pre-1965) could not be found and may have been destroyed; often, drainage of land within the benefit area was carried out concurrently with land outside and separate costs may not have been recorded; since 1980 MAFF have not recorded details of underdrainage schemes in such a thorough manner (due to the abolition of the requirement for prior approval for grant-aided drainage schemes). Additionally, at the time of writing, drainage files had not been obtained for 11 installations at Temple Mill (Tame Division) as permission to view the MAFF files had not been confirmed with the Crown Commissioners. The nature of these data is described more fully in Annexe III.

The spatial distribution of schemes is summarized in Table VI.4 below; 35% of the schemes were in the Lower Trent Division and these accounted for 53% of the area drained. The scheme characteristics are summarized in Figure VI.10.

In order to bring costs to a common price base it was necessary to find an index that was applicable to underdrainage. A number of indices were examined and the Retail Price Index (modified slightly for the period 1971 to 1979) was chosen. The reasons for this, and the indices adopted are given in Appendix VI.B.

Fig VI.10 THE NATURE OF SCHEMES

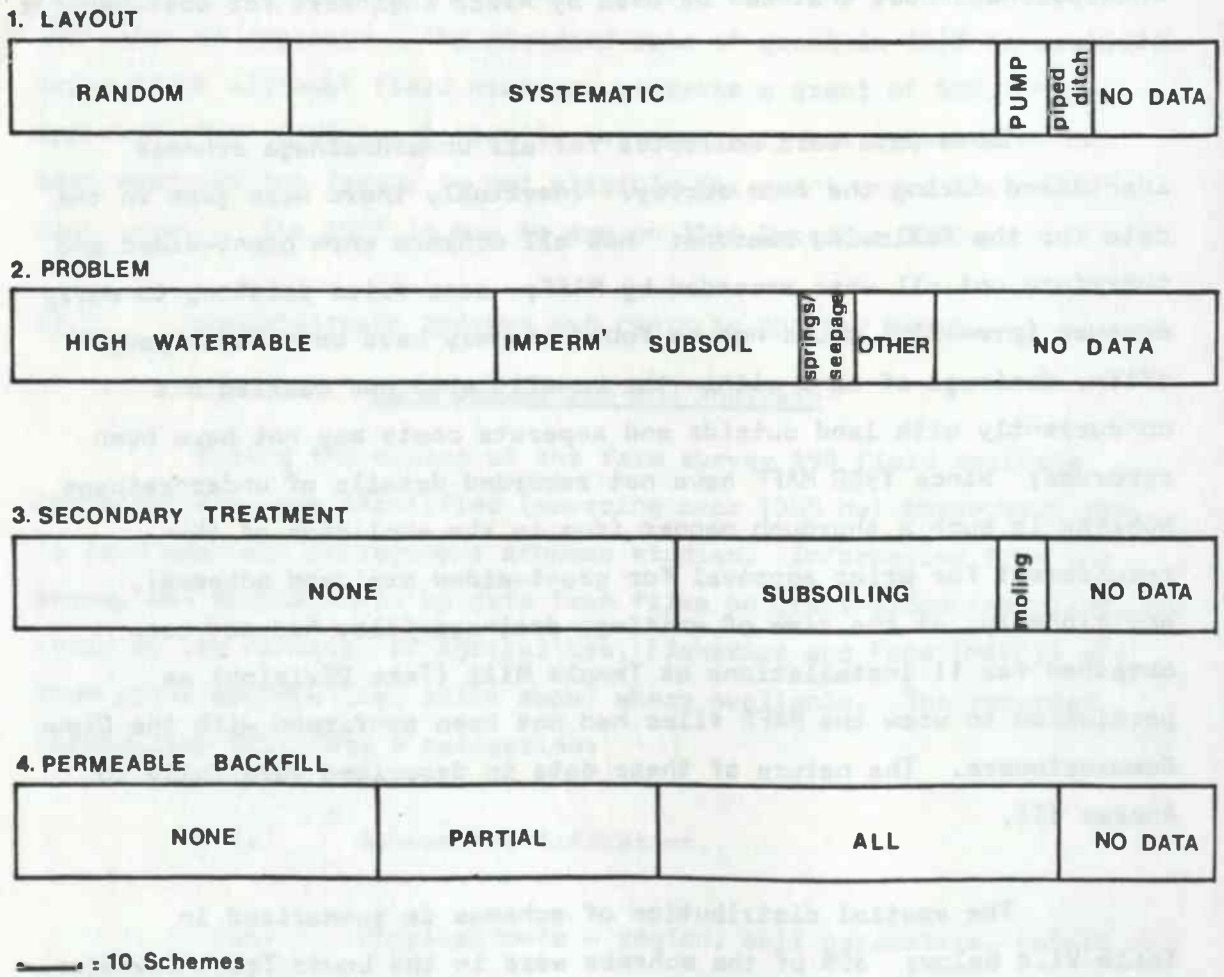


TABLE VI.4

Distribution of Drainage Installations

Land Drainage Scheme	No. of underdrainage schemes	Area drained (ha)
River Soar - Sharnford to Croft	18	57
River Sence - Kilby Bridge to Wistow	7	33
SOAR DIVISION	25	90
Doley Brook	17	69
River Trent - Alrewas to Yoxall Bridge	0	-
River Blithe - Blythe Bridge to Cresswell	1	11
UPPER TRENT DIVISION	18	83
River Morda	25	77
Sleap Brook	21	159
UPPER SEVERN DIVISION	46	236
Beckingham Marshes	41	481
River Idle - Bawtry to Mattersey	18	110
River Idle - Idle Stop to Bawtry	11	106
LOWER TRENT DIVISION	70	697
River Tean	4	9
DERWENT DIVISION	4	9
River Sence - Temple Mill	11	64
TAME DIVISION	11	64
River Severn - Saxon's Lode to Mythe Hook	1	25
River Severn - Bushley to Upper Lode	11	57
S. Gloucs IDB - Oldbury	3	14
S. Gloucs IDB - Epney	9	47
LOWER SEVERN DIVISION	24	143
TOTAL	198	1319

As a test of the accuracy of the index chosen, the correlation between the cost per hectare (after indexing) and the date of installation was calculated using the product moment correlation coefficient. A coefficient of 0.07 suggests that there is no linear trend in drainage costs over time beyond that explained by the index accounting for general inflationary trends.

The data collected on the drainage schemes were coded and entered onto the VAX computer at Cranfield Institute of Technology and analysed using the Statistical Package for Social Scientists (SPSS) version 9.1 (Nie et al, 1975; Hull and Nie, 1981).

VI.3.2 Drain Spacing

VI.3.2.1 Factors Influencing Drain Spacing:

The factors influencing the drain spacing of systematically laid out schemes were tested using analysis of variance techniques. The agro-climatic region (representing rainfall), subsoil texture, nature of the drainage problem, and nature of secondary treatments were all found to be significant influences on drain spacing (at the 5% level) but these 4 factors could only explain 42% of the variation (R^2 = 0.418).

There are a number of reasons why such a low R^2 value may have been obtained:

(a) In practice the drain spacings do not vary greatly. The mean spacing was 17.77 m and the standard deviation was only 4.6 m. The variation within classes was also low except between moling and non-moling schemes.

(b) All schemes were by definition in riverine areas. Soils did not vary greatly, with most schemes being in clays, silty clays or peat.

(c) Drainage theory shows that the hydraulic conductivity of the soil is a crucial determinant of the required drain spacing. In practice, site specific data is not usually available and soil texture and structure are used as surrogates for hydraulic conductivity. In the present data set information on soil texture and structure is limited. Where MAFF forms have been completed the required data are often (though not always) given. For many schemes soil parameters have to be inferred from often limited soils data. It should be noted that the National Soils Map (Soil Survey, 1983) was based on existing detailed surveys covering about 50% of England and Wales. Where no previous surveys existed soil associations were inferred from geological, climatic and landscape information. It is therefore not a good means of estimating soil texture and structure for specific sites.

(d) It is possible that drainage design does not rely heavily upon theory and that local practice and 'experience' are more relevant. Even if this is the case however, it is likely that the solutions adopted will be technically sound and appropriate to the conditions as, at least until 1980, all schemes were vetted by MAFF prior to installation.

VI.3.2.2 The Relationships Between Actual and Estimated Drain Spacing:

Drain spacing was estimated using the system described in Appendix IV.A for all systematically laid out schemes. This was compared with the actual drain spacing as recorded on the MAFF form, or where absent, as measured from the 1:2,500 plan. Student's T-test was applied. A product moment correlation coefficient of 0.428 was found to be significant at the 0.1% level but the T-test upon the pairs of values showed that the difference between actual drain spacings and the estimated spacing was significant at the 5% level (but not at the 1% level). The differences between the actual and estimated were small in real terms, with a mean of 0.76 m and standard deviation of 4.2 m, but as shown above the schemes did not vary greatly from the mean 17.77 m spacing.

Given these results, it would be unwise to assume that the method used to estimate drain spacing was invalid. There are a number of other factors that should be considered first:

(a) Estimating 'K':

To estimate accurately the drain spacing it is necessary to estimate the hydraulic conductivity (K) of the soil, to which predicted spacing is very sensitive. In the present study, K has been estimated from data on soil textural class which itself has often been inferred from the soil series. This is unsatisfactory because K varies widely within soil textural classes, due largely to variations in soil structure. The hydraulic conductivity of peat in particular is extremely variable and cannot be reliably estimated without site-specific information.

(b) Estimating 'q':

The method used is only applicable where the input of water (q) is from rainfall. In situations where seepage and springs are significant (as is common on riparian land) the model should be adjusted to include non-pluvial inputs, where they can be estimated.

(c) Estimating 'D_o':

The depth of the unconfined aquifer (D_o) is unknown for most of the cases examined. Unless the rather scant local information indicated otherwise it was assumed that there was a depth of 1.0 m below the drain to the impermeable layer. The estimated drain spacing is sensitive to the value of D_o in peat and deep permeable soils. It is likely therefore that the statistics above reflect the paucity of reliable data rather than any invalidity of the model. This does, however, highlight the difficulties of using the model for any practical purposes.

(d) The T-test was based upon a sample of 110 schemes and showed the different to be significant at the 5% level but not at the 1% level. A larger sample may give more conclusive results.

VI.3.3 <u>Estimating Drainage Cost</u>

The primary objective of this study was to devise a system for estimating the likely cost of a drainage scheme based upon readily available data. Section VI.3.2.2 above has shown that a likely drainage design cannot be accurately predicted using the theoretical system for estimating drain spacing outlined in Appendix VI.A. Any method of cost estimation based on costing of the materials needed at that spacing will therefore be largely indefensible. A more valid approach was required which would provide justifiable predictions whilst still using easily available information as inputs. It was therefore decided to examine statistically the variation in drainage costs and the factors influencing variation and to use a direct approach employing regression analysis.

The costs of the systematic schemes were first brought to a common (September 1982) price base and then expressed as a cost per hectare of benefit. The mean cost was found to be £700/ha but the standard deviation was high (£274) and the range was between £300 and £1600 per hectare. The following variables were then tested for their influence on cost:

Region,
Use of permeable fill,
Drain spacing,
Number of ancillaries.

All were found to be significant at the 1% level, however the main influences were found to be the region and the use of permeable fill which between them accounted for two-thirds of the variation ($R^2 = 65\%$). The number of 'major' ancillaries (such as piped ditches, culverts and water supply) was found to have a significant influence upon total costs. Schemes with a large ancillary component were therefore excluded from subsequent analysis (this accounted for 9 schemes).

In order to carry out a Multiple Regression on cost per hectare it was necessary to derive some parameter to represent 'region' in the equation. For this purpose a Multiple Classification Analysis was carried out to find the mean cost per hectare of systematic schemes in each of 5 agro-climatic regions have taken into account the influence of permeable fill. These were then divided by the Grand Mean to provide a weighting index. This method is equivalent in effect to using 'Dummy Variables'. The following indices were computed:

TABLE VI.5

Regional Weighting Indices (from the present data)

Region	Index
Staffs	1.40
Gloucs	0.64
Worcs	0.85
Salop	1.29
Leics	1.02
Notts	0.80

These figures were compared with values estimated from national statistics (Table VI.6) and, allowing for the different spatial units used, the comparison appears to be very good.

TABLE VI.6

Regional Weighting Indices (based on national statistics)[1]

MAFF Division	Index
Crewe	1.3
Gloucester	0.8
Worcester	0.9
Shrewsbury	1.2
Northampton	0.8
Nottingham	0.8

Having found that region was one of the main determinants of drainage cost, it was necessary to examine the interaction between region and in particular, the effect of permeable fill on average cost per hectare. An Analysis of Variance, considering region and the use of permeable fill showed the interaction to be not significant at the 5% level.

1. See Appendix IV.C.

A Stepwise Multiple Regression was carried out on the total cost per hectare. Variables were included in the equation if an analysis of variance showed them to be significant at the 5% level. The resultant equation contains 4 variables, each with regression coefficients significant at the 1% level. These are: the regional weighting index (see above), the use of permeable fill, the drain spacing and the number of minor (hedging and ditching) ancillaries. The equation has an R^2 value of 75%.

It would have been desirable to have had an expression without ancillaries. However, a large number of schemes do involve either hedge removal or ditch clearance, or both, and to exclude these from the analysis would have drastically reduced the sample size. By setting the variable accounting for ancillaries to zero a predicted cost, excluding hedging and ditching costs can be computed.

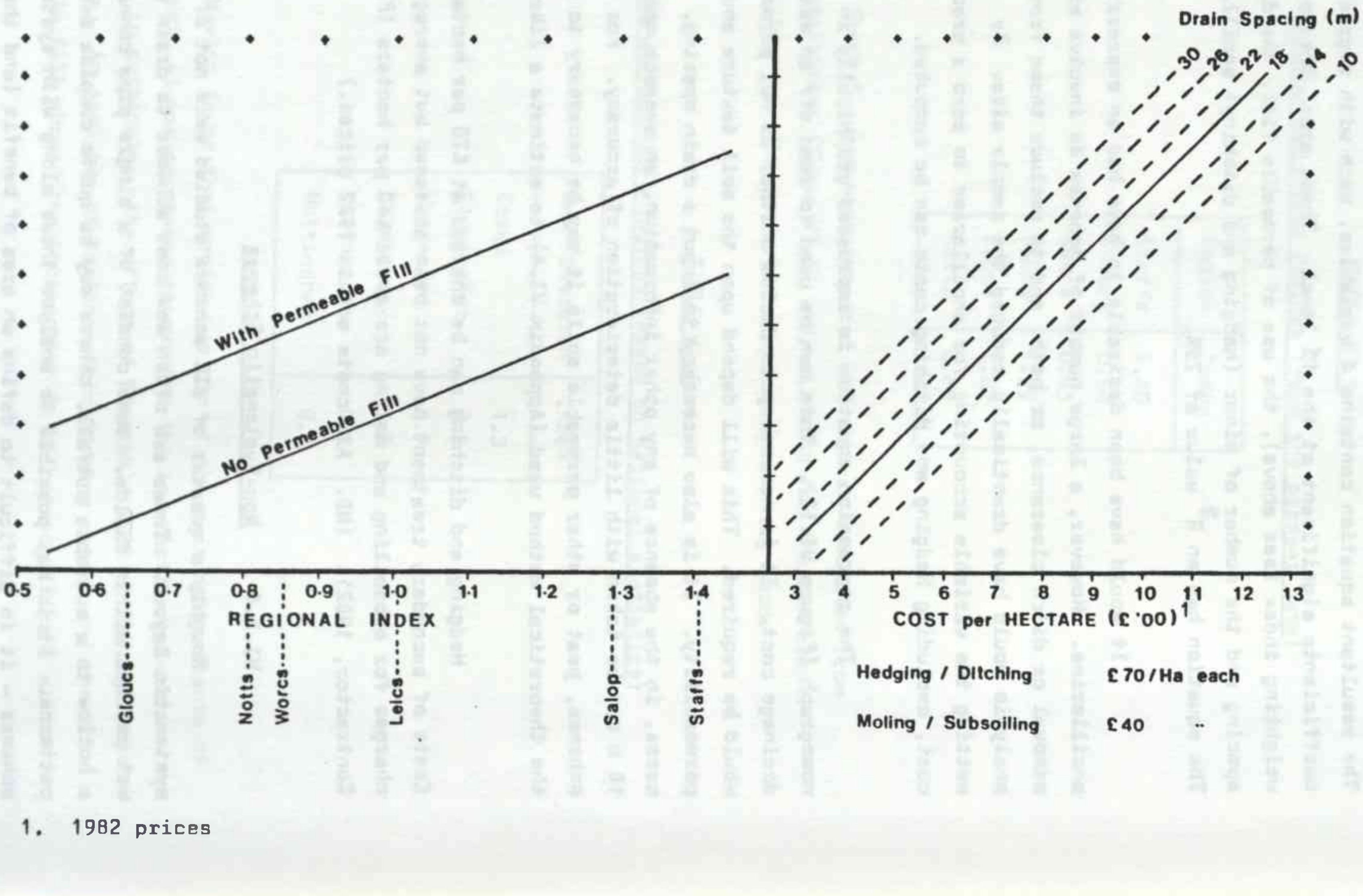
The regression equation is expressed graphically in the nomograph (Figure VI.12). This can be used to read off an estimated drainage cost. It is necessary to decide whether or not permeable fill would be required. This will depend upon the soil texture and subsoil permeability. It is also necessary to input a drain spacing. In most cases, in the absence of any other information, an average spacing of 18 m can be taken with little deterioration of accuracy. For moling schemes, peat or other permeable soils it may be necessary to refer to the theoretical method used (Appendix VI.A) to estimate a likely spacing.

Hedging and ditching can be charged at £70 per hectare each. Costs of secondary treatment have not been assessed but average contractor charges for subsoiling and moling are about £40 per hectare (Farm Contractor, 1982). (NB. All costs are in 1982 prices.)

VI.3.4 Non-Systematic Schemes

Roughly a quarter of all schemes studied were not of systematic layout. These are often low cost schemes to drain small wet patches within fields. Some consist of a single pipe connecting a hollow to a suitable outfall, others may be quite complex dendritic patterns. It is not possible to analyse these along with systematic schemes - it is difficult to define an area of benefit (and therefore a cost per hectare) and costs are likely to be higher as more manual work is involved. For the present exercise any cost estimate based on length of pipe would be useless as a detailed survey would be necessary to decide what area needs draining and the length of work

Fig VI.11 ESTIMATION OF UNDERDRAINAGE COST



1. 1982 prices

required. A cost estimate based upon a systematic layout reduced according to area is likely to be as good a method as any.

VI.4 DRAINAGE CONTRACTOR SURVEY

A survey was undertaken of drainage contractors who had been identified from MAFF records as operating in the various benefit areas. Twelve contractors were interviewed, personally or by telephone.

A consistent approach to drainage design was found from all the contractors surveyed regardless of area. The main design features may be summarized as follows:

(a) Drain Spacing:

The range of spacings was between 15 m and 20 m regardless of soil type. A spacing of 20 m, equivalent to one chain in Imperial units, was habitually used in clayey soils by many contractors.

(b) Drain Depth:

This varied with soil type. For clay soils the range of depths used was 0.8 m to 1 m. For lighter soils depths of 1 m to 1.2 m were used. For peat soils the largest depth possible given outfall and topographic conditions was used. This was generally 1.4 m.

(c) Permeable Fill:

This was used in clay soil situations and usually would be brought to within 350 mm of the soil surface.

(d) Secondary Treatments:

Mole drainage was not widely used but subsoiling was a regular practice incorporated into the drainage installation for all mineral soils.

All except one of the contractors surveyed undertook the bulk of their own design work, making only small use of Ministry advisers, and basing their designs on their own experience. The other contractor preferred to use a surveyor with laser equipment. All contractors were familiar with the MAFF guidelines for workmanship and materials and used the MAFF recommended pipe sizing methods.

Most contractors tended to cost their schemes by the length of pipe that had been installed, taking account of pipe size and any special outfall structures. Competition for work seemed to increase towards the lower reaches of both the River Trent and the River Severn.

This survey supports the findings from the MAFF drainage files and confirms that field drainage design as practiced in these benefit areas is a traditional art. In comparison with the theoretical approach it is seen that very safe designs tend to predominate. Spacings of drains tend to allow a very rapid removal of drainage water from the field.

The questionnaire used is reproduced in Appendix VI.D.

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APPENDIX VI.A

A THEORETICAL METHOD FOR ESTIMATING THE DRAIN SPACING FOR UNDERDRAINAGE IN BENEFIT AREAS

VI.A.1 INTRODUCTION

The cost of field drainage depends on the intensity of the underdrainage system installed. Current practice relies on local experience and custom. With the abandonment of prior approval for drainage schemes, the decision concerning the intensity of drainage is largely in the hands of the contractor.

There is little evidence that objective scientific methods are applied to drainage design in the U.K. However, this is not to imply that current drainage practice gives poor results, rather there is a tendancy to overdesign.

These design charges and supporting data are intended to give an objective approach to drainage design.

VI.A.2 DRAINAGE CRITERIA

Drainage design requires various site specific parameters to be quantified. These are:

(i) The hydraulic conductivity of the soil (K).

(ii) The depth to the unconfined aquifer (D_o).

(iii) The rainfall input to the system (q).

In drawing up this method it has been assumed that the maximum height of the water table is 0.5 m above the drains, except in the case of peat soils where a height of 0.2 m was used.

For permeable soils the classic approach proposed by Hooghoudt (1940) was used (see Figure VI.A.1). For heavy

Fig VI-A.1 DRAINAGE DESIGN FOR A DEEP PERMEABLE SOIL

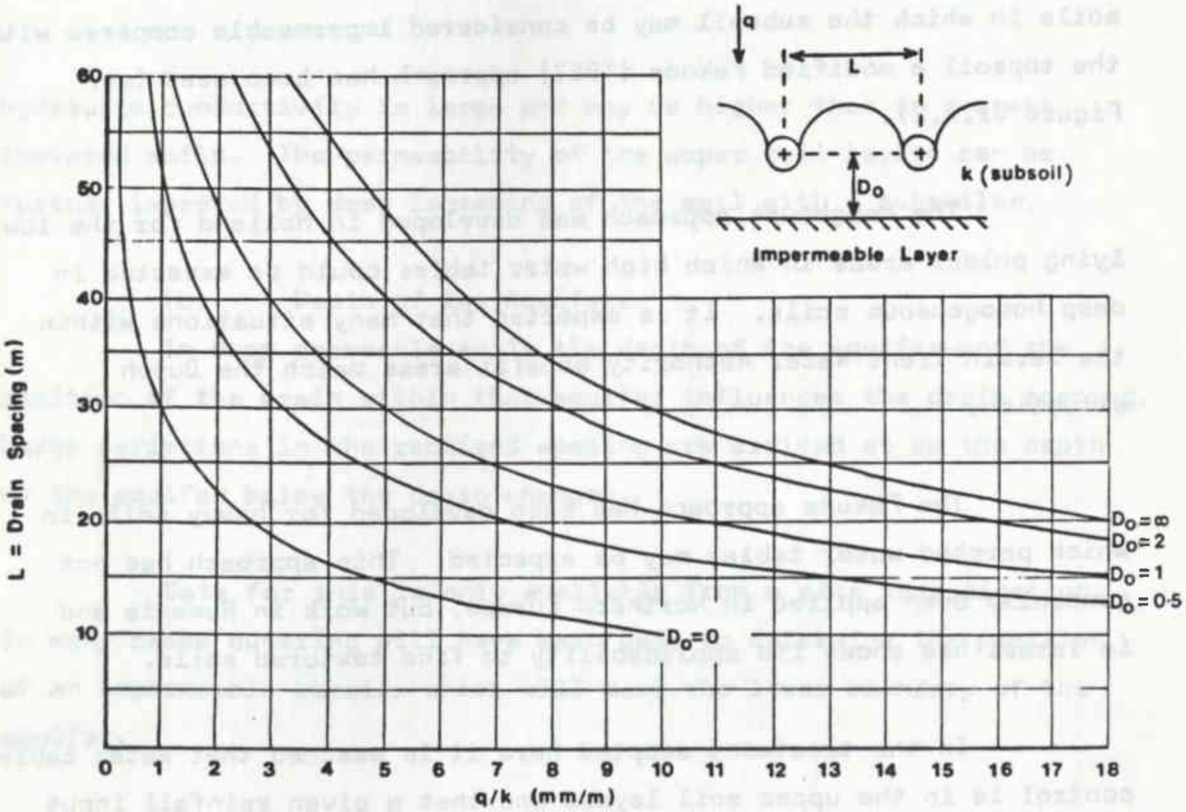
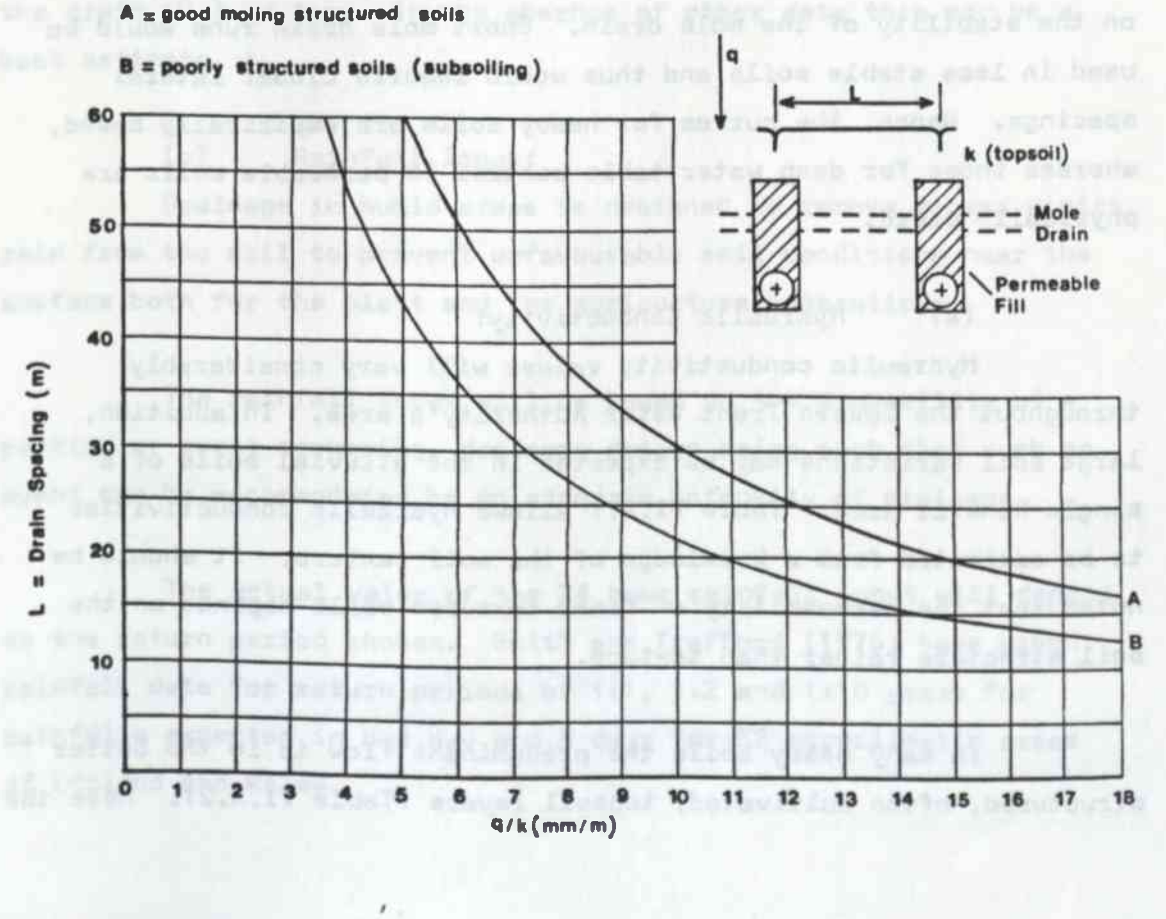


Fig VI-A.2 DRAINAGE DESIGN FOR A SHALLOW, FINE TEXTURED SOIL

A = good moling structured soils

B = poorly structured soils (subsoiling)



soils in which the subsoil may be considered impermeable compared with the topsoil a modified Fakuda (1957) approach has been used (see Figure VI.A.2).

The Hooghoudt approach was developed in Holland for the low lying polder areas in which high water tables could be expected in deep homogeneous soils. It is expected that many situations within the Severn Trent Water Authority benefit areas match the Dutch situation.

The Fakuda approach has been developed for heavy soils in which perched water tables may be expected. This approach has not generally been applied in Northern Europe, but work in Rumania and in Israel has shown its applicability to fine textured soils.

In the treatment adopted here it is assumed that water table control is in the upper soil layers and that a given rainfall input is discharged within 24 hours. The curves have been derived from the Miers system by making assumptions about soil structure and hydraulic conductivity in the benefit areas under different rainfall conditions. In physical terms the spacing of laterals is dependent on the stability of the mole drain. Short mole drain runs would be used in less stable soils and thus would require closer lateral spacings. Hence, the curves for heavy soils are empirically based, whereas those for deep water table control in permeable soils are physically based.

(a) Hydraulic Conductivity:

Hydraulic conductivity values will vary considerably throughout the Severn Trent Water Authority's area. In addition, large soil variations may be expected in the alluvial soils of a single benefit area. Table VI.A.1 allows hydraulic conductivities to be estimated from a knowledge of the soil texture. It should be noted that the permeability of finer textured soils depends on the soil structure rather than texture.

In many heavy soils the predominant flow is in the better structured, often cultivated, topsoil layers (Table VI.A.2). Here the hydraulic conductivity is large and may be higher than in coarser textured soils. The permeability of the upper soil layers can be further improved by deep loosening of the soil with a subsoiler.

(b) Depth of the Aquifer:

In deep permeable soils the depth of the aquifer and the position of the drain within that aquifer influences the drain spacing. Large variations in the required spacing are arrived at as the depth of the aquifer below the drain changes.

Data for this is only available from a site investigation. In many cases augering will have been used to determine the position of an impermeable barrier which will mark the lower boundary of the aquifer.

It is common for augering to take place to a depth of 2 m only. If no impermeable layer is found within this depth the impermeable layer (D) may be taken as being at 2 m depth. For drains placed at 1 m depth this gives a depth to the impermeable layer below the drain (D_o) as 1 m. In the absence of other data this may be a best estimate.

(c) Rainfall Input:

Drainage in humid areas is designed to remove excess winter rain from the soil to prevent unfavourable soil conditions near the surface both for the plant and for agricultural operations.

The rainfall input will be based on the probability of a particular event occurring, drainage design being such that such an event can be accommodated by an adequate intensity of drainage.

The actual value of the 24 hour rainfall input will depend on the return period chosen. Smith and Trafford (1976) have given rainfall data for return periods of 1:1, 1:2 and 1:10 years for rainfalls expected in one day and 5 days for 52 agroclimatic areas of England and Wales.

Figure VI.A.3 shows the agroclimatic areas as an overlay related to the Severn Trent Water Authority's divisions. Table VI.A.3 gives the rainfall data proposed for these agroclimatic areas for 2 broad categories of soil - deep permeable soils and heavy soils on which some form of secondary treatment is installed, either mole drainage and/or subsoiling.

For most benefit areas a 1:1 or 1:2 year return period rainfall figure should be chosen. Only where very high value, excess water sensitive, crops are to be grown should a higher return period be chosen.

VI.A.3 DRAINAGE DESIGN

There are 6 factors to be considered when designing a field drainage scheme, none of which can be considered independently. These are:

(i) Drain spacing

(ii) Drain depth

(iii) Drain layout

(iv) Drain size

(v) Filters and permeable fill

(vi) Secondary treatments

(a) Drain Spacing:

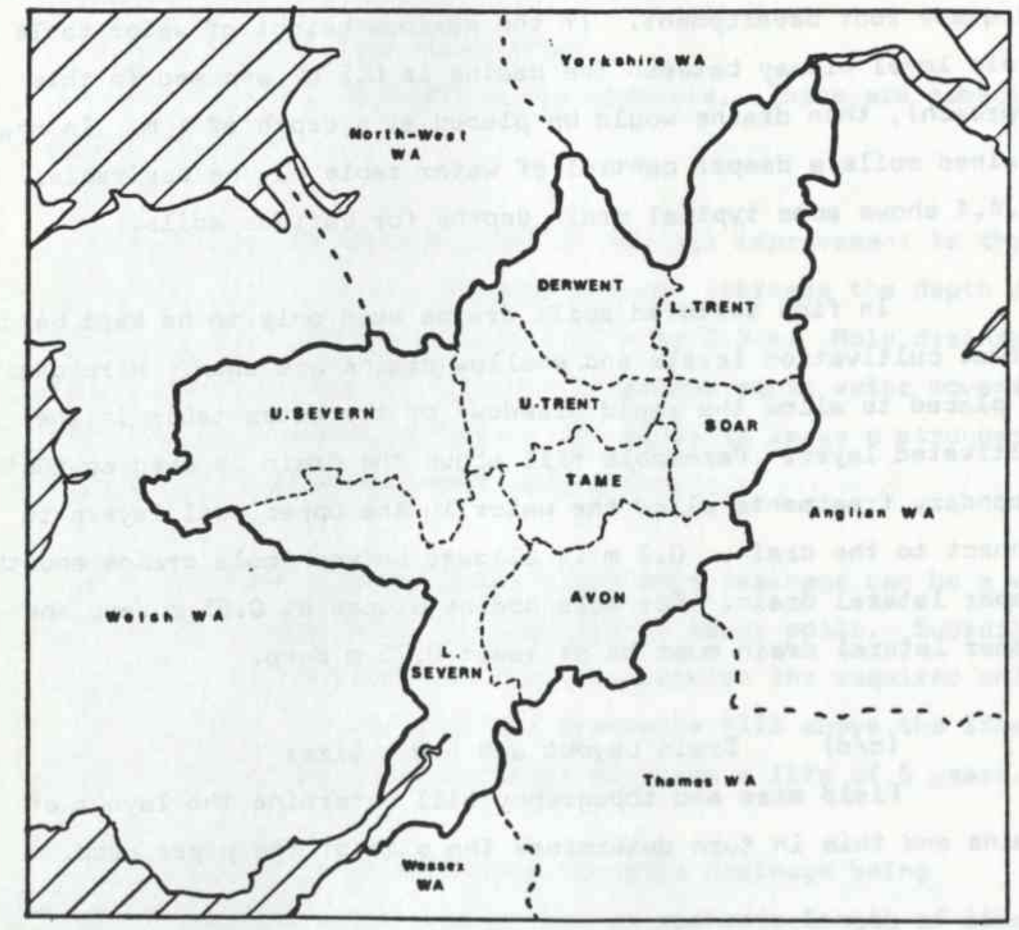
Drain spacing requires the inputs already outlined in section VI.A.2.

(b) Drain Depth:

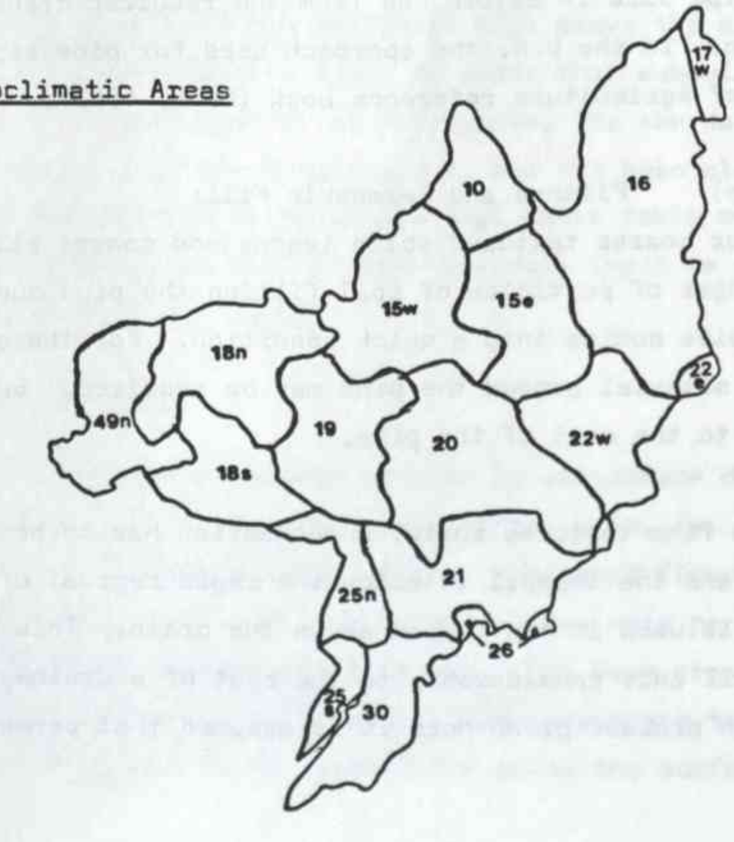
The depth to which drains are placed depends on soil factors, hydraulic conductivity and available water holding capacity, on crop factors and on outfall availability. It will also be influenced by the drainage machine.

FIGURE VI.A.3

(a) Severn Trent Water Authority : Land Drainage Divisions



(b) Agroclimatic Areas



It is generally recognized that in deep permeable soils the water tables should be kept below 0.5 m from the soil surface to allow adequate root development. If the maximum height of water table above drain level midway between the drains is 0.5 m (assumed in this approach), then drains would be placed at a depth of 1 m. In coarse grained soils a deeper control of water table may be desirable. Table VI.A.4 shows some typical drain depths for various soils.

In fine textured soils drains need only to be kept below normal cultivation levels and shallow drains are used. Here drainage is placed to allow the rapid drawdown of the water table in the cultivated layer. Permeable fill above the drain is used so that secondary treatments allow the water in the upper soil layers to connect to the drain. 0.2 m is allowed between mole drains and the deeper lateral drain. For mole drains placed at 0.55 m deep the deeper lateral drain must be at least 0.75 m deep.

(c/d) Drain Layout and Drain Size:

Field size and topography will determine the layout of drains and this in turn determines the size of the pipes used.

Pipe size is determined from the required transport capacity of the drain. In the U.K. the approach used for pipe size is given in a Ministry of Agriculture reference book (MAFF, 1982).

(e) Filters and Permeable Fill:

For coarse textured soils (sands and coarse silts) there may be a danger of particles of soil filling the pipe due to the soil around the pipe coming into a quick condition. For these soils a filter wrap material around the pipe may be required. Such materials can add 50% to the cost of the pipe.

In fine textured soils, a connection has to be made between the subsoil and the topsoil to allow the rapid removal of water. A gravel pack is used in the trench above the drain. This use of permeable fill adds considerably to the cost of a drainage scheme. In the design process given here it is assumed that permeable fill is used above the drain in all fine textured soils.

(f) Secondary Treatments:

Two secondary treatments are possible. These are subsoiling and/or mole drainage.

Effective subsoiling gives an overall improvement to the hydraulic conductivity of the topsoil and can increase the depth of more permeable soil, typically from 0.20 m to 0.3 m. Mole drainage provides an unlined drain at 0.55 m. It allows rapid water movement from the topsoil to the lined drain. It tends to leave a stronger surface for trafficking than does subsoiling.

A combination of subsoiling and mole drainage can be a very effective means of improving the drainage of heavy soils. Subsoiling alone gives some improvement but does not provide the required unlined drain. Mole drains connect with the permeable fill above the lined lateral drain and in good moling soils may have a life of 5 years.

Not all soils are suitable for mole drainage being incapable of holding a mole channel for an economic length of time. In such cases the depth of the permeable fill above the drain can be increased, with an increase in cost, in order that subsoiling can connect with it. Determination of the spacing for the deeper lateral drains where there are mole drains above, has not been clearly defined. The approach adopted here is to assume that water table control is in the upper soil layers and that a given rainfall input is discharged from this layer within 24 hours.

VI.A.4 CROP FACTORS

The water table control offered by subsurface drains is intended to allow the removal of excess winter rain, ie. that amount of rain in excess of evapotranspiration. Published figures (Smith and Trafford, 1976) show that this excess winter rain period lasts in general from October to February or March. For most crops the required rooting depth is small during this period and the proposed control of water tables to at least 0.5 m below the surface in permeable soils should be adequate for arable crops and grassland found in the benefit areas.

Without a rainfall input water table levels drop to the level controlled by ditches or river levels. As these levels should be below subsurface drain level adequate rooting depth should be available to all crops through the deficit growing season, March to October.

Of more importance is trafficability over soils in the excess rainfall period. In these cases it would seem that where water tables are controlled to below 0.5 m from the surface, soil strength is adequate both for implements and tractors and to resist poaching by cattle.

VI.A.5 USE OF THE DESIGN CHARTS

Case A:

Field in benefit area - agroclimatic area 15 w.

Soil texture - sandy loam, no impermeable barrier found in top 2 m.

Drains to be placed at 1.2 m depth.

∴ Depth to impermeable layer (D_o) taken as 2 - 1.2 = 0.8 m

From Table VI.A.3 - rainfall figure for arable crop taken:

q = 11 mm/day

Hydraulic conductivity of soil is known: K = 1.5 m/day

∴ q/K = 11/1.5 = 7.3 mm/m

From Figure VI.A.1 - design chart for deep permeable soil -

Find q/K = 7.3 mm/m on horizontal axis.

Move vertically to a point between D curve for D_o = 1 and D_o = 0.5 extrapolating for D_o = 0.8.

Read horizontally to vertical axis to find required drain spacing.

In this case L = 22 m

Case B:

Fine textured heavy clay soil in agroclimatic area 15 w.

Suitable for mole drainage.

Drains to be placed at 0.8 m depth.

Occasional subsoiling to be practiced - moderately developed structure.

From Table VI.A.3 - rainfall figure for arable land: q = 28 mm/day

Hydraulic conductivity of cultivated layer: K = 2 m/day

∴ q/K = 14 mm/m

From Figure VI.A.2 - design chart for heavy soil -
Find 14 mm/m on horizontal axis, move vertically to position between curve A and B, a position related to soil structure and subsoiling.
Read horizontally to the vertical axis and find required drain spacing.

∴ Drain spacing L = 20 m (+ mole drainage at 2 m spacing)

VI.A.6 CONCLUSIONS

The design charts given here allow the drain spacing for a range of climatic and soil conditions to be estimated.

A limitation to the use of the charts is imposed by the data that is available for the site in question. This is particularly so for the values of hydraulic conductivity and the depth of the aquifer for which the computed spacing is very sensitive.

The charts will allow the possible range of drainage spacings to be estimated, allowing an objective comparison with practice or proposal to be made.

The use of this design procedure allows the major components of a drainage scheme to be identified. If field shape and topography are known then this can lead to a proposed bill of quantities from which cost estimates might be made.

It is hoped that future work will allow a partitioning of costs for field drainage schemes. With this information the sensitivity of the design approach in economic terms can be made.

TABLE VI.A.1

Hydraulic Conductivity, K (m/d), of Subsoils by Textural Class

Soil Texture	K m/d	
	Suggested K	K range
ZyC (if well structured)	0.5	0.1 - 1.0
SyC (if well structured)	0.5	0.1 - 1.0
ZyCL	1.2	0.1 - 10.0
SyCL	1.5	0.3 - 10.0
SyL	2.0	0.3 - 10.0
All other loams	2.0	-
S	2.5	1.0 - 10.0
P	5.0	1.0 - 10.0
SyP or peat over sand or gravel	10.0	-

TABLE VI.A.2

Hydraulic Conductivity, K (m/d), of Topsoils by Textural Class

Soil Texture	Suggested K (m/d)
All clays	2.0
CL, ZyCL or SyCL	2.5
All other loams	3.0

TABLE VI.A.3

Agroclimatic Data

Area	Return Period					
	Heaviest Rainfall Expected in 5 Days ÷ 5			Heaviest Rainfall Expected in 1 Day		
	1:1 yr	1:2 yr	1:10 yr	1:1 yr	1:2 yr	Mean Annual Rainfall
10	15	17	21	36	41	1151
15w	9	11	14	25	28	840
15e	8	9	12	20	25	714
16	7	8	11	18	23	622
18n	9	10	12	21	26	763
18s	10	11	11	24	29	845
19	7	9	11	18	22	700
20	8	9	11	19	23	695
21	7	9	11	18	22	660
22w	7	8	10	19	22	661
25n	10	11	14	22	27	627
25s	13	15	18	29	34	575
26	8	10	13	21	25	726
30	9	10	13	22	27	775
	mm/day			mm/day		

Notes:

For grassland take 1:1 or 1:2 return period.

For arable crops take 1:2 return period.

For high value short season crops take a value between 1:2 and 1:10 return period.

For coarse textured soils it is suggested that values of rainfall are taken from the first 3 columns which gives the average daily rainfall rate calculated from the heaviest rainfall expected in a 5 day period.

Table VI.A.3 continued:

For fine textured soils in which perched water tables are expected it is suggested that values are taken from the fourth and fifth columns which five the heaviest rainfall expected in one day.

TABLE VI.A.4

Drain Depth

Soil Texture:	
Clay soil	0.75 - 0.9 m
Silty soil	0.8 - 1.0 m
Sandy soils	0.9 - 1.4 m
Peat soils	1.0 - 1.4 m

Note:
There may be topography and machine constraints on placing drains at depths in excess of 1.5 m.

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APPENDIX VI.B

THE CALCULATION OF DRAINAGE COST INDICES

VI.B.1 INTRODUCTION

For the purposes of data analysis, in particular of the 'drainage files', it is necessary to reduce all 'actual' drainage costs to a constant price base. Generally, within the STWA project the base date to be used is September 1982.

VI.B.2 DATA SOURCES

A number of cost indices are published and are of varying relevance to underdrainage. Those considered here are; the Retail Price Index (all items) (RPI), the Cost of New Construction Index (CNCI), and the Agricultural Inputs Index (all goods and services) (AII). There are few sources of trends in drainage costs, the most complete being the statistics published by FDEU (Armstrong, 1978, 1980). Average drainage costs can be calculated from data given on area drained and total cost for the period 1971 to 1979 but these need to be extrapolated to cover the period 1960 to 1983.

VI.B.3 METHOD AND RESULTS

The data on average cost of 'normal' underdrainage (ie. where more than 75% of the cost was on underdrainage) were converted into an index using 1979 as a base year (Table VI.B.1). These were then compared with the RPI, CNCI and AII over the same period using the same base (Table VI.B.2). A cursory glance suggests that the drainage index bears more resemblance to the RPI than either other index and this is confirmed by the calculation of correlation coefficients. The correlation coefficient for drainage Vs RPI is 0.994 (that for the AII is next best at 0.963).

It is pertinent to note that the index for drainage cost is consistently below the RPI if 1979 is taken as a base. This suggests that drainage was relatively more expensive in 1979 than earlier in the 1970's and any extrapolation beyond 1971 and 1979 will reflect this relativity.

TABLE VI.B.1

Average Cost of 'Normal' Underdrainage (England and Wales)

Year	Cost (£/ha)	Index (1979 = 100)
1979	469	100
1978	394	84.0
1977	337	71.8
1976	301	64.2
1975	262	55.9
1974	214	45.6
1973	192	40.9
1972	167	35.6
1971	157	33.5

Source: Based on Armstrong (1978, 1980)

TABLE VI.B.2

Comparison of Indices (1979 = 100)

Year	RPI (Sept)	CNCI	AII	Drainage
1979	100	100	100	100
1978	85.9	81.4	90.6	84.0
1977	79.6	73.3	87.9	71.8
1976	68.8	67.7	84.5	64.2
1975	60.2	62.1	65.7	55.9
1974	47.6	52.8	54.0	45.6
1973	40.6	91.3	47.6	40.9
1972	37.1	73.9	39.1	35.6
1971	34.8	66.5	35.6	33.5

Given the close correlation between the Drainage Index and the RPI it was decided to extrapolate the Drainage Index to 1960 and 1983 using the RPI. Post-1979 the Index follows the RPI; pre-1971 a line is drawn from the 1971 Drainage Index parallel to the RPI. Although this is maintaining a fixed price relativity, inflation rates in the 1960's were generally low and the error is likely to be small.

The Retail Price Index (all items) and the extended Drainage Index are shown in Table VI.B.3 below.

TABLE VI.B.3

Retail Price Index (all items) for September and 'Extended' Drainage Index (September 1982 = 100)

Year	Retail Price Index (Sept)	Drainage Index	RPI Monthly Average
1983	105.1	105.1	-
1982	100.0	100.0	100.1
1981	93.2	93.2	91.4
1980	83.6	83.6	81.7
1979	72.2	72.2	69.3
1978	62.0	60.6	61.1
1977	57.5	51.9	56.4
1976	49.7	46.3	48.7
1975	43.5	40.3	41.7
1974	34.4	32.9	33.6
1973	29.3	29.5	28.9
1972	26.8	25.7	26.5
1971	25.1	24.2	24.8
1970	22.8	22.0	22.6
1969	21.3	20.5	21.3
1968	20.3	19.6	20.2
1967	19.2	18.5	19.3
1966	18.9	18.2	18.8
1965	18.2	17.5	18.1
1964	17.3	16.7	17.3
1963	16.7	16.1	16.7
1962	16.4	15.8	16.4
1961	15.7	15.1	15.7
1960	15.2	14.7	15.2

Sources:

Armstrong (1978) : 'A Digest of Drainage Statistics, 1971-78'. FDEU Tech. Rep. 78/7, HMSO.

Table VI.B.3 continued:

Armstrong (1980) : 'Drainage Statistics, 1978-80. FDEU Tech. Rep. 80/1, HMSO.

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APPENDIX VI.C

THE CALCULATION OF REGIONAL DRAINAGE COST INDICES FROM NATIONAL STATISTICS

VI.C.1 OBJECTIVE

The aim was to examine published statistics on field drainage installations to identify spatial (regional) variations in drainage costs and so derive a Regional Weighting Index.

VI.C.2 DATA SOURCES

The only available national statistics were those published by the Field Drainage Experimental Unit (Armstrong, 1978, 1980). These quote data for the total area drained, total cost of drainage and percentage of schemes using permeable fill by MAFF Division for the period 1971-79.

VI.C.3 METHOD AND RESULTS

The total cost of underdrainage (for 'normal' schemes, ie. where more than 75% of the cost is on underdrainage) was divided by the total area drained to produce an average cost per hectare for each division for each year. These figures were converted to a common September 1982 price base using the method described in Appendix VI.B. These were averaged for each division.

Although this shows the regional trend in the average cost per hectare, it conceals the fact that the percentage of scheme with permeable fill in each division varies from an average of 24% in Crewe Division to 93% in Nottingham Division. It is necessary therefore to modify the average costs to account for variations in the use of permeable fill. In the absence of more specific data, it was assumed that permeable fill adds an extra 50% to the cost per hectare. The average cost was calculated, therefore, from the following:

$$C' = \frac{\bar{C}}{1.5\,p + (1 - p)}$$

where C' = the cost of a scheme without permeable fill

$\bar{C}$ = mean cost per hectare

p = % of schemes using permeable fill

The average cost of schemes using permeable fill is $1.5\,C'$.

The results are summarized in Table VI.B.1 below.

TABLE VI.B.1

Results for 1971-79

MAFF Division	Mean Cost/ Ha (£)[1]	% Schemes With P.F.[2]	Cost/Ha No P.F. (£)	Cost/Ha With P.F. (£)	Index
Crewe	800	24	714	1071	1.3
Shrewsbury	791	40	659	988	1.2
Nottingham	677	93	462	693	0.8
Northampton	672	93	460	690	0.8
Worcester	667	57	519	778	0.9
Gloucester	633	80	452	678	0.8

Notes:

(1) All costs are for September 1982.

(2) P.F. = Permeable Fill

APPENDIX VI.D

DRAINAGE CONTRACTOR QUESTIONNAIRE

Name ....

Area ....

1. What are the main soil types in your area? Please give details of your usual practice for each type in the space provided below. Continue overleaf if necessary.

	1	2	3
(a) Soil type			
(b) Spacing			
(c) Depth			
(d) Permeable fill?			
(e) Secondary treatment?			
(f) Special features*			

*Please give details of any particular problems you commonly have to deal with, such as use of filter wrapped pipe to exclude fines, use of close spacings to deal with incoming groundwater, etc. There is more space on the back of the questionnaire.

2. Is your practice based on:

(a) Your experience? ☐

(b) Local practice? ☐

(c) Ministry guidelines? ☐

(d) Other? (please specify) ☐

....

....

....

3. Do you always use your own drainage design? Give the percentage each of the source of design.

(a) Your own ... %

(b) Consultant/surveyor ... %

(c) Farmer's own ... %

(d) Other (please specify) ... %

....

....

....

4. How do you cost a proposed drainage scheme?

(a) By area? ☐

(b) By length of work? ☐

(c) By costing materials to be used? ☐

(d) Other? (please specify) ☐

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ANNEXE VII

AGRICULTURAL SECTOR REVIEW

ANNEXE VII

AGRICULTURAL SECTOR REVIEW

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List of Abbreviations

CAP	Common Agricultural Policy
EEC	European Economic Community
FCGS	Farm Capital Grant Scheme
FHDS	Farm and Horticulture Development Scheme
FMS	Farm Management Survey
GDP	Gross Domestic Product
MAFF	Ministry of Agriculture, Fisheries and Food
MLC	Meat and Livestock Commission
MMB	Milk Marketing Board
NFU	National Farmers Union
RPI	Retail Price Index
STWA	Severn Trent Water Authority
UK	United Kingdom of Great Britain and Northern Ireland

ANNEX VII

AGRICULTURAL SECTOR REVIEW

VII.1 INTRODUCTION AND SCOPE

This Annex provides a brief review of the background to recent agricultural policy, examines in general terms the major features of and changes in the agricultural sector in order to provide a context for the examination of drainage investment and benefit uptake. In summary agricultural policy has used pricing and subsidies to persue an expansionist policy justified in terms of increasing self sufficiency in temperate foods. In response agricultural output has continually increased, whilst the sector has undergone rapid structural change involving a move to specialisation, larger farms, and a much reduced agricultural workforce. In spite of Government support aggregate increasing costs have reduced aggregate incomes, with the livestock sector being hardest hit. The intensification of farming, in which land drainage has played an important role (see Annexe VI), has been a means of protecting farm profitability.

The Annex, drawing on the results of the farm survey, provides a brief statement of farming systems in the STWA scheme areas.

VII.2 AGRICULTURAL POLICY FRAMEWORK

VII.2.1 Agriculture's Contribution to the Economy

Agriculture's contribution to the UK economy is summarised in Table VIII. Agriculture's relatively modest share of gross domestic product (GDP) belies its important role in an otherwise predominantly industry oriented economy. The contribution of agriculture can be generalised in terms of:

- Food production; security of supply at reasonable prices
- Balance of payments contribution

- Direct contribution to GDP; value added market contribution, forward and backward linkages, capital formation
- Rural resource use; land management, employment, rural incomes, the rural economy
- Food Aid

In the context of the UK the sector accounts for 2.2% of GDP (8.1% for agriculture and allied (including food industries)), 2.7% of total capital formation, and 2.8% of total employment. Agriculture has demonstrated an important import saving role in the face of rising import prices, whilst exports earnings have also increased. The UK is now over 76% self sufficient in temperate-type food items, compared to 50% in 1962, and food prices have on average inflated at less than the retail price index for the 1972-82 period as a whole.

VII.2.2 Special Features of the Agricultural Sector

At one time, perhaps the agricultural sector conformed more than any other to the economist's model of perfect competition: many producers and many consumers all operating independently and expressing themselves freely in the market square. In some segments of the industry, particularly horticulture, the laissez faire rule may still apply, but for the most part of the sector has been a major arena for Government intervention.

The justifications for Government involvement arise out of the particular features of the agricultural sector, interacting with Government macro-economic policy subjectives.

The particular features of agriculture relate to problems with demand;

(i) income in elasticity of demand for agricultural produce: bellies and food consumption are limited such that agriculture's (and particularly the farming sectors) relative share of economic growth will inevitably decline

(ii) price inelasticity of demand: demand is not very responsive to price; big falls in prices are needed to mop up extra supplies and vice versa;

and problems with supply;

(iii) supply is subject to unpredictable biological processes

(iv) supply is price inelastic: producers are not very responsive to price changes, especially in a downward direction due to limited resource mobility. Declining real prices may encourage extra output to maintain revenues and net income, which further depresses prices.

The result of these features can be low and variable produce prices and low and variable farm incomes and, if not a depressed, then an uncertain farming sector . Because of this, Governments intervene to protect farm incomes, secure food supplies and boost agriculture's supportive role in the economy. A Government can do this by a number of means, involving commodity price support, grants/subsidies for improvements, aids for structural change (eg retirement grants), and assistance to particular less-favoured areas. In Britain all of these measures have been employed.

VII.2.3 Agricultural Policy in the UK

Following various ad hoc policy incursions, including the infamous Corn Laws, the earliest comprehensive measures were the Agricultural Marketing Acts of 1931 and 1933 which established statutory Producer Marketing Boards to improve marketing and regulate the market to effect improved producer prices.

The most important legislation, pre EEC CAP, was the 1947 Agricultural Act which undertook to 'promote a stable and efficient industry' producing 'such part of the nation's food as is in the national interest' at 'minimum prices', 'consistent with proper remuneration and living conditions to farmers and workers', 'and adequate return on capital invested.' The main concern post war was with maximising production, saving imports, removing rationing, and continuing the pursuit of a cheap food policy. Following

TABLE VII.1

Agriculture's Contribution to the U.K. Economy

Calendar years

	Average of 1971–73	1978	1979	1980	1981	1982 (provisional)
Agriculture's contribution to gross domestic product (*a*) £ million ..	1 550	3 417	3 744	4 134	4 601	5 420
percentages ..	2.7	2.3	2.3	2.1	2.2	..
Agriculture's share of gross fixed capital formation (*b*) £ million ..	342	894	1 002	1 050	962	1 150
percentages ..	2.8	3.0	2.9	2.7	2.4	2.7
Manpower engaged in agriculture (*c*) ('000)	723	677	661	651	637	633
Percentage of total civilian manpower engaged in all occupations (*c*)	3.0	2.7	2.7	2.7	2.8	2.8
Imports of food, feed and alcoholic beverages (*d*)						(Jan.–Sept.)
£ million ..	2 417	6 289	6 816	6 519	6 913	5 699
Import volume index (1975=100)..	103.7	99.2	103.2	98.6	99.2	104.5
Import price index (1975=100)	55.3	141.1	145.5	150.4	158.5	169.8
Exports of food, feed and alcoholic beverages (*d*)						(Jan.–Sept.)
£ million ..	658	2 725	2 697	3 055	3 391	2 539
Export volume index (1975=100)..	77.6	130.6	120.7	131.5	138.1	136.8
Export price index (1975=100)..	63.8	147.7	156.2	167.9	186.6	193.9
Consumers' expenditure on food and alcoholic beverages						(Jan.–June)
£ million ..	11 759	28 064	32 377	37 506	39 182	19 546
of which: food (*e*) £ million ..	8 784	20 602	23 530	26 353	27 748	14 334
Expenditure on food as a percentage of total consumers' expenditure ..	20.7	20.8	20.1	19.4	18.4	18.4
Value of home-produced food (*f*) as a percentage of					(estimated) 1981–1982	
All food consumed in the UK	50.1	53.1	54.5	60.5	62	
All indigenous-type food consumed in the UK..	62.3	67.0	69.0	74.8	76	

procedures set up in the 'War Ag', a review system was adopted to fix producer prices and provide input subsidies to encourage production and secure incomes. In the 1950's this procedure was formalised into a system of Deficiency Payments whereby the Exchequer paid farmers the difference between average market prices and some guaranteed minimum price deemed consistent with proper remuneration. Farm incomes were supported whilst consumers enjoyed relatively low food prices kept down by unrestricted imports.

During the late 1950's pressure from the NFU for security of guarantee was given in the 1957 act. (The Government could not reduce guarantees by more than 4% per year, 9% over three years for livestock). In 1964, standard quotas were introduced on cereals, together with minimum import prices in an attempt to limit Exchequer Liability. The 1965 National Plan encourage 'selective agricultural expansion' through productivity (rather than prices), aiming for 3½% growth for all sectors, but especially dairy, beef, cereals. The 1967 Act saw a number of structural measures for farm amalgamations, cooperatives, and retirement schemes.

The 1969 Annual Review provides an interesting insight. The selected expansion programme was to be extended to 1972/3 mainly justified in terms of import saving, with priority to cereals and beef (more of the former to feed more of the latter.) Reduced distribution of school milk made the Review authors ask whether milk output could be 'economically absorbed'. But more beef calves were likely to mean more milk. Over the 1969-73 period more emphasis was given to be given to capital investment grants including drainage, as a means of improving output.

In 1971 the Farm Capital Grant Scheme (FCGS) was introduced to provide a more comprehensive and consistent package of farm improvement measures. In 1974 a Farm and Horticultural Development Scheme (FHDS) was introduced partly encouraged by EEC funding, to assist low income but potentially viable, farms with capital investment funding and advice (see Annex VI).

Pricing policy in the early 1970's saw a shift away from deficiency payments and the preparation for accession into Europe. In 1971, import levies were applied to protect (/raise prices in) the domestic market and help finance support measures. In the early seventies the Reviews reported the generally good state of the sector, confirming that the 'expansion of efficient food production remains in the national interest', and that short term (cost squeeze) difficulties should not obscure the 'excellent long term prospects'. The 1975 White Paper 'Food from our Own Resources' further emphasised agriculture's import saving role and set 1980 targets for dairy production, sugar beet and cereals, all of which were subsequently met.

The main policy event in the 1970's was of course the substitution of the 1947 Act by the EEC Common Agricultural Policy. Whilst the objectives were similar the methods employed were very different.

CAP objectives are fivefold:

- increased agricultural productivity
- assurance of fair standards of living for farmers and workers
- stabilization of agricultural markets
- guarantee of reasonable food supplies
- reasonable food prices.

The methods employed by CAP are essentially of two types each of which is managed by a separate organisational 'Sector'. They are:

- the Guarantee Sector which protects the EEC internal common market by means of import levies and intervention buying. Variable levies are placed on imports to maintain high internal prices. If internal overproduction (in response to high prices) results in surplus, this is removed by intervention buying and disposed of by various means within and without the EEC

- the Guidance Sector which attempts to overcome poverty/ structural problems by grants and subsidies for farm improvement, cooperatives, training, and retirement incentives. Whereas at the onset it was proposed that the Guidance Sector, in that it offered the long term solution to the European small farm problem, would be the area of greatest activity and expenditure, in practice the opposite has transpired. CAP accounts for about 70% of total EEC budget expenditure. Some 96% of this goes on Guarantee (price support) measures, 4% on the Guidance programme. Milk and cereals alone account for 45% and 20% Guarantee expenditure respectively.

The purpose of this brief historical perspective has been to provide an overview of the policy framework in which to examine the justification for and performance of land drainage investments, and the nature and rate of benefit uptake. A critique of the policies are available elsewhere. (Self and Storing, 1972; Body, 1982; C.A.S., 1983). In summary, the message coming across to both farmer and nation in the last 40 years has been one of at first general and more latterly selective expansion justified in terms of agriculture's contribution to national welfare. The economic rationality of the policies are more open to debate. Only in the last year, and arising out of financial (CAP) necessity rather than any economic assessment, are there signs of actively discouraging further increases in agricultural output using combined price and quota restrictions.

VII.3 THE CHANGING PERFORMANCE AND STRUCTURE OF THE UK FARM SECTOR

VII.3.1 Land, Crop Areas, and Livestock Numbers

Table VII.2 contains crop areas and livestock numbers for the 20 year period 1962-82. The main observations are that the cropped area has fallen by some 51,000 hectares per year since 1962, although the rate since 1972 has been 36,000 hectares. There has been a rise in the cereals area, notably wheat which has increased by 45% since 1972. Root and horticultural production have declined, whilst oil seed rape has increased 20 times since 1972. The total tillage area has increased by 14% in 20 years. Cattle numbers peaked

TABLE VII.2

Crop Areas and Livestock Numbers (UK)

Crops and Grass			
000 Ha	1962	1972	1982
Wheat	913	1127	1664
Barley	1613	2288	2221
Other Cereals	673	383	145
Sub total	3199	3798	4030
Roots	480	427	395
T. Grass	2842	2357	1860
Total arable	7324	7222	6978
	5033	4997	5093
Rough grazing	7302	6655	6210
Other (farmsteads)	-	301	501
Livestock			
000 head			
Dairy cows	3290	3325	3251
Beef cows	978	1476	1397
Heifers in calf	802	954	849
Total cattle & calves	11859	13483	13275
Sheep & lambs	29498	26877	33049

in the early 1970's, since which time they have declined overall. The dairy herd has remained reasonably stable. Sheep numbers have risen significantly in recent years. In the main, these changes have been in response to changing relative output and input prices and structural response within the sector, reflecting both general economic circumstances and particular policy measures.

VII.3.2 Output

A main feature of agriculture in the last 20 years has been the almost relentless growth in output, inspite of variations in input and output prices, world recession, inflation, and credit squeezes. Figure VII.1 shows the trend in the volume of agricultural output for the UK and EC(9) since the mid 1960's. Poor weather years account for the dip in 1975 and 1976. Figure VII.2 shows the increase in production of cereals and milk which increased from 10Mt to 22Mt, and from 10Mt to 16Mt respectively over the 1960-1982 period.

The effect of these increases in production on self sufficiency, which has been a fundamental policy aim and justification, is shown in Table VII.3.

TABLE VII.3

U.K. Agricultural Commodity Production and Self Sufficiency

'000 tonnes	1962	1972	1962
Cereals:			
Wheat	3158 (44%)	4865	10258 (106%)
Barley	4976 (88%)	8936	10884 (128%)
Oats	1676 (108%)	1230	587 (101%)
Total cereals	10229 (58%)	15258	21791 (104%)
O.S. Rape	-	18	571 (95%)
Potatoes	5981 (main crop only)(97%)	6894	6818 (90%)
Sugar	821 (30%)	978	1340 (54%)
Meat:			
Beef & veal	850 (71%)	930	994 (90%)
Sheep meat	254 (42%)	230	284 (64%)
Milk:			
Butter	53 (12%)	87	214 (64%)
Cheese	112 (46%)	176	240 (71%)
Skimmed M.P.	67 (81%)	144	304 (164%)

Source: An. Reviews

(Figures in brackets indicate % Self-sufficiency.)

FIGURE VII.1 : The Volume of Agricultural Output
EC (——) & UK (----). 1975 = 100
Source: Capstick (1983)

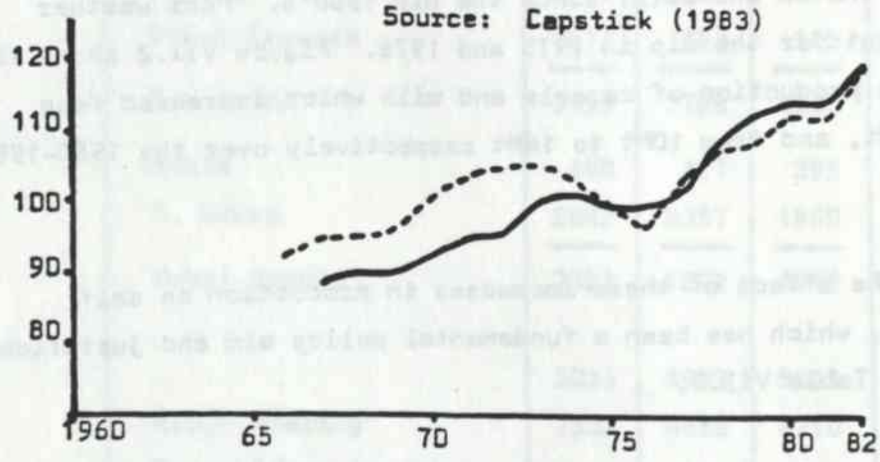
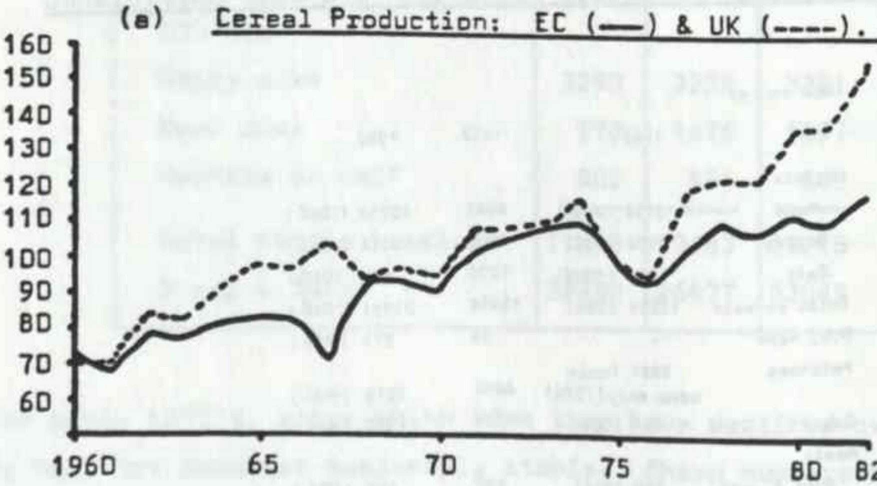
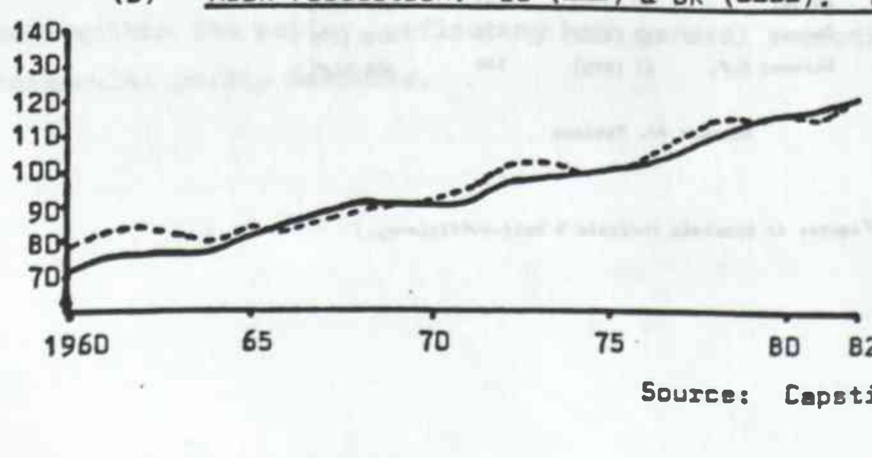


FIGURE VII.2 : Cereal and Milk Production

(a) Cereal Production: EC (——) & UK (----). 1975 = 100



(b) Milk Production: EC (——) & UK (----). 1975 = 100



Source: Capstick (1983)

VII.3.3 Yields

A major source of increased output given the marginally declining total area and livestock numbers over the last 20 years, has been that of increased yields per hectare.

Table VII.4 contains estimated yields per hectare and milk per cow per year for the period 1972-1982.

TABLE VII.4

Estimated Average Yields of Crops and Livestock Products

	Unit	1972	1978	1982
Wheat	Tonnes/ hectare	4.33	5.26	6.20
Barley	"	3.92	4.10	4.90
Oats	"	3.85	3.92	4.50
Potatoes	"	28.92	34.24	35.55
Sugar beet	"	39.2	34.70	45.00
Oilseed rape	"	2.10	2.40	3.30
Milk	Litres/ cow	3968	4618	4859

Source: Annual Reviews

Cereal yields for instance, have increased from an average 2.8t/ha in 1950 to 6.2t/ha in 1982, an average 3.8% increase per year. About 55% of this increment has been attributed to variety improvement, the balance to other factors such as improved timeliness, fertiliser and chemical applications, and drainage. Milk production has shown an average increase of about 2% per year during the last 15 years due to generally improved standards of livestock management.

VII.3.4 Prices Output and Input

The interpretation of price movements during the 1970's is complicated by a world energy crisis, affecting fertiliser and energy prices, high world market prices during 1972-4 period, inflation peaking at 25% per year, currency devaluation, and the transition to CAP pricing. The trends for output and input prices are shown in Table VII.5. Whilst producer prices have risen in money terms, once deflated by the retail price index the long term trend of decline is apparent (except the 1973-6 period of energy, world commodity shortages, and domestic dry years). Real 1982 prices were below 1972 values. Input prices excluding labour, machinery and buildings, have increased at a greater rate than output prices, particularly due to higher feed prices. An additional cost has been the high cost of borrowing since the mid 1970's. Furthermore labour and capital investment items increased by more than the RPI in the 1970's. The net effect has been a cost squeeze on farm incomes, especially since 1976.

TABLE VII.5

Farm Output and Input Price Indices 1970-82

(1975 = 100)

	1970	71	72	73	74	75	76	77	78	79	80	81	82
Farm Output Prices													
Index of Actual Prices	49	53	56	72	82	100	129	134	138	152	162	178	190
Real Prices*	91	89	89	104	102	100	110	99	94	92	82	81	80
Farm Input Prices													
Index of Actual Prices	47	52	55	71	91	100	123	142	147	165	185	204	219
Real Prices Deflated*	88	88	87	103	113	100	106	106	100	99	94	93	92

Source: Annual Review

* Deflated by Retail Price Index.

VII.3.5 The Value of Output, Inputs and Net Income

Table VII.6 summarises the value of aggregate output, input and net income since the late 1960s. In 1982, 63% of Total output came from the livestock sector and 35% from cropping. Of Net Farm Income 41% went to family and hired labour, 12% for interest payments, 2% for imputed rent, and 45% remained as net farm income. This is the definition of net farm income used for Annual Review purposes. Figure VII.3 shows the trends in Net farm incomes so defined over the 1968 to 1982 period. The measure has been criticised because it changes annual average depreciation rather than actual yearly capital investment and excludes the sizeable share of net product paid as incomes to family workers and partners. Two alternative less variable measures are shown in Table VII.7, namely sector cash flow and net product (value added after depreciation). The trend in aggregate incomes to the farming sector is negative by any measure.

TABLE VII.7

Measures of Farming Income 1973-1982

	Gross cash flow		Farming income		Net product	
	Index (1972=100)	% change in index	Index (1972=100)	% change in index	Index (1972=100)	% change in index
1973	126.7	26.7	128.2	28.2	120.2	20.2
1974	102.5	−19.0	92.8	−27.7	102.7	−14.7
1975	134.3	31.0	93.5	0.8	101.0	−1.6
1976	128.8	−4.8	103.7	10.7	106.5	5.4
1977	97.8	−23.7	87.4	−15.5	95.6	−10.2
1978	100.4	2.7	80.5	−7.9	94.2	−1.4
1979	88.3	−11.9	64.7	−19.6	89.1	−5.4
1980	81.2	−8.1	49.3	−23.7	81.6	−8.4
1981	91.6	13.0	54.7	10.9	82.3	0.7
1982	97.7	7.0	73.1	33.5	97.5	18.6

	Change in index		Change in index		Change in index	
	Total	Annual rate	Total	Annual rate	Total	Annual rate
1973–1982	−2.3	−0.2	−26.9	−3.1	−2.5	−0.2
1974–1980	−36.9	−4.4	−61.5	−9.1	−32.1	−3.8

TABLE VII.6

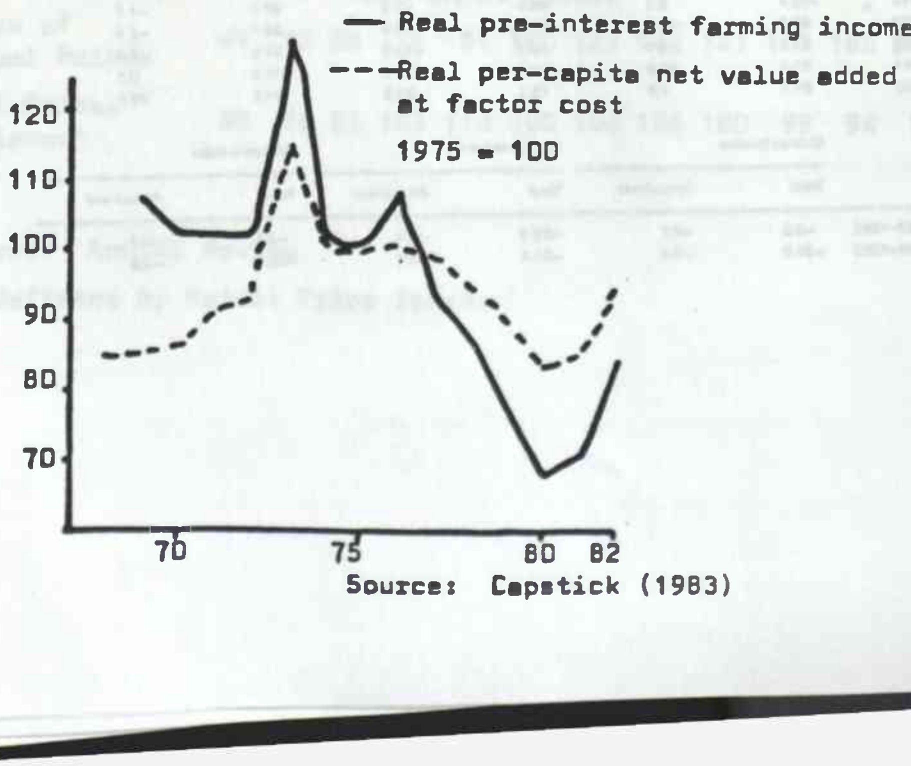
Aggregate Value of Output, Input, and Net Farm Income

	1967/8 £m	% of Total Output	1982 £m	% of Total Output
Output:				
Farm Crops	404	20	2867	27
Horticulture	232	12	1019	9
Livestock	718	36	3846	36
Livestock products	635	31	2659	27
Other	28	1	138	1
Total Output	2016	100	10829	100
Gross Output: including grants & subsidies and output valuation changes		% of Gross Output		% of Gross Output
	2201	100	11145	100
Gross Input	1115	51	5725	51
Gross Product	1086	49	5420	49
Depreciation	161	7	1281	12
Net Product	925	42	4139	37
Net Farm Income	527	24	1849	16
Deflated by RPI	100		70	

Source: Annual Reviews

FIGURE VII.3

Real Net Farm Income 1968-82



Source: Capstick (1983)

VII.3.6 Capital Structure and Investment

The agricultural sector currently invests about £1000M per year : 50% on new plant machinery and vehicles and 50% on buildings and works.

The financial status of the industry can be observed from the aggregate balance sheet in Table VII.8 derived from

TABLE VII.8

The Financial Structure of British Agriculture

	1970 £m.	%	1980 £m.	%	1982 £m.	%
Assets						
Land Buildings/Fixed Equipment	5,800	66	37,000	76	43,000	76
Livestock & Machinery	2,100	24	8,700	18	9,900	18
Crops & Stores	570	6	2,000	4	2,440	4
Current Assets	400	4	1,200	2	1,000	2
	8,870	100	48,900	100	56,340	100
Liabilities						
AMC, SASC, LIC	170	2	425	1	440	1
Building Societies/Ins. Co's	30	-	30	-	50	-
Bank Credit	500	6	3,150	6	4,300	7
Private & Family Credit	350	4	350	1	350	1
Merchant Credit & H.P.	270	3	940	2	940	2
	1,320	15	4,895	10	6,080	11
Equity Investment of Owners and Tenants	7,550	85	44,005	90	50,260	89
	8,870	100	48,900	100	56,340	100

Land, buildings and fixed equipment are the main assets, and the increase in assets shows the increase in land values over the period. Ninety percent of assets are owned by landlords and tenants. But there was a large increase in the use of credit to finance working capital indicating cash flow problems. Whereas in 1970 the farming sector could finance gross capital investment from (whichever definition) of net farm income, this became more difficult in the late 1970's. The need to borrow to invest generated debt charges which have further reduced aggregatd liquidity. The following financial ratios indicate the general trend.

	1970	1981
Net surplus income : total capital employed	6.3%	1.9%
Net surplus income : working capital	18.0%	8.0%
Net surplus income : sales (output)	23.0%	12.0%

VII.3.7 Labour and Machinery

A combination of increasing yields and a declining labour force gave agriculture an impressive record of labour productivity. Between 1965 and 1975 labour productivity increased by 6% per year and the total labour force fell by an average 4.5% per year. Between 1975 and 1982, labour productivity increased by about 4% per year, with a lower rate of departure at about 3%. In 1982/3, about 2% of the labour force left.

The agricultural sector now with 203,000 full time farmers and 171,000 full time workers, has more chiefs than indians. Over the period 1972-82, 83,000 full time and 23,000 part-time workers left the industry. Full time farmers declined by 24,000 in the period, but some of these probably remained in the growth of 18,000 part time farmers. Seasonal and casual workers have increased to partly offset the fall in regular workers. Table VII.9 summarises the trend over the last 10 years.

Mechanisation expenditure has increased as a proportion of total fixed costs over the period, although annual capital purchases have varied much with the varying fortunes of different farming groups. Although tractor numbers were much the same in 1972 as in 1965, average kw/ha increased by 60%.

TABLE VII.9

Labour Employed in Agriculture

	(a)	(b)	(b)/(a)
	1972	1982	
Workers			
Regular whole time	254	171	.67
Regular part time	85	62	.73
Seasonal/casual	78	98	1.25
Managers	n/a	8	
Total employed	417	338	0.81
Farmers and Partners			
Whole time	227	203	0.89
Part time	74	92	1.11
Total farmers	301	295	0.98
Grand Total	721	633	0.88

Source: Annual Reviews

VII.3.8 Farm Structure

VII.3.8.1 Number and Size of Holdings:

Table VII.10 summarises the trends in farm numbers and sizes over the period 1967 to 1982 (with some gaps in data due to changing definitions). Since the mid 60's, the total number of farms has declined by 30% (over 100,000 farm units) particularly in the smallest size categories. Meanwhile, the number of larger farms, and their share of total cropped area, has increased. The average size of a full time farm was 118 hectares (providing theoretical full time employment for 3-4 men) in 1982.

TABLE VII.10

Number and Size of Holdings (UK)

Year / Hectares	1967	1975	1982
	000's of holdings		
0-19.9	179.7	119.9	96.4
20-49.9	n/a	73.2	65.9
50-99.9	n/a	41.7	41.4
100+	n/a	29.3	30.5
Total holdings	338.3	264.1	234.1
Average size (ha)	36.0	45.2	51.0
Average size over 250 SMD (ha)	n/a	111	118
% of total crop & grass on			
holdings under 20 ha	11.8	8.2	6.7
holdings over 100 ha	35	48	51

Source: Annual Reviews

VII.3.8.2 Type of Holdings:

The convention used for classifying farms into different types before 1977 was on the basis of the proportion of total standardised labour input directed to the various enterprises on the farm. Thus a farm which, using standard labour requirements, spent 75% of these on dairy cows was designated a specialist dairy farm. With membership of the EEC, the European method of classification according to standardised gross margins was introduced.

Table VII.11 lists the main types of farms relevant to the study and the criteria for classification. A classification based on standard man days has been used in the study.

TABLE VII.11

Farm Type Classifications and Criteria

Farm Type	Standard Man Days	Gross Margin
Specialist dairy	75%+ dairying	67%+ dairying
Mainly dairying	50-75% dairying	33-67% dairying, and biggest enterprises
Livestock rearing and fattening:	50%+ livestock	
Mostly cattle	(75% cattle)	Livestock biggest enterprise
Mostly sheep	(75% sheep)	33%+, usually 67%+
Cattle and sheep		
General cropping	50%+ cropping, (25%- cereals)	33-67%+ field crops and biggest enterprise
Mostly cereals	50%+ cropping, (25%+ cereals)	67%+ cereals
Mixed	50%- on any main enterprise	
General horticulture	50-75%+ horticulture	33-67%+ horticulture and biggest enterprise
Pigs and poultry	50-75%+ pigs and poultry	33-67%) pigs and poultry and biggest enterprise

Table VII.12 shows the distribution of farm types in U.K. for 1977 and 1982.

TABLE VII.12

Farm Type : England (1981 Census)

	% of Farms	% of Area
Dairy	20	21
Livestock	26	22
Cropping	27	51
Pigs and Poultry	8	4
Horticulture	9	3
Unclassified	10	2

VII.3.8.3 Enterprise Trends:

Enterprise trends at farm level can be generalised in terms of a reduced enterprise mix in order to exploit the opportunities afforded by specialisation and economies of scale. Table VII.13 considers the statistics for cereals and dairy, and the inferences would apply to most enterprises in the sector. The total number of holdings growing cereals declined by over 20% between 1975 and 1982, but the average cereal enterprise size increased from 30 to 40 hectares. The number of growers with less than 20 hectares of cereals fell by one third, whilst those with more than 50 hectares grew, and provided an increasing share of cereal area. The same trend is apparent in dairying. There were 22,000 less holdings with dairy cows in 1982 compared to 1975, a reduction of some 3,000 per year, particularly involving those with under 29 cows. More cows were held in 60+ size herds which accounted for almost 70% of total cows in 1982. The average dairy herd increased from 40 to 55 milk cows in the seven year period. This enterprise adjustment is indicative of the rapid structural change which has occurred with many small farmers leaving dairying or the farming sector altogether, often in response to Government incentives.

The main physical and financial features of farm enterprises relevant to the study are discussed in Annex V.

TABLE VII.13

Cereal and Dairy Enterprise Trends (U.K.)

	Total No. of Holdings (a) 1975	(b) 1982	b/a
Cereals			
No. of holdings (000)			
with 0.1-19.9 ha	77.6	54.1	.70
with 20-49.9 ha	22.7	21.7	.96
with 50 + ha	21.0	23.8	1.13
Total	121.3	99.6	0.82
Average cereal area (ha)	30.1	40.4	1.34
% of all cereals on holdings with 50+ ha cereals	66	73	1.11
Dairy Cows			
Total No. of holdings (000's)			
with 1 to 29 cows	39.9	19.5	0.49
with 30 to 59	23.4	17.7	0.76
with 60 cows +	17.6	21.3	1.21
Total	81.0	58.6	0.72
Average herd size	40	55	1.38
% of total dairy cows in 60+ cow herds	53	68	1.28

Source: Annual Reviews

VII.3.8.4 Farm Incomes by Farm Type:

The main source of data on farm incomes by farm type is the Regional Farm Management Survey which 'standardises' farm accounts to enable comparative analysis. A definition of net farm income is derived which shows the return to management and tenant type capital (ie management and investment income) and the remuneration to family workers.

Table VII.14 shows the changes in real average net farm incomes per farm by main farm type over the period 1977-82. Net incomes on arable farms have increased whilst those in the livestock Sector have fallen significantly since 1977, particularly due to high feed costs. Annual fluctuations in net income are apparent for all types , especially for livestock which are more susceptible to weather conditions.

TABLE VII.14

Real Net Farm Income by Farm Type

	Dairy	LFA Cattle and Sheep	Lowland Cattle and Sheep	Cereals	Other Cropping	Pigs and Poultry
1977/78 ..	100	100	100	100	100	100
1978/79 ..	106	109	107	126	188	134
1979/80 ..	66	50	48	92	181	94
1980/81 ..	65	58	57	97	109	84
1981/82 ..	81	101	66	93	157	96
1982/83 ..	93	85	53	147	165	67
1983/84 .. (forecast)	65	80	45	160	230	25

Source: Annual Review based on FMS data : Net Farm Income : return to family labour, management and tenant type capital.

All farm types have been subject to a cost squeeze. To remain profitable farms have either grown bigger or intensified, or both. Cereal farmers, facing lower real prices, and rising fixed costs have found comfort in higher yields and economies of scale, and the possibility to switch into other cropping enterprises such as oilseed rape and sugar beet. With respect to dairy and livestock producers, the cost squeeze has been heightened by dependence on feeds, and in the case of dairy high fixed costs with, on mainly small farms, limited opportunity for economies of scale or switching to other more financially attractive enterprises. MMB and MLC results show that the most profitable farms have been the bigger herds which have simultaneously adopted more intensive methods, with respect to yields, (milk or live-weight), stocking rates, and feed management.

VII.4 FARMING IN THE STWA REGION

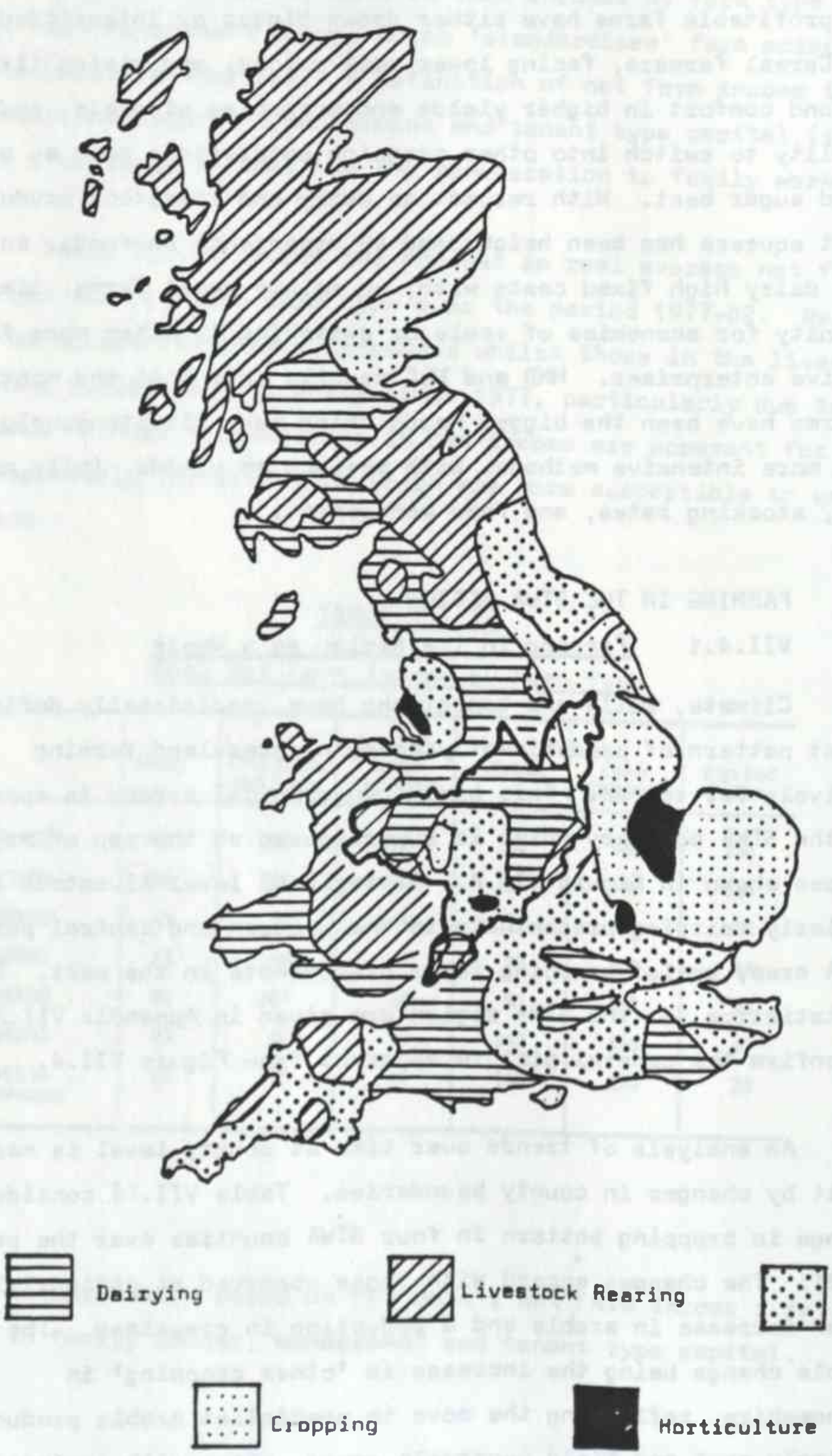
VII.4.1 Farming in the Region as a Whole

Climate, soils and topography have traditionally defined an east/west pattern of predominantly cropping/grassland farming respectively for the UK. This broad geographical spread is apparent within the STWA boundary which is superimposed on the map of major farm types shown in Figure VII.4. At regional level livestock farms, particularly dairying predominate in the western and central part of the STWA area, whilst cropping farms predominate in the east. County level statistics for the STWA region are given in Appendix VII.A, and these confirm the general picture apparent from Figure VII.4.

An analysis of trends over time at county level is made difficult by changes in county boundaries. Table VII.15 considers the change in cropping pattern in four STWA counties over the period 1971-1981. The changes accord with those observed at national level, namely an increase in arable and a reduction in grassland. The most noticeable change being the increase in 'other cropping' in Nottinghamshire, reflecting the move to specialist arable production, particularly root and field vegetable crops, often with irrigation on lighter soils.

FIGURE VII.4

Dominant Farm Systems in U.K. and STWA



An examination of county statistics, notwithstanding boundary changes and classification changes, shows that the STWA region as a whole has been subject to the trends observed at national level with respect to agricultural performance, structure, and net incomes.

Table VII.15

Regional Trends in Cropping, 1971-81 for Four Selected STWA Counties

Crop Type:	Cereals		Other crops (incl. Hort.)		Permanent and Temporary		Rough grazing	
Year:	1971	1981	1971	1981	1971	1981	1971	1981
County:								
Gloucestershire	33	37	4	6	58	51	4	*
Shropshire	27	29	7	8	60	57	5	*
Staffordshire	22	24	6	7	68	63	4	*
Nottinghamshire	51	53	13	20	35	26	1	*

* Rough grazing not available for 1981.

VII.4.2 Farm Type

Table VII.16 contains the classification of STWA sample farms (n = 177) in terms of % of farms, and the % of the benefit area which they accounted for. The national averages for England and Wales are included. The STWA farms are dominated by (specialist and mainly) dairy farms who accounted for 46% of all farms and 41% of the benefit area surveyed. Cropping farms were the next main farm type followed by livestock rearing and fattening farms. Within the sample, the number of and area commanded by dairy and cropping farms was greater than the regional average.

TABLE VII.16

Farm Type in the STWA Benefit Area

	STWA Benefit Areas		STWA Region*		England*	
	% of farms	% of area	% of farms	% of area	% of farms	% of area
Dairy	46	41	23	25	20	21
Livestock	18	14	29	21	26	22
Cropping	28	41	23	47	27	51
Pigs and Poultry	} 5	} 2	}	}	8	4
Horticulture	}	}	} 24	} 8	9	3
Unclassified	3	2	}	}	10	2

* MAFF County and England Statistics, 1981 Census.

Farm type was recorded post scheme. The prescheme farm type would have been more heavily orientated to dairy and fatstock. The Divisional distribution of farm type is given in Table VII.17, and is generally consistent with the distribution at regional level (Table VII.18). Whilst dairy farms are common throughout, mixed and cropping farms are mainly found on the Soar, Upper Trent and Lower Trent Schemes. An important factor in determining farm type is the conformation of the benefit area and the % of a farm's total area within it. The smaller the % in benefit, the more likely the farms will conform to regional distribution of farm type.

TABLE VII.17

Farm Type Distribution by STWA Division and Scheme

STWA Division	Scheme	Number of Farmers Interviewed	Type of Farm : % of Farms						Type of Farm : % of Area					
			Dairy	Live-stock	Cropping	Mixed	Other	No Data	Dairy	Live-stock	Cropping	Mixed	Other	No Data
Soar	Sharnford	14	43	29	7	14	7	-	40	21	1	31	6	-
	Kilby Bridge	9	67	-	-	11	2	-	44	-	-	44	12	-
Upper Trent	Doley Brook	10	50	30	10	10	-	-	43	30	9	19	-	-
	Alrewas	13	46	8	23	15	-	8	59	3	15	22	-	1
	Blithe	7	57	29	-	14	-	-	65	27	-	8	-	-
Upper Severn	Morda	23	61	22	4	-	4	9	62	27	1	-	1	9
	Sleap Brook	18	50	11	22	6	-	11	48	12	33	4	-	2
Lower Trent	Beckingham	14	7	21	72	-	-	-	1	15	84	-	-	-
	Mattersey	10	20	-	80	-	-	-	41	-	59	-	-	-
	Misson	10	20	10	70	-	-	-	25	3	72	-	-	-
Derwent -	Tean	9	67	22	-	-	-	11	49	41	-	-	-	11
Tame -	Temple Mill	2	100	-	-	-	-	-	100	-	-	-	-	-
Lower Severn	Ripple	8	12	38	-	25	25	-	10	25	-	51	13	-
	Bushley	7	14	4	14	14	14	-	22	28	39	6	6	-
	Oldbury	14	86	7	-	-	7	-	91	9	-	-	-	-
	Epney	2	50	-	50	-	-	-	66	-	34	-	-	-
Total		170	46	18	22	6	5	3	41	14	31	10	2	2
Valid Cases (%)			←			93		→	←			93		→

TABLE VII.18

STWA Regional Pattern of Agriculture

	Dairy	Cattle & Sheep LFA	Cattle & Sheep Lowland	Cropping	Pigs & Poultry	Hort.	Unclassified
% of total holdings:							
Derbys.	35.00	13.17	19.60	13.89	5.74	3.80	9.02
Gloucs.	21.41	-	30.00	20.77	6.48	8.60	12.81
Herefore & W.	11.78	4.29	31.00	20.65	6.35	16.58	9.48
Leics.	18.55	-	28.16	33.00	6.67	3.99	8.29
Nottingham	9.34	-	12.24	52.00	11.12	7.06	8.18
Salop	29.00	9.71	24.37	20.10	6.36	2.37	7.92
Staffs	38.00	3.43	24.47	12.31	6.58	3.47	11.28
Warwicks	15.60	-	25.11	34.00	7.49	6.34	10.99
W. Mids.	12.34	-	21.00	20.04	15.21	13.24	17.71
% of total area of crops and grass:							
Derbys	43.00	21.49	12.47	19.30	1.87	0.88	2.88
Gloucs.	25.43	-	15.96	51.00	2.53	2.41	2.84
Hereford & W.	15.72	4.72	25.46	42.00	2.96	7.20	2.42
Leics.	17.33	-	16.64	61.00	2.32	0.42	1.97
Nottingham	9.51	-	4.26	79.00	4.05	1.46	1.66
Salop	29.11	11.42	14.39	40.00	2.65	0.56	1.77
Staffs	45.00	2.96	15.39	28.63	2.96	1.69	3.20
Warwicks	15.57	-	14.22	63.00	2.08	1.74	2.94
W. Mids.	22.38	-	19.64	44.00	5.23	2.95	6.01

Source: MAFF 1981 Census

TABLE VII.19

Land Use in STWA Divisions and Schemes

Scheme	Pre-Scheme Land Use - % of Area						Post-Scheme Land Use - % of Area						Land Use Change - % of Area		
	Rough Grass	Permanent Pasture	Temporary Grass	Arable /Ley	Crops	Non Agric.	Rough Grass	Permanent Pasture	Temporary Grass	Arable /Ley	Crops	Non Agric.	Decline	No Change	Improved
Sharnford	-	63	14	19	4	-	-	56	15	25	4	-	-	93	7
Kilby Bridge	5	87	-	-	-	8	-	86	-	5	-	8	-	82	10
Doley Brook	8[1]	55	2	26	-	9	8[1]	50	6	19	13	4	5	73	20
Alrewas	-	57	34	-	9	-	-	56	34	-	10	-	-	99	1
Blithe	8	92	-	-	-	-	-	84	16	-	-	-	-	77	23
Morda	-	86	5	8	1	-	-	73	12	13	2	-	7	73	20
Sleap Brook	-	63	-	7	17	14[2]	-	31	7	22	34	5[2]	6	48	43
Beckingham	3	68	1	-	28	-	-	18	-	-	82	-	-	46	54
Mattersey	-	62	-	5	33	-	-	30	6	8	56	-	-	70	30
Misson	6	83	-	-	6	4	-	25	-	5	64	5	-	33	65
Teen	-	91	8	-	-	1	-	66	8	12	-	14[4]	-	75	10
Temple Mill	-	81	-	-	-	19[3]	-	10	-	72	-	19[3]	-	10	72
Ripple	-	86	-	2	7	4	-	73	-	4	19	4	-	82	14
Bushley	-	95	-	5	-	-	-	31	-	31	38	-	-	34	66
Oldbury	-	93	1	2	1	4	-	89	4	3	1	4	-	95	4
Epney	-	87	13	-	-	-	-	39	-	57	4	-	-	39	61
Total	2	75	4	5	11	4	1	47	7	12	31	3	2	64	32
Valid Cases (%)	← 98 →						← 99 →						← 99 →		

1. Doley Common
2. Sleap Airfield
3. Sibson Wold
4. A50 By-pass

VII.4.3 Farm Size

The average size of STWA farms was 105 hectares and 926 standard man days as shown. This compares with 118 hectares and 915 standard man days for the national (UK) average.

Table VII.20 shows the distribution of farm sizes by number of STWA farms, and Table VII.21 the distribution of farm size by farm type. The statistics confirm that dairy and livestock farms are generally smaller and more labour intensive than their arable counterparts.

TABLE VII.20

Distribution of STWA Farm Sizes

ha class:	% of Farms	% of Benefit Area
ha class:		
0.1-19.9	10	3
20.0-49.9	30	17
50.0-99.9	30	26
100+	30	54
SMD class:		
0.1-250	20	9
251-500	23	18
501-1000	29	23
1000+	28	50

TABLE VII.21

Distribution of STWA Farm Type by Farm Size

Farm Type	ha class			
	0.1-19.9	20.0-49.9	50.0-99.9	100+
Dairy	4	30	24	20
Livestock	6	9	9	6
Cropping	0	5	11	21
Mixed	0	0	7	4
Other	6	7	1	0

Chi-squared statistic significant at 0.0000

The average farm size and distribution of farm sizes for individual schemes is largely a reflection of farming type.

VII.4.4 Proportion of Farm in Benefit Area

The average proportion of the total farm area lying within the benefit area of the STWA scheme is 42%, an overall average of 30 hectares per farm. Table VII.22 shows the distribution of this statistic, also the average proportion of farm area in benefit for individual schemes. The variation partly reflects the configuration of the scheme and local farming type.

TABLE VII.22

Percentage of Farm in Benefit Area

% of Farm in Benefit Area	% of Farm	% of Benefit Area
0.1-25	38	19
25.1-50	30	41
50.1-75	17	23
75.1-100	15	17

Farm size x % of farm area in benefit:

% of Farm Area in Benefit	ha classes 0.1-19.9	20.0-49.9	50.0-99.9	100+
0.1-25%	2	13	25	24
25.1-50%	4	11	14	21
50.1-75%	2	13	8	5
75.1-100%	7	13	5	1

Chi-squared statistic significant at 0.0001

VII.4.5 Farm Tenure

The STWA farms were 37% all owned, 19% all rented, and 44% partly owned and rented. This compares with a national (E & W) average of 54%, 23%, and 23%. Fields within the benefit area, however, were 56% owned which conforms more with the national average.

VII.4.6 Cropping Pattern

The land use pattern found within STWA benefit areas is given in Table VII.19. The prescheme land use situation which was 80% grass, largely reflects pre-scheme drainage condition. The post-scheme land use pattern however is partly influenced by regional farming system and farm type characteristics. The greatest proportion of change to arable cropping occurred on arable type farms, and these predominate in the eastern Divisions. Specialist dairy producers took up benefits mainly by intensifying grass production.

With respect to pre and post scheme cropping pattern, Table VII.23 shows the move to winter cereal cropping as a result of drainage improvements.

TABLE VII.23

Arable Cropping Patterns for STWA Farms

	Pre Scheme % of arable area		Post Scheme % of arable area	
	Main Crop*	Secondary Crop*	Main Crop	Secondary Crop
Winter Cereals	30	25	78	42
Spring Cereals	60	12	10	7
Potatoes	4	25	6	17
Sugar beet	3	11	3	10
Field vegetables	3	23	3	5
Other Crops	0	0	0	15
	100	100	100	100
% of Total Area in Arable	11		37	

* Main Crop. Most important crop in rotation

* Secondary Crop. Second most important crop in rotation.

VII.4.7 Livestock Systems

Reference is made in Annexe IV to regional climate and soil factors influencing livestock management, particulary with respect to fertilizer use and stocking rates for dairy and beef production (see Annexe V, section

VII.4.7.1 Dairy:

The average STWA dairy herd size was 84 milk cows, using an average 197 kg N/ha in the benefit area, implying a stocking rate, assuming average diets, of about 1.8 cows/ha. Table VII.24 compares the STWA survey results with MMB's sample of costed farms for 1982/3.

TABLE VII.24

Dairy Herds on STWA Farms

	STWA Sample	MMB (by gross margin) Top 25%	Bottom 25%
Herd size	84	126	95
Litres/cow	5550	5888	4867
N level	197*	326	212
Stocking rate	1.83**	2.58	1.63
Farm size	78	80	

* in benefit areas only.

** estimated for benefit areas on basis of observed N, site class, and average diet.

Ten surveyed farmers reported leaving dairying during the 1970's mainly for reasons not entirely associated with drainage improvements, in most cases as part of a grant aided farm reorganisation programme.

VII.4.7.2 Livestock Rearing and Fatterning:

A variety of livestock fattening systems are to be found as summarised in Table VII.25. Overwintered and grass fattening stores and medium stores fattened at grass predominate.

TABLE VII.25

Post Scheme STWA Beef Systems

	% of total grass area in beef
Mixed systems	20
Specialist calf rearing	3
Cereal Beef	6
18-24m beef	21
Sucklers	12
Overwintering and grass finishing	19
Grass finishing	16
Other	3
	100

In the pre-scheme situation the grass fattening and finishing of medium store cattle is relatively more important.

VII.4.7.3 Farm Level Stocking Rates:

Farm level stocking rates were 1.73 livestock units per hectare of grass, and 1.97 livestock units per hectare of grass weighted by area in the benefit area. These ratios do not take account of non grass feeding, for which detailed information was not available. They are therefore higher than the expected average carrying capacity of grass in the benefit areas.

VII.4.7.4 Nitrogen Use on Grass and Stocking Rates:

On the basis of the observed relationship between nitrogen application of grass and stocking rate, table VII.26 summarises the distribution of nitrogen application and expected stocking rates for STWA farms. The rates at which these convert into different stock types are given in Annexe V

TABLE VII.26

Distribution of Fertiliser Use and Expected Stocking Rate

N kg/ha on grass	Pre-scheme % of benefit area	Post-Scheme % of benefit area	Estimated Post-scheme stocking rate glu/ha*
0 - 50	38	25	0.76
50 - 100	32	26	1.08
100 - 150	4	11	1.43
150 - 200	8	9	1.63
200 - 300	6	6	2.05
300+	12	23	2.28+

* Grazing livestock units/ha.

VII.4.7.5 Grass Conservation Practice:

Most of the grass area in benefit is grazed but the introduction of silage making, together with more nitrogen, has increased, as shown in Table VII.27. Variations in nitrogen use is considerable within management systems.

TABLE VII.27

Average Nitrogen Levels with Grass Conservation

	% of Grass Area	Mean Nkg/ha	SD
Grazed only	51	132	121
Hay	19	88	67
Silage	30	217	126

VII.4.8 Financial Performance

The main source of data on the financial performance and status of farms within the STWA region are the Regional Farm Management Surveys (FMS) conducted from the Agricultural Economics Departments of Manchester and Nottingham. These two cover the greater part of the area, although parts of fall in the remit of Reading, Exeter, Newcastle, Aberystwyth and Ascum Bryan.

The FMS data provides standardised financial data based on farm accounts, a description of major crop and livestock characteristics, and a set of performance indicators such as yields, and gross output per £100 spent on power and machinery. Only one sampled STWA farmer contributed to the FMSsurvey.

By way of example Table VII.28 shows average per hectare income and expenditure by farm type for the Manchester Province which takes in the north wester part of the STWA Region. The sample confirms that lowland dairy farms are generally smaller, but exhibit higher gross margins and fixed costs per hectare than arable or mixed farms. Livestock rearing and fattening farms operate more extensive systems.

TABLE VII.28

Average Outputs and Inputs per Hectare by Farm Type : Manchester Province

	ARABLE			MIXED ARABLE			LOWLAND DAIRY			UPLAND DAIRY			HILL SHEEP			LIVESTOCK REARING	
	1979/80	1980/81	1981/82	1979/80	1980/81	1981/82	1979/80	1980/81	1981/82	1979/80	1980/81	1981/82	1979/80	1980/81	1981/82	1980/81	1981/82
	£	£	£	£	£	£	£	£	£	£	£	£	£	£	£	£	£
Main Crops*	599	636	776	311	307	379	46	39	50	-	-	-	-	-	-	62	92
Forage Crops & Main Crop by products†	32	27	31	1	14	4	6	10	10	5	6	11	2	7	7	7	-
Milk	-	-	-	570	668	760	1016	1157	1279	901	1011	1145	98	112	130	-	-
Cattle	42	47	59	117	162	267	228	251	372	176	180	315	144	156	186	217	252
Sheep and Wool	11	11	18	4	6	6	5	6	8	16	22	28	58	112	150	178	240
Pigs	25	30	29	6	8	1	5	3	3	32	30	20	20	12	-	1	1
Poultry and Eggs	25	24	25	36	29	26	9	5	4	62	107	118	29	27	29	1	1
Miscellaneous	16	23	18	9	14	13	10	13	12	11	12	13	4	5	4	10	10
TOTAL GROSS OUTPUT (1)	750	798	956	1054	1208	1456	1325	1484	1738	1203	1388	1650	355	431	506	476	596
Feed	69	64	65	315	329	364	555	567	599	581	624	681	183	182	165	122	135
Seeds	42	59	58	40	34	39	12	10	9	2	2	1	1	-	1	7	11
Fertilisers	65	77	86	78	82	98	75	87	92	38	42	52	19	21	20	30	29
Other Inputs: Crops	71	78	91	31	38	40	10	11	12	2	4	3	1	1	1	15	12
Livestock	4	4	5	27	32	42	52	72	85	59	85	92	16	18	19	23	26
TOTAL VARIABLE INPUTS (2)	251	282	305	491	515	583	704	747	797	682	757	829	220	222	206	197	213
GROSS MARGIN [(1) - (2)] (3)	199	516	651	563	693	873	621	737	941	521	631	821	135	209	300	279	383
Power	198	209	216	182	183	198	209	224	238	157	167	187	59	65	67	88	102
Labour	146	180	194	157	187	220	188	220	242	208	243	264	72	83	89	119	135
Land Expenses	80	97	115	84	95	117	107	127	145	78	93	108	35	39	50	66	72
General Overheads	19	28	30	22	30	34	32	44	48	25	37	43	8	14	16	16	18
TOTAL FIXED INPUTS (4)	443	514	555	445	495	569	536	615	673	468	540	602	174	201	222	289	327
Management and Investment Income [(3) - (4)] (5)	56	2	96	118	198	304	85	122	268	53	91	219	-39	8	78	-10	56
Farmer's & Wife's Labour (6)	39	47	52	34	40	45	90	109	115	115	140	151	37	45	49	58	65
Net Farm Income [(5)+(6)] (7)	95	49	148	152	238	349	175	231	383	168	231	370	-2	53	127	48	121
Breeding Livestock Appreciation (8)	-	2	5	22	30	74	41	45	122	32	32	104	-10	23	41	13	45
N.F.I. less B.L.S.A. [(7) - (8)]	95	47	143	130	208	275	134	186	261	136	199	266	-12	30	86	35	76
No. of farms		36			11			56			21			18		17	
Average Hectares	115	115	117	113	113	113	56	57	57	41	41	41	137	137	137	96	96

* Includes farm consumed. † Includes only sales and valuation.

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ANNEXE VIII

NATURE AND RATE OF UPTAKE

ANNEXE VIII

NATURE AND RATE OF UPTAKE

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List of Abbreviations

CLA	Country Landowners Association
IDB	Internal Drainage Board
N	Nitrogen
NFU	National Farmers Union
SE	Standard Error
SPSS	Statistical Package for the Social Sciences
STWA	Severn Trent Water Authority

ANNEXE VIII

NATURE AND RATE OF UPTAKE

VIII.1 INTRODUCTION AND SCOPE

Previous studies of the uptake of benefits of land drainage improvement schemes have concentrated upon one of 2 single physical parameters - land use change or area of underdrainage (see Annexe II). Whilst both of these parameters may be easily, and fairly reliably identified, in a post-scheme evaluation they are merely substitutes for what is really of interest, that is the value of the benefit measured in financial or economic terms.

In the present study therefore physical parameters have been examined alongside the estimates of financial benefits calculated for the purposes of the scheme appraisal (see Annexe V). All the data collected from the farm survey, along with physical data on soils and land classification were stored on computer with the estimates of gross margins and net returns on a field by field basis. These data sets were then examined individually and in association using the Statistical Package for Social Scientists (SPSS).

This Annexe falls into 5 sections: firstly, the observed variation in the nature of uptake is examined and the factors encouraging uptake identified; secondly, the rate of uptake is studied and factors that are associated with early uptake identified; thirdly, curves of uptake are presented which will enable benefits identified in a pre-scheme evaluation to be phased over time; fourthly, the factors associated with the uptake of benefits are examined at scheme level. Finally, the attitude of farmers towards field drainage is discussed.

VIII.2 VARIATION IN THE NATURE OF UPTAKE OF BENEFITS

VIII.2.1 Observed Variation in the Nature of Uptake of Benefits

Largely as a result of the methodology employed to assess the benefits (see Annexe IV) there are 7 factors which are likely to influence the value of the agricultural benefit from land drainage improvement schemes. These are:

(i) Change of land use class,

(ii) Installation of field drainage,

(iii) Change in nitrogen application (on grassland),

(iv) Change in conservation system (on grassland),

(v) Increased yields (crops),

(vi) Extended grazing (grassland),

(vii) Reduced flood damage.

The benefits v, vi and vii are largely automatic benefits, in that they do not require an additional input from the farmer and therefore cannot be considered in terms of 'uptake'. When considering uptake it is likely that i to iv above will be the important factors to consider. An analysis of variance showed that all 4 had a significant effect upon the value of benefit (measured as the change in gross margin[1]) at the 0.1% level, and on grassland, drainage, change in nitrogen application and change in grass conservation between them accounted for 73% of the observed variation in benefit.

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1. Change in gross margin is a better indicator of uptake than change in net return in most cases as it does not generally include automatic benefits (which are reflected in reduced costs). In some cases however an increase in net return can be accompanied by a decrease in gross margin. Change in gross margin does not, therefore, provide a perfect measure of uptake.

TABLE VIII.1

Distribution of Benefits from Land Use Change - All Sites

Shift[1]	% of Benefit		Average Benefit £/ha		Area %
	Δ Gross Margin	Δ Net Return	Δ Gross Margin	Δ Net Return	
0	40	35	68	46	67
1	4	3	117	69	4
2	13	12	217	136	8
3	37	43	252	212	18
4	2	2	432	275	1
5	6	5	429	247	2
Total	100	100	122	87	100

TABLE VIII.2

Distribution of Benefits from Drainage - All Sites

Post-Scheme Drainage	% of Benefit		Average Benefit £/ha		Area %
	Δ Gross Margin	Δ Net Return	Δ Gross Margin	Δ Net Return	
None	39	37	69	47	68
Drained	61	63	232	172	32
Total	100	100	122	87	100

1. The shift in land use class is calculated as the numerical value of the post-scheme class minus the pre-scheme class. Classes were coded as follows: 0 - not used, 1 - rough pasture, 2 - permanent grass, 3 - temporary grass, 4 - crop/ley rotation, 5 - crops, 6 - horticulture.

TABLE VIII.3

Distribution of Benefits from Increased Nitrogen - Grassland

Change in "N" Rate	% of Benefit		Average Benefit £/ha		Area %
	Δ Gross Margin	Δ Net Return	Δ Gross Margin	Δ Net Return	
None	10	19	12	14	50
Upto 50 kg	3	4	30	23	7
50-100 kg	19	19	44	27	25
100-150 kg	26	24	148	87	10
150-200 kg	5	6	112	78	2
Over 200 kg	42	30	418	184	6
Total	100	100	59	36	100

TABLE VIII.4

Distribution of Benefits from Change in Grass Conservation - Grassland

Change in Conservation	% of Benefit		Mean Benefit £/ha		Area %
	Δ Gross Margin	Δ Net Return	Δ Gross Margin	Δ Net Return	
No change	41	56	30	24	76
Increased cuts	4	2	99	40	2
Hay to silage	23	12	158	50	8
Grazing to silage	14	6	78	19	10
Hay to grazing	18	24	247	195	4
Total	100	100	55	33	100

These Tables show that 65% of the benefits observed (measured in terms of a change in gross margin) occurred on sites which had changed land use (33% of the area) and the greater the change, the greater the benefit. Similarly 63% of the benefits occurred on sites which had been drained following the scheme (32% of the area). Although the total figures involved are very similar, and drainage was often associated with a change of land use, 60% of the sites that were underdrained also changed land use. The average benefit on drained sites was almost twice as high as that on undrained sites.

On sites which have stayed in grass, 90% of the benefits occurred on sites which had had an increase in nitrogen application (50% of the area). The average benefit to grassland sites that have not increased 'N' was low (£14/ha) and that on other sites was directly proportional to the amount of the increase.

Change of conservation system appears to be less important, with 56% of the benefits accruing to sites where there has been no change (76% of the area). The greatest benefits accrue to those sites which have gone from hay to zero conservation or from hay to silage. Those sites which have gone into silage from zero conservation benefit highly in terms of gross margins but lower when measured in net returns due to the high fixed costs associated with silage making.

It is clear therefore that the sites with the most benefit will be those which have one or a combination of the following:

(i) those which have changed to higher order land uses,

(ii) those which have been underdrained,

(iii) grassland sites where the 'N' rate has been increased, and

(iv) grassland sites which have gone from hay making to silage or zero conservation.

VIII.2.2 Factors Explaining the Variation in Nature of Uptake

VIII.2.2.1 Change of Land Use:

The farms surveyed were classified according to the percentage of the benefit area that has changed land use since the scheme into 4 groups, namely, 'none', 'less than half', 'more than half' and 'all'. Chi-squared statistics (or where appropriate Pearson's r) were calculated to identify the variables which have a significant influence upon the observed variations in area of land use change. The results are summarized below.

TABLE VIII.5

Farm and Farmer Factors Associated with Land Use Change

Significant Variables (Signif < 0.05)	Significance
Farm size (ha) (Pearson's r = 0.23)	0.001
Percentage of the farm in the benefit area (Pearson's r = -0.23)	0.000
Percentage of farm underdrained since the scheme (Pearson's r = 0.50)	0.000
Farmers age group	0.024
Farm type	0.013
Change of management since scheme	0.011
Insignificant Variables (Signif > 0.05)	
Whether brought up on the present farm or not	0.999
Agricultural qualifications	0.166
View of farming as a business	0.782
Expected family lineage	0.346
Membership of farming groups	0.883
Representation upon committees	0.597
Change of ownership of the farm	0.24
Farm management status	0.189
Farm tenure	0.421
Standard man day requirement (Pearson's r = 0.16)	0.159

Secondly, the fields were divided into 3 groups, viz. those which have not changed land use class, those which have 'improved' (a positive shift), and those which have 'declined' (negative shift). Field level variables were cross-tabulated against these 3 classes and Chi-squared statistics calculated. The results are summarized below.

TABLE VIII.6

Field Factors Associated with Land Use Change

Significant Variables (Signif < 0.05)	Significance
Field tenure status	0.000
Whether the land was acquired pre- or post- scheme	0.000
Pre-scheme underdrainage	0.000
Contiguity of field with farm	0.000
Pre-scheme drainage status	0.000
Distance of field from farm	0.000

Finally, all the variables with a significance of less than 0.05 were entered into a stepwise Discriminant Analysis to attempt to differentiate between sites which have changed land use and those which have not. All sites which were not naturally free draining and free from drainage problems before the scheme, were used in the analysis.

A discriminant function with 9 variables was obtained which correctly classified 78% of the cases studied. The variables are listed below along with their standardized coefficients[1].

1. The standardized coefficients are used to compute the discriminant score where the original discriminating variables are in standard form (Z-scores). The absolute value of the coefficient represents the relative contribution of its associated variable to the function. The sign denotes whether the variable is making a positive or negative contribution.

TABLE VIII.7

Change of Land Use - Standardized Discriminant Function

Variable	Standardized Coefficient
Pre-scheme land use	-0.65
Arable farm	0.55
Dairy farm	-0.32
Percentage of the farm in the benefit area	-0.51
Pre-scheme drainage status	0.32
Pre-scheme gross margin	0.29
Farm size	-0.21
Length of occupancy prior to the scheme	-0.21
Change of management since the scheme	0.29

These variables fall under 3 headings:

(i) Farm type and size: Land belonging to arable farms is more likely to have changed its land use class and that belonging to dairy farms, less likely. The larger farms appear less likely to change land use after the scheme as do those with a high proportion of the farm area within the benefit area.

(ii) Land use and drainage: Not surprisingly, sites which prior to the scheme were in low-order land use classes are more likely to change than land that was already in a higher class. Similarly, land which was previously wetter is more likely to have changed than drier land. Sites with a higher gross margin per hectare before the scheme are more likely to change after; suggesting that those who are likely to change will already be exploiting a greater proportion of the potential output of the land than others who are less likely to change.

(iii) Length of occupancy and change of management: Sites which have changed hands after, or soon before the scheme are more likely to have changed land use than those with a long occupancy.

Similarly farms which have changed management since the scheme are more likely to have changed land use.

If post-scheme drainage is entered as an independant variable an improved discriminant function containing 11 significant variables is obtained which correctly classified 85% of the cases studied. Post-scheme drainage became the variable with the highest coefficient and with a positive sign. Fully tenanted sites also enters as a significant variable, also with a positive sign, indicating a tendancy towards land use change on fully tenanted land. It does however have the weakest influence on the function, having the lowest standardized coefficient.

VIII.2.2.2 Field Drainage Installation:

A similar approach was adopted to the examination of factors influencing post-scheme underdrainage. Firstly, the farm and farmer variables were cross-tabulated against the percentage of the farm underdrained. The significance of the Chi-squared (or Pearson's r) statistics are summarized below.

TABLE VIII.8

Farm and Farmer Factors Associated with Underdrainage

Significant Variables (Signif < 0.05)	Significance
Change of management since scheme	0.004
Farm size (ha) (Pearson's r = 0.26)	0.000
Percentage of farm that was poorly drained and in the benefit area (Pearson's r = -0.18)	0.000
Percentage of the farm that has changed land use (Pearson's r = 0.50)	0.000
Farm type	0.039
Farmers age group	0.037

continued:

Table VIII.8 continued:

Insignificant Variables (Signif > 0.05)	Significance
Change of ownership since the scheme	0.229
Farm management status	0.374
Farm tenure status	0.303
Standard man day requirement	0.133
Whether brought up on the present farm or not	0.507
Agricultural qualifications	0.672
View of farming	0.313
Membership of farming groups	0.083
Representation on committees	0.155

Secondly, all fields were divided into 2 groups, those drained post-scheme and those not. Post-scheme drainage was then cross-tabulated against a number of field level variables and Chi-squared statistics were again calculated. The results are summarized below.

TABLE VIII.9

Field Factors Associated with Underdrainage

Significant Variables (Signif < 0.05)	Significance
Field tenure status	0.000
Whether land was acquired pre- or post-scheme	0.000
Pre-scheme drainage status	0.000
Distance of field from farm	0.000
Whether field is contiguous with farm or not	0.000
Pre-scheme flood frequency	0.000
Pre-scheme land use class	0.002
Insignificant Variables (Signif > 0.05)	
Pre-scheme underdrainage	0.299

Finally, all variables with a significance of less than 0.05 were entered into a stepwise Discriminant Analysis to attempt to differentiate between those fields which have been drained since the scheme and those which have not. All fields that were not naturally freely drained were entered and 8 variables were used in the discriminant function. These related to the type of farm; percentage of the farm in the benefit area; whether or not the field had changed management since the scheme; tenure status; and the pre-scheme gross margin per hectare. The resultant discriminant function had the following standardized coefficients.

TABLE VIII.10

Drainage Installation - Standardized Discriminant Function

Variable	Standardized Coefficient
Dairy farm	-0.64
Livestock farm	-0.19
Owned land	0.62
Fully tenanted land	0.50
Farm changed management since the scheme	0.24
Field changed occupier since the scheme	0.32
Pre-scheme gross margin (per hectare)	0.14
Percentage of farm in benefit area	-0.57

The computed discriminant function correctly classified 68% of the cases (fields) entered. The standardized coefficients suggest that fields belonging to livestock or particularly dairy farms, are less likely to have been drained than others; that land that is owner-occupied or fully tenanted is more likely to have been drained than land where the tenure is less secure and that fields which were more intensively farmed prior to the scheme (and have a higher gross margin) are more likely to have been drained. The percentage of the farm in the benefit area appears to have a strong influence - where it is low, the likelihood of the fields within the benefit area being drained is higher and vice versa. Fields which have changed occupant since the scheme are more likely to have been drained.

If change of land use post-scheme is included as a discriminating variable a function which correctly classifies 76% of cases can be obtained. Pre-scheme land use also becomes a significant discriminating variable with a negative coefficient, suggesting that the lower the pre-scheme drainage class, the greater the likelihood of the field being drained following the scheme. Livestock farms and change of management are dropped from the discriminant function.

VIII.2.2.3 Change in Nitrogen Application on Grassland:

A stepwise multiple regression was carried out on all fields that have stayed in grass since the scheme to identify factors that account for the observed variation in the change in nitrogen application. All field, farm and farmer variables were entered and an equation including 13 variables emerged. The variables included related to: drainage status and underdrainage, farm type, education and training of the farmer, age and social participation of the farmer, the pre-scheme nitrogen application, change in grass conservation system, and change in the occupation of the land since the scheme. The variables included are shown below along with their standardized regression coefficients - (beta weights) - which indicate the relative contribution and direction of influence of the associated variable.

TABLE VIII.11

Factors Affecting the Increase in Nitrogen Application on Grassland

Variable	Beta Weight
Number of farming groups belong to	0.31
Livestock farm	-0.17
Agricultural education and qualifications	0.13
Pre-scheme drainage status	0.21
Arable farm	-0.13
Farmers age group	-0.18
Family to follow tenure of farm	0.14
Change of occupier since scheme	0.19
Pre-scheme 'N' application	-0.14
Pre-scheme underdrainage	-0.17
Mixed farm	0.11
Number of representations	0.09
Change in hay cutting	-0.19

$R^2 = 0.62$

The effects can be studied under the following headings:

(i) Farm type: Livestock and arable farms are associated with low increases in nitrogen application whereas mixed farms are associated with higher increases. Dairy farms do not influence either way.

(ii) Farmer characteristics: Membership of farming groups, such as NFU, CLA, IDB's or local farmers' groups has a strong positive influence upon change of nitrogen application on grassland. Representation upon farming or local council committees also has a positive, but less important, impact. Younger farmers and those who have been to college and/or have obtained an agricultural qualification are likely to have increased nitrogen application levels by more than others, as are those who have family expected to follow in the management of the farm.

(iii) Physical attributes: Sites with a wetter pre-scheme drainage status are associated with a greater increase in nitrogen post-scheme. This is as would be expected if the drainage status was precluding optimal nitrogen application. Similarly fields which were underdrained prior to the scheme are associated with lower increases in nitrogen application.

(iv) Agricultural factors: The above trend is emphasised by a negative relationship between pre-scheme nitrogen levels and the post-scheme increases. Those sites where previously application rates were necessarily low because the land was so wet, are the ones that benefit most from increased nitrogen after the scheme. Where there has been a move out of hay cutting to grazing or silage, nitrogen application rates have tended to increase more than on sites which have moved into, or stayed in hay. Change of management since the scheme also appears to be positively correlated with higher increases in nitrogen application.

VIII.2.2.4 Change in Grass Conservation System:

To examine factors influencing the change in the grass conservation system, all sites, which stayed in grass were classified into one of 3 groups, viz. no change, change from hay to zero conservation, or change from hay or zero conservation to silage. A stepwise Discriminant Analysis was again used to differentiate between the groups. As there were 3 groups, 2 discriminant functions were obtained (which between them correctly classified 74% of the cases), and therefore interpretation is more complex. The first function however appears to differentiate between those sites where no change takes place and those that have gone into silage. Characteristics associated with a change to silage are (in declining order of importance):

Smaller farms,
Sites with a low pre-scheme nitrogen application,
Farmers who sit on committees of farming or other groups,
Fields which are not tenanted,
Farmers who have been to college,
Younger farmers,

Farms which are one of a number of holdings in the same farm business,

Farms with a larger regularly employed labour force,

Farmers who are not qualified,

Farmers who were not brought up on this farm,

Farms which are not mixed,

Fields which are not owned,

Fields recently acquired,

Farms which are not livestock farms,

Fields closest to the farm,

Dairy farms,

Land that was previously wet.

(Three other variables were significant).

The sites most likely to change to silage cutting (which yields a fair benefit) are; small dairy farms which are part of a larger business and have a large regularly employed labour force; younger farmers, who have been to college (but are not qualified!) have moved from elsewhere and participate on committees of farming groups; fields which are neither owned nor tenanted; have recently been acquired; are close to the farm buildings, and previously had little nitrogen applied.

The second discriminant function appears to isolate those fields which have gone from hay to zero conservation. The characteristics associated with this group are:

Fields which are not owned,

Fields which are not fully tenanted,

Farms which are not dairy,

Smaller farms,

Younger farmers,

Individual fields, away from the farm,

Farms with a larger regularly employed labour force,

Qualified farmers,

Farms that are not livestock farms,

Farms which are one of a number of holdings in the same business,

Farmers that have not been to college,
Farmers that have arrived from elsewhere,
Land that has been recently acquired,
Land that was previously wet.
(Three other variables had significant coefficients).

The sites which are most likely to go from hay cutting to grazing are therefore; smaller arable or mixed farms and farms which are part of a larger business and have a larger regularly employed labour force; younger farmers who have not been to college and those that are qualified; who were not brought up on the present farm; individual fields away from the farm upon which there is no secure tenure, and those which have recently been acquired; also land that was previously wet.

By inference therefore the sites where no change has occurred in the grass conservation system are associated with; larger farms and those with a small regularly employed labour force and are not part of a larger business; mixed farms; older farmers who have not been to college; drier land that previously had high levels of nitrogen applied and has been under the present occupier for many years; land that is owned or fully tenanted.

VIII.2.3 <u>Summary of Factors Influencing the Nature of Uptake</u>

A comparison of factors which are associated with higher benefits from land use change, drainage, increased nitrogen application and change in the grass conservation system reveal a strong overlap between land use change and drainage and between increased 'N' and change in grass conservation. This is not surprising as there are strong interaction effects between the 2 pairs. What is more surprising is the lack of overlap between the 2 pairs - some factors are even contradictory. The only variable that appears to contribute towards explaining all 4 independents is the length of occupancy of the land. It is clear that land which changes hands after, or soon before, the scheme is more likely to change land use, be drained, increase nitrogen or change grass conservation, all in a way that will lead to high benefits. New arrivals appear to be more willing to improve the land through investment.

Land use change and drainage are both more likely on farms other than dairy farms with a low proportion within the benefit area and on farms which have changed management since the scheme. Sites with a relatively high gross margin prior to the scheme are more likely to change land use and to be drained. Pre-scheme drainage status and land use class affect post-scheme land use change but not drainage - change being more likely on previously wet, low-order land uses. Security of tenure affects the likelihood of drainage, but not land use change.

On sites which have stayed in grass, actions which are associated with higher benefits, viz. increased nitrogen application and a change from hay to grazing or silage making, are more likely on sites that were previously wetter and with a low nitrogen rate; on farms that are not livestock farms, and with farmers who are younger and those who have been to college and are qualified in some aspect of agriculture. Also farmers who show social participation in representation upon committees of farming groups, IDB's or local councils are more likely to take up potential benefits on grassland. Change in nitrogen rate is associated with a change in grass conservation. A movement out of hay cutting seems also to be associated with farms which are one of a number of holdings in a larger business with more regular employees.

VIII.3 VARIATION IN THE RATE OF BENEFIT UPTAKE

VIII.3.1 Observed Variation in the Rate of Benefit Uptake

The field by field analysis of financial benefits revealed that fields may be classified into one of 3 groups upon the basis of the rate at which financial benefits are taken up: those with no take-up of potential benefits; those where the take-up is gradual; and those where take-up is abrupt. The relative importance of these 3 types can be seen from Table VIII.12 below.

TABLE VIII.12

Types of Benefit Uptake

Type of Uptake	% of Sites	% of Benefit (1)	% of Area
Negative or zero uptake	52	-	44 46
Abrupt uptake (2)	35	75	37 38
Gradual uptake	14	25	15 16
Total	100	100	100

Notes:

(1) Excluding negative benefits. Measured as the difference in gross margin.

(2) Defined as sites where 50% or more of the increase in gross margin occurred in one year.

Three-quarters of the financial benefits observed (measured in terms of the change in gross margin) occurred on sites where over 50% of the benefit arose in one year. The timing of benefit uptake is critical where discounting techniques are used for scheme investment appraisal.

Generally, the approach adopted in the study of take-up of new farming practices has been to place farmers on a continuum of adopter categories ranging from innovators to laggards, and to study differences in the characteristics of farmers in the 2 extreme groups. Korsching <u>et al</u> (1983), for example, studied the rate of adoption of minimum tillage practices amongst farmers in Iowa and found results consistent with the traditionally expected characteristics of innovators (see Annexe II). In the study of uptake of potential benefits of land drainage improvement schemes, however, the situation is more complicated. The dependant variable, in this case, uptake of benefits, is not binomial, that is at any point in time farmers cannot be classified into those who have, and those who have not, taken up potential benefits. Some may have taken up potential benefits on one part of the farm, but not on another. Even at field level the binomial situation does not exist; part of the potential benefit may have been taken up (eg. the land may have been drained) but there may still be further potential (eg. a change to a higher order land use class).

It is therefore more useful to look at the components of the benefit and study rates of take-up of these. These can then be related to the financial benefit. Section VIII.2 showed how the value of the benefit was related to change in land use, drainage installation, change in nitrogen application and change in the conservation of grass in addition to automatic benefits. Automatic benefits tend to occur immediately after the scheme and these are not dependant upon the farmer. Change in nitrogen application (where not accompanied by any other change) tends to occur gradually over the life of the scheme until a plateau is reached. Again therefore it is not possible to identify factors encouraging rapid uptake. No data were collected regarding the timing of changes in grass conservation and in any case this is influenced by factors exogenous to the scheme (eg. the development of the 'bagged' silage system).

Data are available, however, for the timing of underdrainage and land use change, both of which were shown to be significantly correlated with the timing of major increases in financial benefits (at the 0.1% level). Regression equations showed that the timing of financial uptake could be predicted from the date of underdrainage or particularly land use change where appropriate ($R^2 = 0.61$ and 0.83 respectively). It is therefore anticipated that factors associated with early land use change and/or drainage will be associated with early uptake in financial terms.

VIII.3.2 Factors Influencing the Rate of Uptake of Potential Benefits

Table VIII.13 below shows the relationship between the classes of uptake defined above and drainage and land use change.

TABLE VIII.13

Land Use Change and Underdrainage by Type of Uptake

Land use change Drainage	NO NO	NO YES	YES NO	YES YES	TOTAL No. of sites
No benefits from scheme	328	15	50	10	403
Abrupt uptake	83 (1)	57	56	78	274
Gradual uptake	65	4	7	31	107
Total	476	76	113	119	784

Significance of Chi-square = 0.000

Notes:

(1) Largely sites where only automatic benefits have accrued, or the farm has changed occupant.

Stepwise multiple regression techniques were used to attempt to derive equations for predicting the timing of uptake on sites where it has been abrupt. Three variables were taken as the dependants. These were:

- the timing of financial uptake (measured as the year in which 50% or more of the change in gross margin occurred),
- the timing of drainage,

and - the timing of land use change.

No meaningful equation could be derived for the timing of financial uptake from the farm, farmer and field variables, however high R^2 values were obtained for regressions on the other 2 dependants.

VIII.3.2.1 Timing of Land Use Change:

Twelve independant variables were included in the final regression equation on the timing of land use change and these are summarized with the relevant Beta weights below.

TABLE VIII.14

Variables Associated with Timing of Land Use Change

Field Variables	Beta Weight
Pre-scheme flood frequency	-0.41
Post-scheme flood frequency	0.58
Soil type : peat	0.22
Distance of field from the farm buildings	0.43
Pre-scheme underdrainage	0.22
Length of occupancy prior to scheme	0.24
Pre-scheme drainage status	0.17
Magnitude of the land use change	-0.58
Farm/Farmer Variables	
Change of management since the scheme	0.10
Agricultural education and qualification	-0.28
Farmers age group	-0.45
Number of holdings farmed	-0.19

$R^2 = 0.77$

A high pre-scheme flood frequency appears to be associated with early change of land use and a high post-scheme flood frequency with later change, suggesting that where there has been a major reduction in flood frequency following the scheme, land use change tends to occur earlier than on sites where the reduction in flood risk has been less marked. Equally important appears to be the magnitude of the 'shift' in land use class. A major change, such as from permanent pasture to continuous cropping has tended to occur sooner than more minor changes (eg. permanent to temporary grass or rotation to coninuous crops).

The variables referring to pre-scheme drainage suggest that the wetter sites change later in the life of the scheme, but so do sites with existing underdrainage. Sites with shorter occupancies tend to change land use earlier as do sites further away from the farm buildings. Sites on peat soils also appear to have changed land use later than others.

Farms where the management has changed since the scheme tend to change later, presumably reflecting the time of take-over. Early change of land use is associated with farmers who are younger and those who have been to college and have a formal agricultural qualification. Additionally, where the farm with land in the benefit area is one of a number of holdings comprising the farm business, change tends to occur earlier.

If post-scheme drainage is included as an independent variable the R^2 value increases to 0.80. The beta weight for post-scheme drainage is -0.20 indicating that where there is a major change involving drainage and land use change, the change takes place relatively soon after the scheme.

VIII.3.2.2 Timing of Drainage Installation:

Eleven variables were included in the multiple regression equation to explain variations in the timing of drainage. These were largely physical descriptions of the land and variables relating to the length of occupancy of the land. The variables included are summarized below.

TABLE VIII.15

Variables Associated with Timing of Underdrainage Installation

Field Variables	Beta Weights
Pre-scheme flood frequency	-0.41
Post-scheme flood frequency	0.44
Soil type : peat	0.39
: loam	0.20
Pre-scheme underdrainage	0.41
Distance of field from farm	0.39
Length of occupancy prior to the scheme	0.36
Post-scheme land use class	-0.39
Farm/Farmer Variables	
Whether farm has changed management	0.29
Whether field is owned	-0.15
View of farming	-0.34

$R^2 = 0.65$

As with land use change, early drainage installation tends to be associated with sites where the change in flood frequency has been highest and those which were not drained prior to the scheme. It appears that peat and loam soils are later drained than other soils, suggesting that clay soils are drained earlier and sites with no previous underdrainage tend to be drained before the redraining of sites with old drains. Fields closer to the farm tend to be drained earlier than those away from the farm and fields which change to higher order land uses tend to be drained early after the scheme.

Fields of farms where the management has changed since the scheme tend to be drained later, presumably reflecting the time of change and the length of occupancy appears to be important with fields that have recently come under the present occupier being drained earlier than those with a long occupation. The tenure status of the field is relevant with fields that are owner occupied tending to be drained somewhat earlier than others.

The farmer's attitude towards farming was the only farmer level variable that was included in the regression equation but the beta coefficient is contradictory to what would have intuitively been expected. Those who purported to view farming as a way of life and did not place great emphasis on profits tended to drain earlier than those who admitted to being more profit orientated. The farm survey however exposed the weakness of this type of question: those who were successful and making a healthy profit were in a position to say that the way of life was most important, whereas those who had not invested in their land and were struggling placed more emphasis upon profit.

VIII.3.3 Summary of Factors Explaining Rate of Land Use Change and Drainage Installation

A number of variables are common to the regression equations for date of drainage and date of land use change. In both cases, physical parameters appear to be of primary importance. A high pre-scheme and low post-scheme flood frequency are associated with early uptake, and sites which were already underdrained with late uptake. Benefits appear to be taken up on sites nearer to the farm buildings before those further away. Major changes in land use tend to occur earlier in the life of the scheme than more minor changes and drainage tends to have occurred sooner if the post-scheme land use is of a higher order. Peat soils appear to be associated with later uptake of drainage and land use change. This was a little surprising given the observed rapid uptake on the schemes on the River Idle (see where much of the soil is peat. However it appears that when all other factors are taken into consideration the effect of peat soil is to encourage later uptake. It is understandable that peat and loam soils, which are generally less dependant upon underdrainage than clay soils tend to be drained later.

The length of occupancy prior to the scheme has an important influence upon rapid uptake with land use change and underdrainage occurring earlier on sites with shorter occupation. The fact that farms which have changed management since the scheme appear to take up benefits later is not contradictory to previous observation as if a farm is taken over later in the scheme history, rapid uptake by the new occupier (suggested by the short occupation time) will still be later in the life of the scheme.

It is interesting to note that the timing of land use change is influenced by the pre-scheme drainage status, with drier sites having changed earlier, yet the timing of drainage installation appears to be independent of the pre-scheme drainage status.

Farm and farmer variables appear less important in accounting for the observed variations in the timing of land use change and drainage. The age and training of the farmer are associated with land use change, with younger, more educated farmers having changed earlier in the life of the scheme, but are not associated with the timing of drainage. The farmer's view of farming as a business is associated with drainage installation but as explained earlier, not necessarily in the direction that might at first be expected.

The low significance of farm and farmer over field variables confirms the suspicion that farmers cannot be classifed in terms of innovators and laggards. It is pertinent to note that drainage within the benefit area often occurs at a number of times throughout the life of the scheme on a single farm. The average length of time between the first and last drainage installations was 2 years and this figure included those where only one block had been drained. The standard deviation was also high (3.8 years) suggesting that many farms are drained over a large number of years. The relatively high emphasis placed by farmers who have drained on future drainage work within the benefit area implies that in most cases there are still fields that would benefit from underdrainage (see section VIII.6).

VIII.4 UPTAKE CURVES

VIII.4.1 Financial Benefit

The observed values for net returns for each year of the project life were converted to a per-hectare benefit by subtracting the pre-scheme net return, and were converted from absolute years to relative 'project' years. The mean benefit, and standard deviation, were calculated for each year from one to 25. As the number of years observed ranged from 2 years for the River Idle (stage 4) to 25 years for the Beckingham Marshes, the size of the sample varies from 5557 ha for year one to 941 ha for years 13 to 25 (see Figure VIII.1).

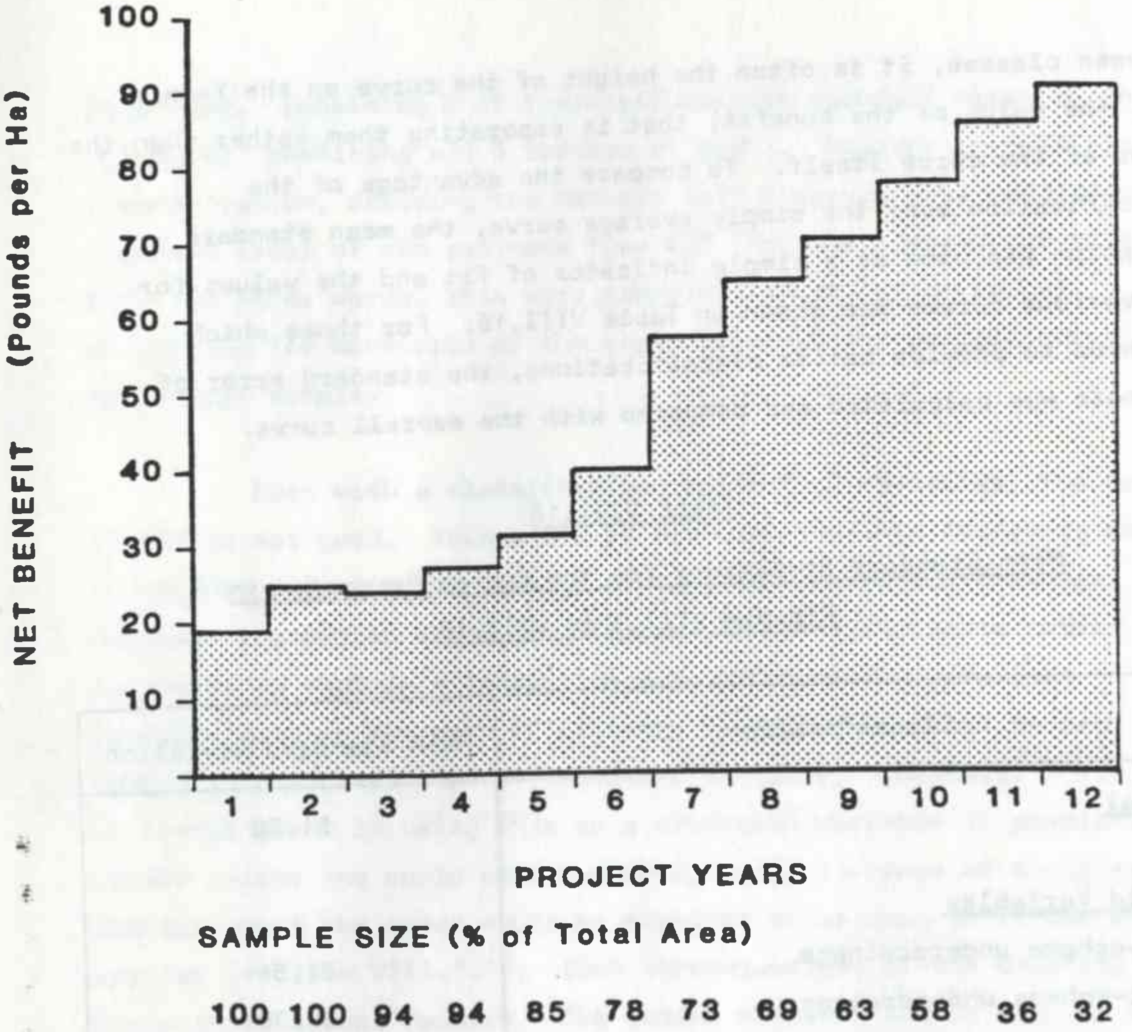
The mean benefit for each year was plotted to derive an overall uptake curve for the entire sample. This is shown in Figure VIII.1. The distribution of points about the curve is wide and was measured by the standard error of estimate.

Figure VIII.2 shows that the pattern of uptake of benefits does not follow the normal distribution that would be expected from traditional patterns of innovation diffusion. What is more apparent is a distinction between 'automatic' benefits that arise during the first 2 years of the project life and the 'uptake' benefits that occur later. The presentation of these data in cumulative form (Figure VIII.1) suggests that the traditional 'S'-curve of uptake does exist but only after the automatic benefits have been accounted for. It is pertinent to note that if the data for the Beckingham Marshes scheme are examined for years 13 to 25 the curve flattens off and then rises sharply in a second 'S'. This late rise coincides with the installation of the new IDB pumping station in 1977 and presumably reflects benefits due to it. For the purposes of the present analysis year 12 has been taken as a cut-off point. It is likely that the curve could be extrapolated to year 16, but by then most of the likely uptake will have occurred.

A number of classifications were examined in an attempt to derive a suite of uptake curves which would maximize the difference between, and minimise the scatter of points within classes. The variables chosen to differentiate between the groups were simple and easily measurable because, if the curves are to be used for simple prediction, complex multivariate interactions would be inappropriate. The variables that were shown to be correlated with rapid uptake of drainage and land use change were examined first.

The curves are shown in Figures VIII.3 to VIII.16 with the aggregate curve for the entire sample shown in faint. Although a number of the classifications appear to differentiate

FIGURE VIII.1 : Mean Financial Uptake Curve



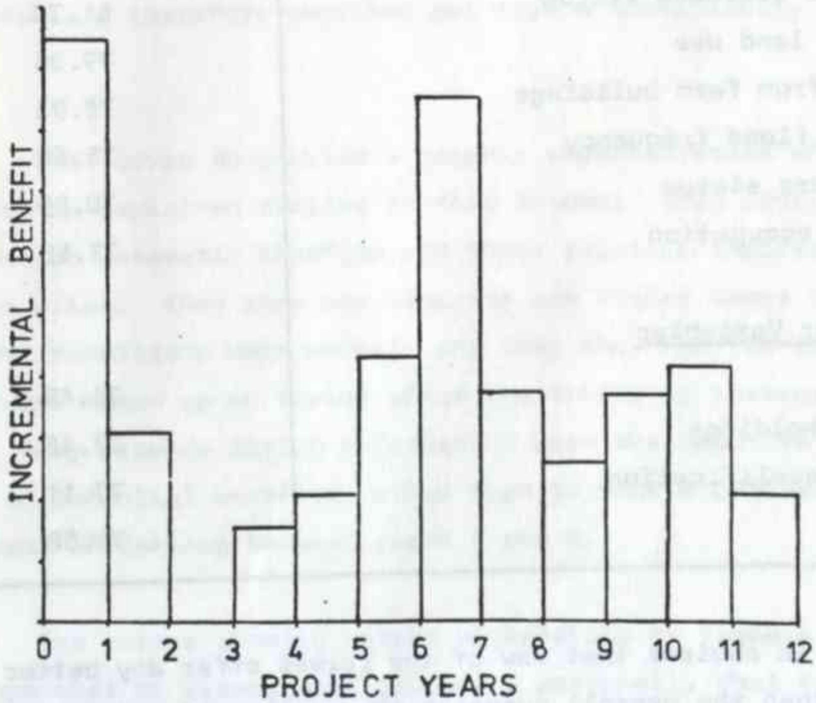


FIGURE VIII.2 : Incremental Benefit

between classes, it is often the height of the curve on the Y-axis (ie. the value of the benefit) that is separating them rather than the shape of the curve itself. To compare the advantage of the classification over the simple average curve, the mean standard deviation was used as a simple indicator of fit and the values for the various curves are shown in Table VIII.16. For those which appeared to provide better classifications, the standard error of estimate was calculated and compared with the overall curve.

TABLE VIII.16

Mean Standard Deviations for the Curves Presented in Figures VIII.3 to VIII.16

Classification	Mean Standard Deviation
Total	81.20
Field Variables	
Pre-scheme underdrainage	81.56
Post-scheme underdrainage	82.30
Pre-scheme drainage status	81.70
Change of land use	79.36
Distance from farm buildings	78.93
Change in flood frequency	75.68
Field tenure status	70.99
Length of occupation	79.50
Farm/Farmer Variables	
Farm type	74.40
Number of holdings	77.48
Education/qualification	77.11
Age group	71.88

It is obvious that few of the curves offer any better explanation than the overall curve as the scatter of points is wide. The 3 best classifications appear to be field tenure, age group and farm type. Combining 2 of these reduced the standard error of the estimate; combining all 3 reduced it again. However, a multiple classification, dividing the farmers into 5 groups only reduced the standard error of the estimate from £78 (for the overall curve) to £67. In other words, this more complex classification is not accounting for much more of the variation than the overall curve for the entire sample.

Even with a classification based on 3 variables, the degree of fit is not good. This would be expected from the foregoing study of factors affecting the timing of land use change and drainage. Both multiple regression equations required a relatively large number of variables to explain a fairly low proportion of the variation (particularly in the case of drainage installation), and in each case, change of occupation was an important variable. Obviously there would be little point in using this as a criterion variable in predicting uptake unless one could satisfactorily predict change of occupier. The scatter about the curve would be expected to be wide as it was shown earlier (section VIII.3.1), that three-quarters of the benefits occur in an abrupt fashion. The uptake curves shown in Figures VIII.3 to VIII.16 are therefore smoothed out from a multiplicity of abrupt steps.

The curves do provide a graphic representation of relationships explained earlier in this Annexe; they underline the importance of automatic benefits and their relative importance on different sites; they show how benefits are higher where the pre-scheme conditions were worse; and they show how few potential benefits are taken up on fields where the tenure is insecure. However, they provide little information upon the relative rate of take-up of potential benefits, other than to show a general increase in the rate of take-up between years 5 and 8.

The curves showing uptake of benefits by farmers of different age groups must be viewed with caution - especially that for young farmers. Forty percent of the land farmed by young farmers belonged to farms that have changed ownership since the scheme and 75% to farms

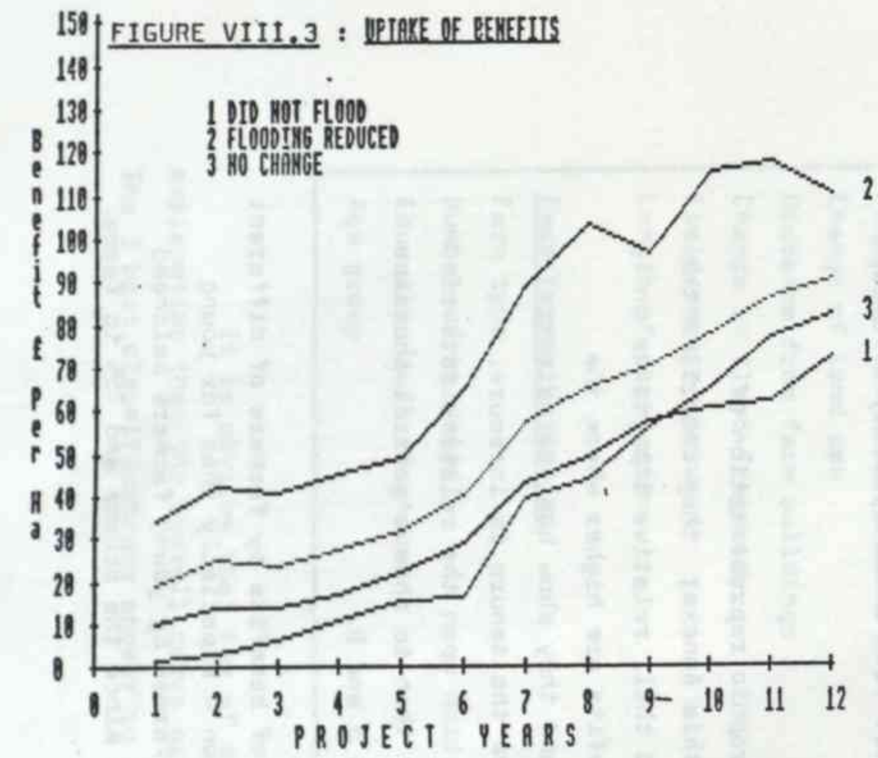


FIGURE VIII.3 : UPTAKE OF BENEFITS
1 DID NOT FLOOD
2 FLOODING REDUCED
3 NO CHANGE
Benefit £ Per Ha
PROJECT YEARS
2
3
1

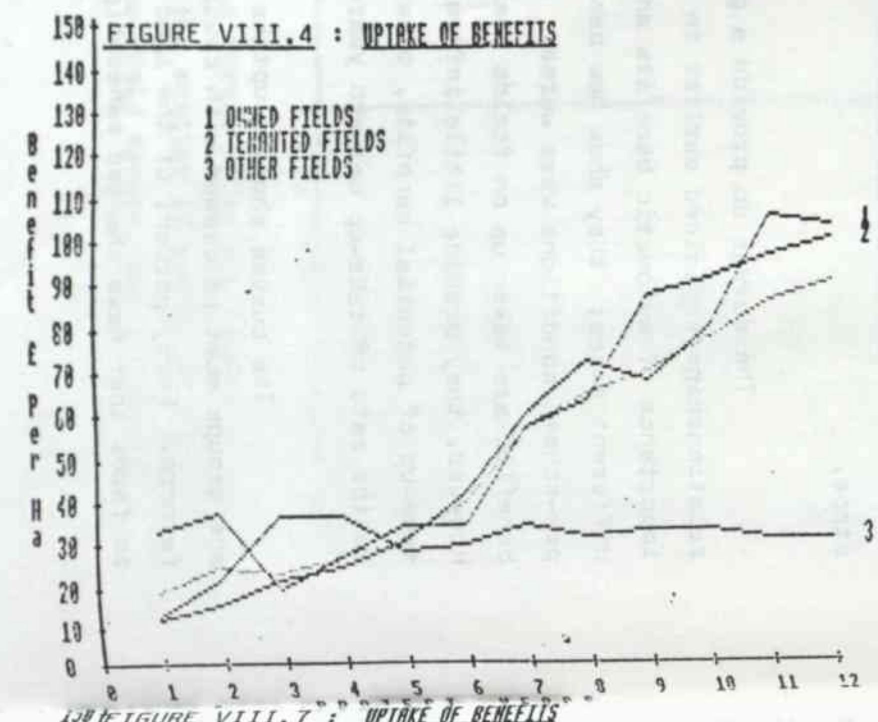


FIGURE VIII.4 : UPTAKE OF BENEFITS
1 OWNED FIELDS
2 TENANTED FIELDS
3 OTHER FIELDS
Benefit £ Per Ha
1
2
3

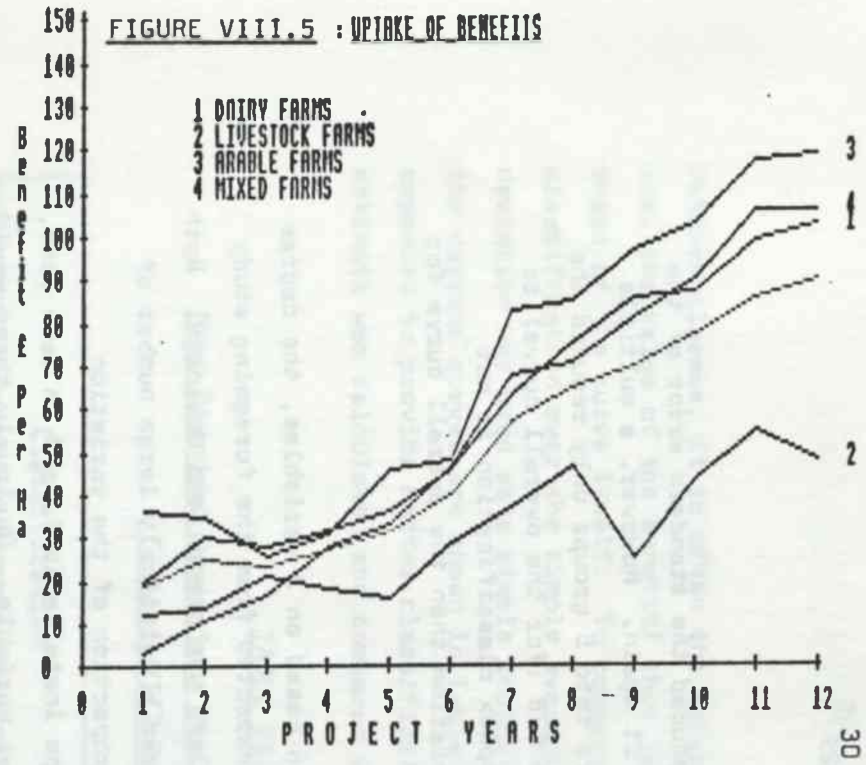


FIGURE VIII.5 : UPTAKE OF BENEFITS
1 DAIRY FARMS
2 LIVESTOCK FARMS
3 ARABLE FARMS
4 MIXED FARMS
Benefit £ Per Ha
PROJECT YEARS
3
4
1
2

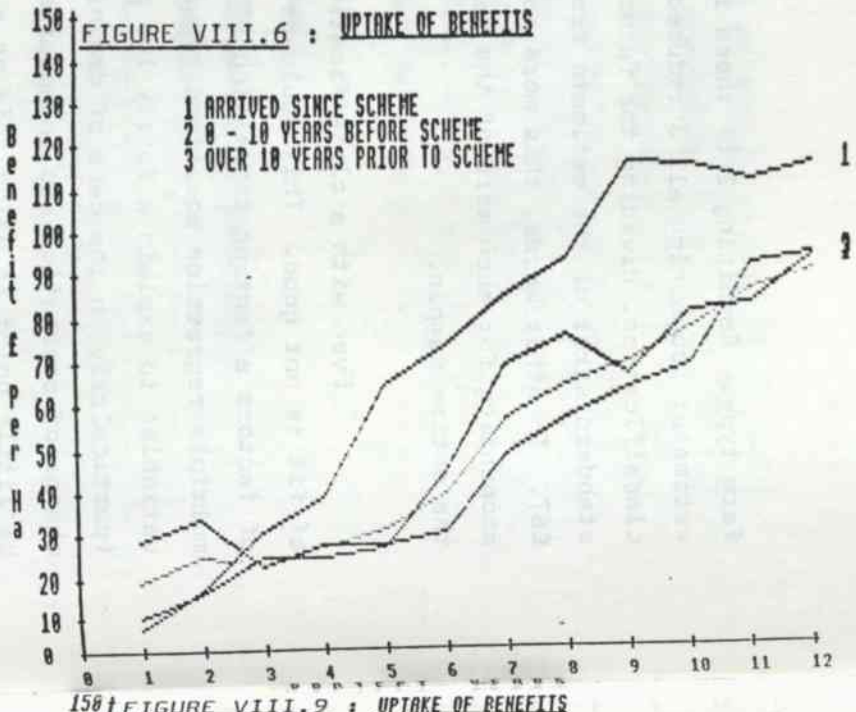


FIGURE VIII.6 : UPTAKE OF BENEFITS
1 ARRIVED SINCE SCHEME
2 0 - 10 YEARS BEFORE SCHEME
3 OVER 10 YEARS PRIOR TO SCHEME
Benefit £ Per Ha
1

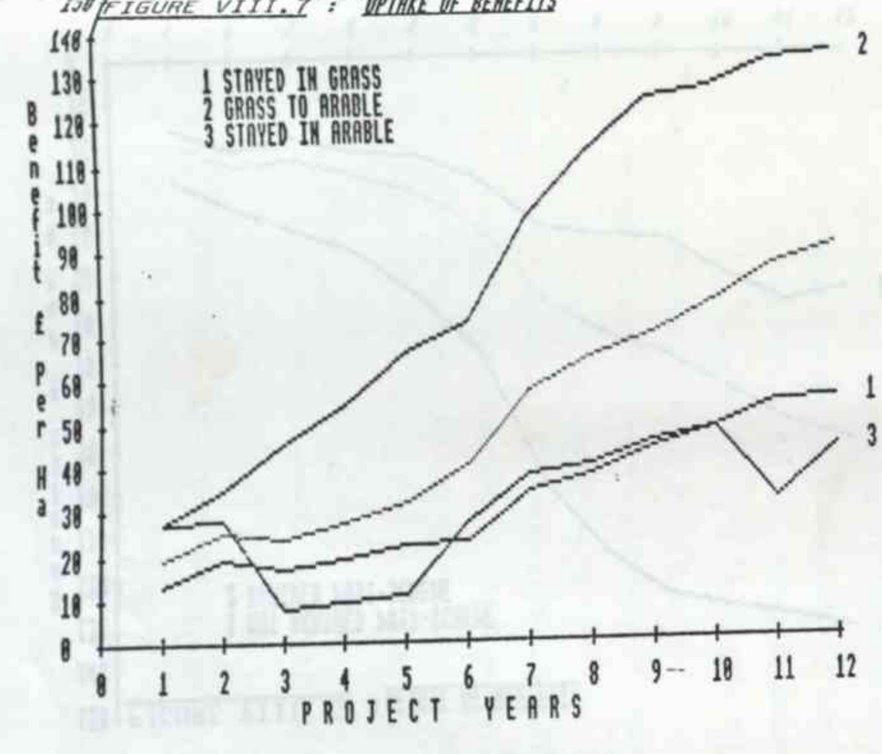


FIGURE VIII.7 : UPTAKE OF BENEFITS
1 STAYED IN GRASS
2 GRASS TO ARABLE
3 STAYED IN ARABLE
Benefit £ Per Ha
PROJECT YEARS
2
1
3

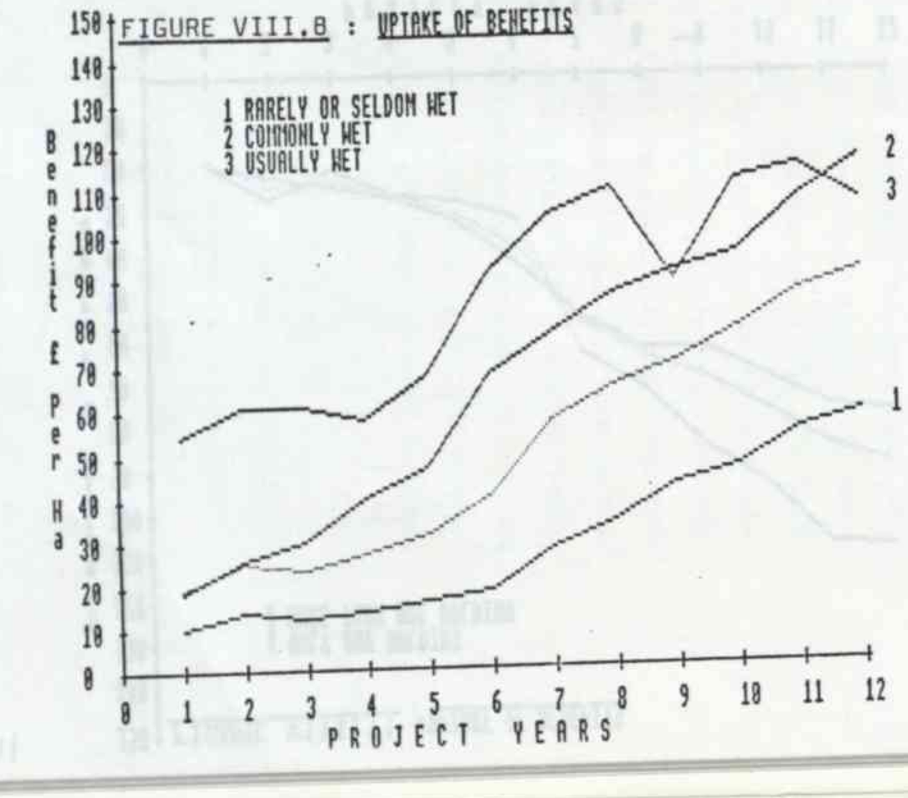


FIGURE VIII.8 : UPTAKE OF BENEFITS
1 RARELY OR SELDOM WET
2 COMMONLY WET
3 USUALLY WET
Benefit £ Per Ha
PROJECT YEARS
2
3
1

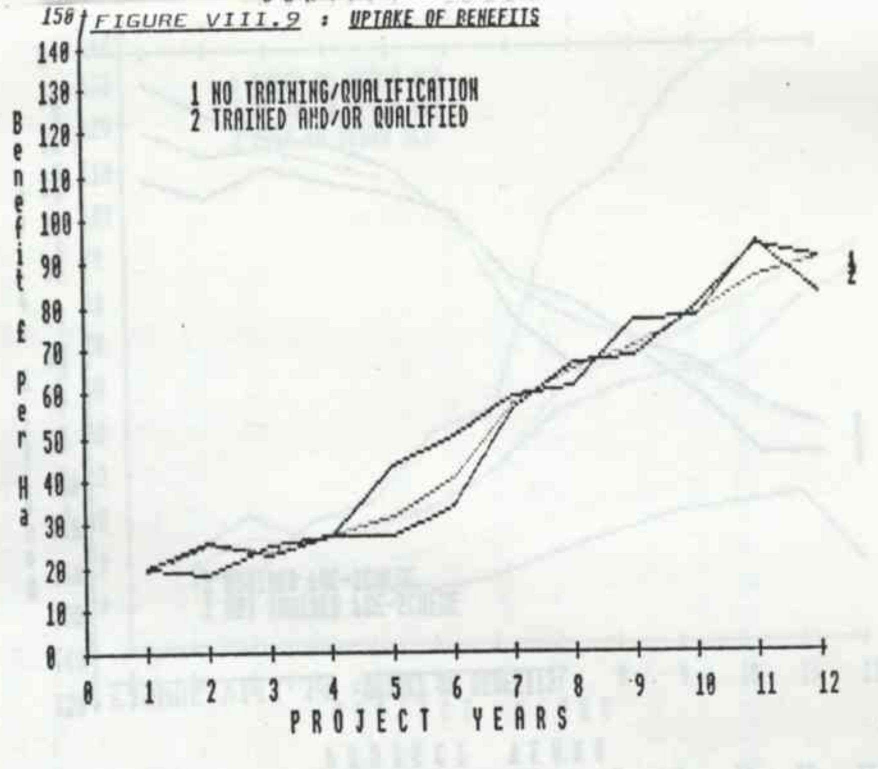


FIGURE VIII.9 : UPTAKE OF BENEFITS
1 NO TRAINING/QUALIFICATION
2 TRAINED AND/OR QUALIFIED
Benefit £ Per Ha
PROJECT YEARS
2

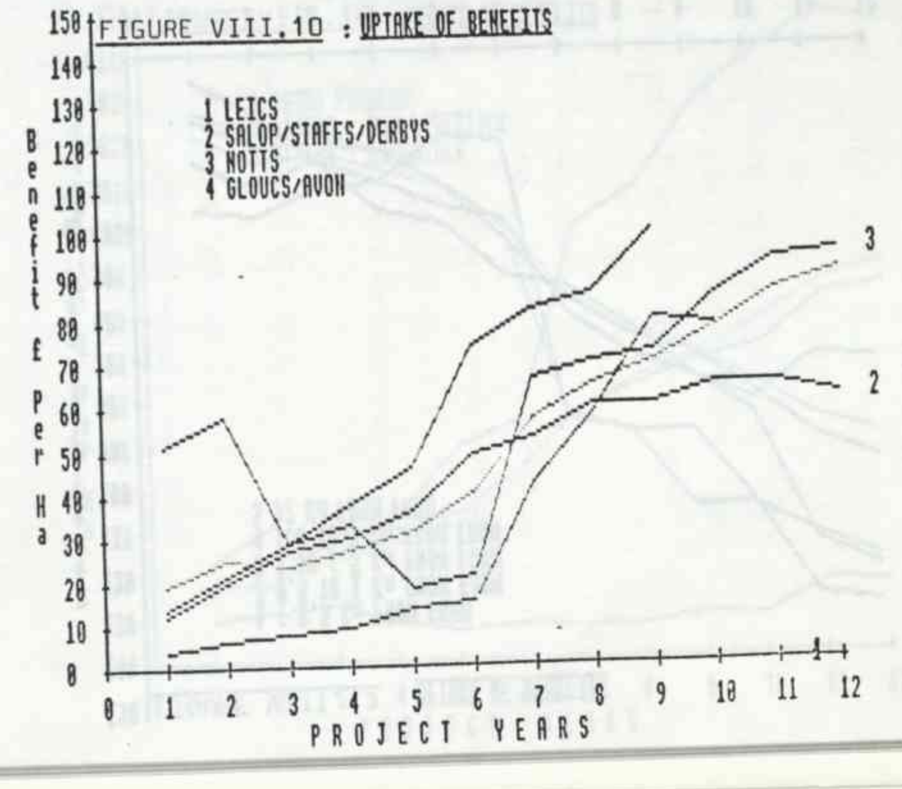


FIGURE VIII.10 : UPTAKE OF BENEFITS
1 LEICS
2 SALOP/STAFFS/DERBYS
3 NOTTS
4 GLOUCS/AVON
Benefit £ Per Ha
PROJECT YEARS
3
2
1

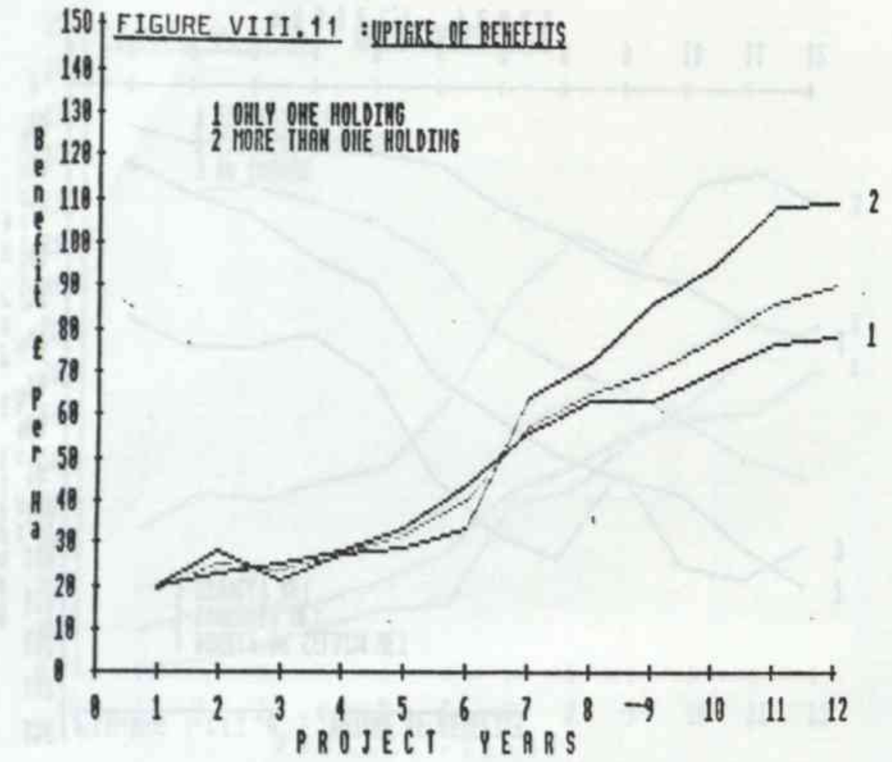


FIGURE VIII.11 : UPTAKE OF BENEFITS
1 ONLY ONE HOLDING
2 MORE THAN ONE HOLDING
Benefit £ Per Ha
PROJECT YEARS

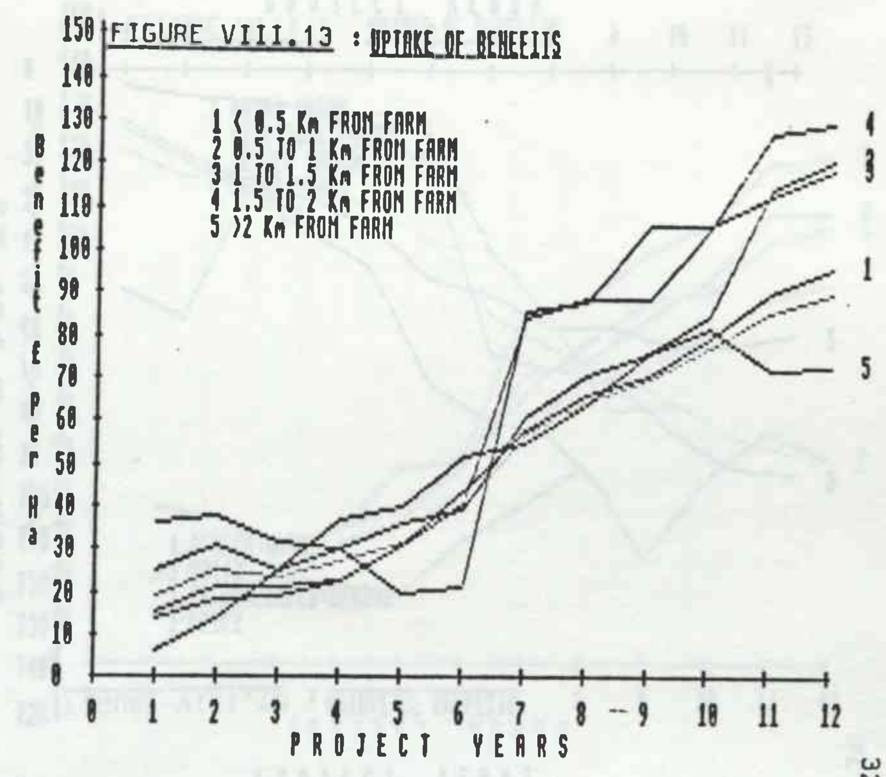


FIGURE VIII.13 : UPTAKE OF BENEFITS
1 < 0.5 Km FROM FARM
2 0.5 TO 1 Km FROM FARM
3 1 TO 1.5 Km FROM FARM
4 1.5 TO 2 Km FROM FARM
5 >2 Km FROM FARM
Benefit £ Per Ha
PROJECT YEARS

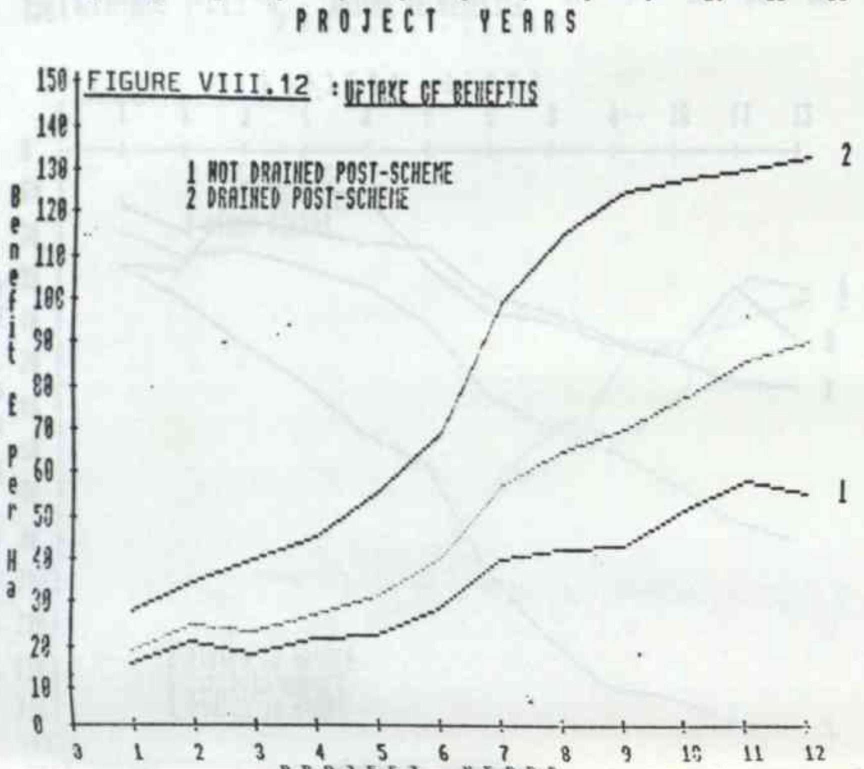


FIGURE VIII.12 : UPTAKE OF BENEFITS
1 NOT DRAINED POST-SCHEME
2 DRAINED POST-SCHEME
Benefit £ Per Ha
PROJECT YEARS

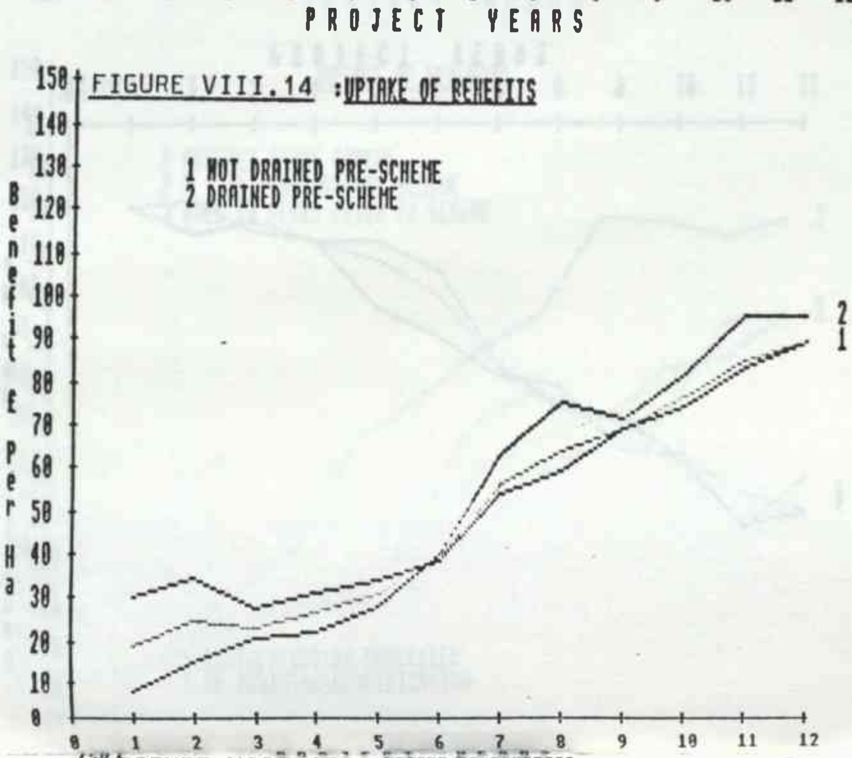


FIGURE VIII.14 : UPTAKE OF BENEFITS
1 NOT DRAINED PRE-SCHEME
2 DRAINED PRE-SCHEME
Benefit £ Per Ha

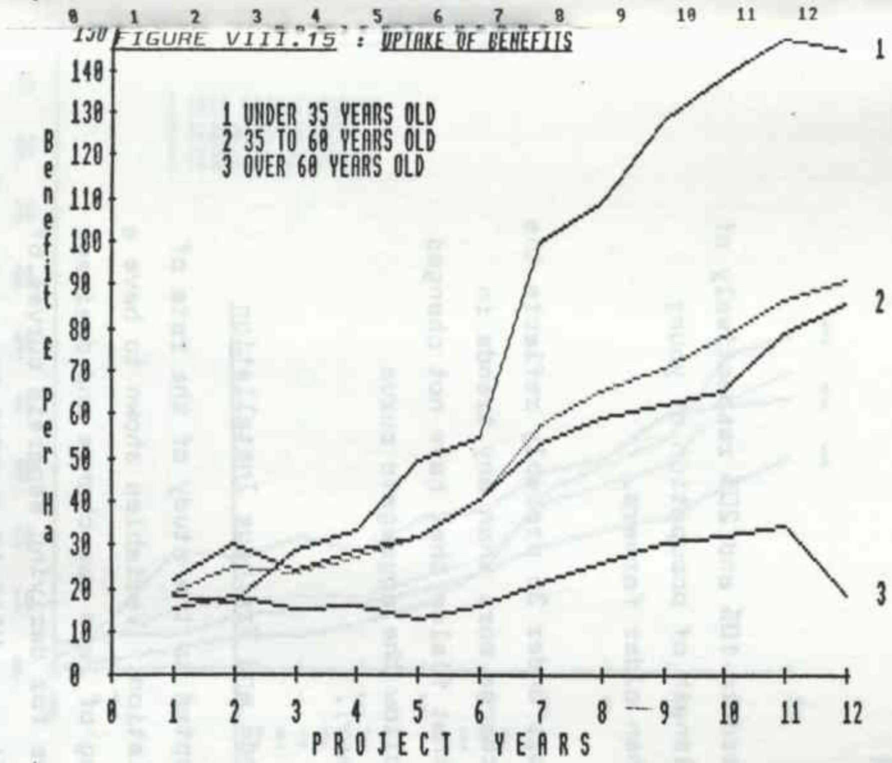


FIGURE VIII.15 : UPTAKE OF BENEFITS
1 UNDER 35 YEARS OLD
2 35 TO 60 YEARS OLD
3 OVER 60 YEARS OLD
Benefit £ Per Ha
PROJECT YEARS

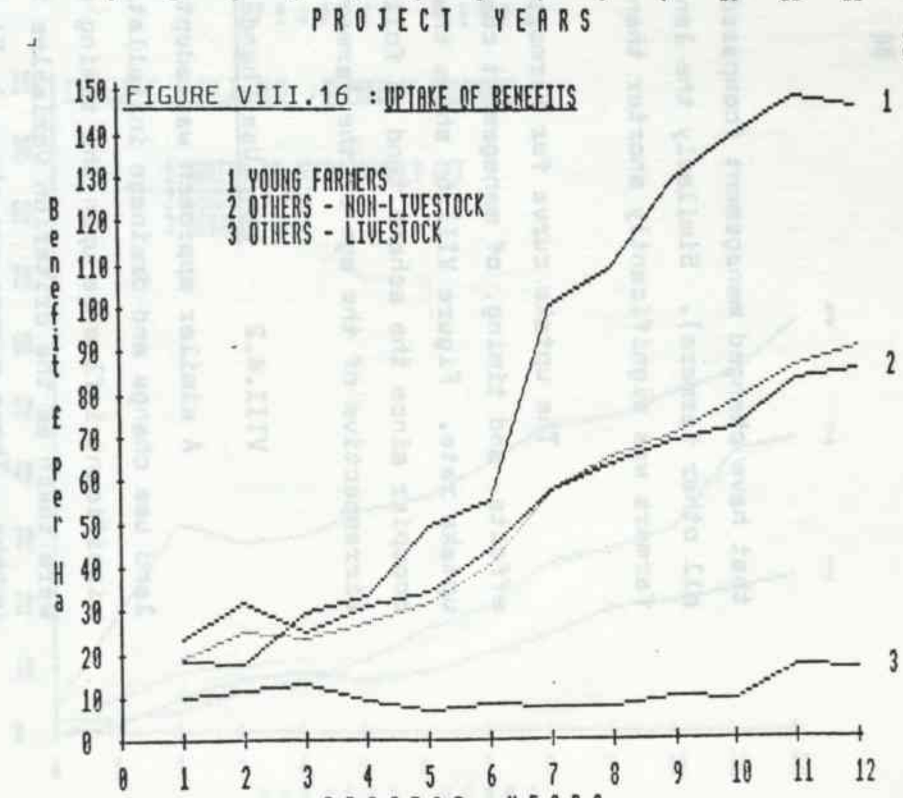


FIGURE VIII.16 : UPTAKE OF BENEFITS
1 YOUNG FARMERS
2 OTHERS - NON-LIVESTOCK
3 OTHERS - LIVESTOCK
Benefit £ Per Ha
PROJECT YEARS

that have changed management (compared to 10% and 20% respectively of all other farmers). Similarly the length of occupation of young farmers was significantly shorter than older farmers.

The uptake curve for farmers under 35 probably reflects the effects, and timing, of management change more than any trends in uptake rate. Figure VIII.6 shows that fields that have not changed occupier since the scheme tend to follow the aggregate curve (irrespective of the age of the farmer).

VIII.4.2 Land Use Change and Drainage Installation

A similar approach was adopted to the study of the rate of land use change and drainage installation. Variables shown to have a significant influence upon the timing of land use change and drainage were taken as the criterion variables for deriving separate curves of uptake. These curves are shown in Figures VIII.17 to VIII.28, with the aggregate curve shown in faint in each case. These curves are less remarkable than the curves for financial benefit shown earlier and again tend to discriminate between the total areas involved in each case (the height of the curve) rather than the rate of uptake (the shape of the curve). For example, more land appears to change use if the frequency of flooding has been reduced but the rate of change is very similar to that on land which was previously free from flooding. Studying the standard errors of estimate (Table VIII.17) for the various curves reveals that there is little if any reduction in scatter by plotting separate curves for many of the classifications. The best set of curves are those based on pre-scheme underdrainage and pre-scheme drainage status for land use change and drainage respectively. The standard error of estimate, however, is only reduced by 5% and 3% respectively: a negligible improvement. These curves therefore provide little extra information on the rate of benefit take-up over the aggregate curves.

It is pertinent to note the different shape of the aggregate curves for land use change and drainage installation (Figures VIII.29 and VIII.30). The former shows a convex curve with more rapid uptake in earlier years, and the latter a concave curve with drainage installation increasing after years 5 to 7.

FIGURE VIII.17 : UPTAKE OF DRAINAGE

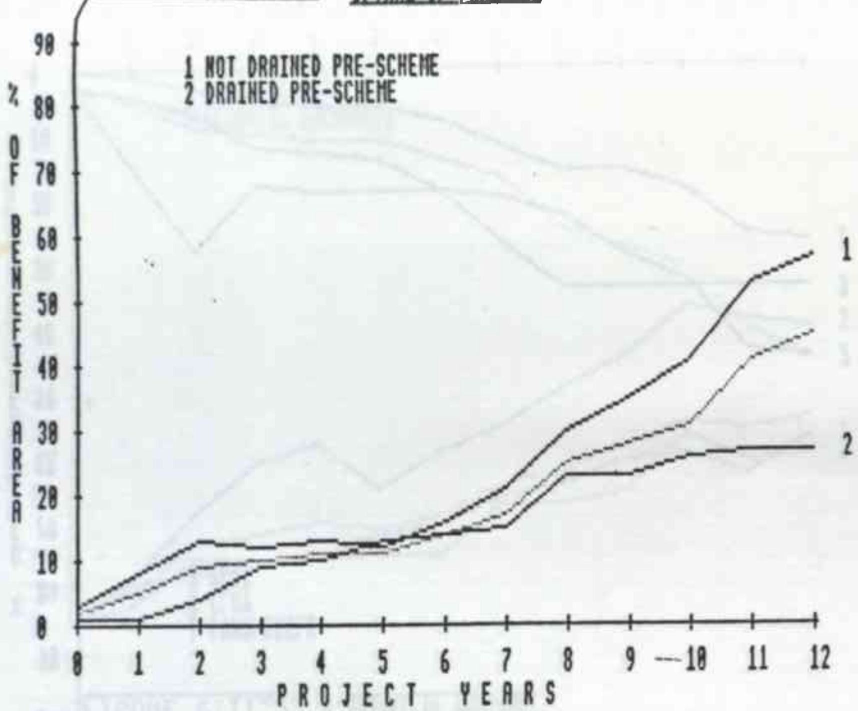


FIGURE VIII.19: UPTAKE OF DRAINAGE

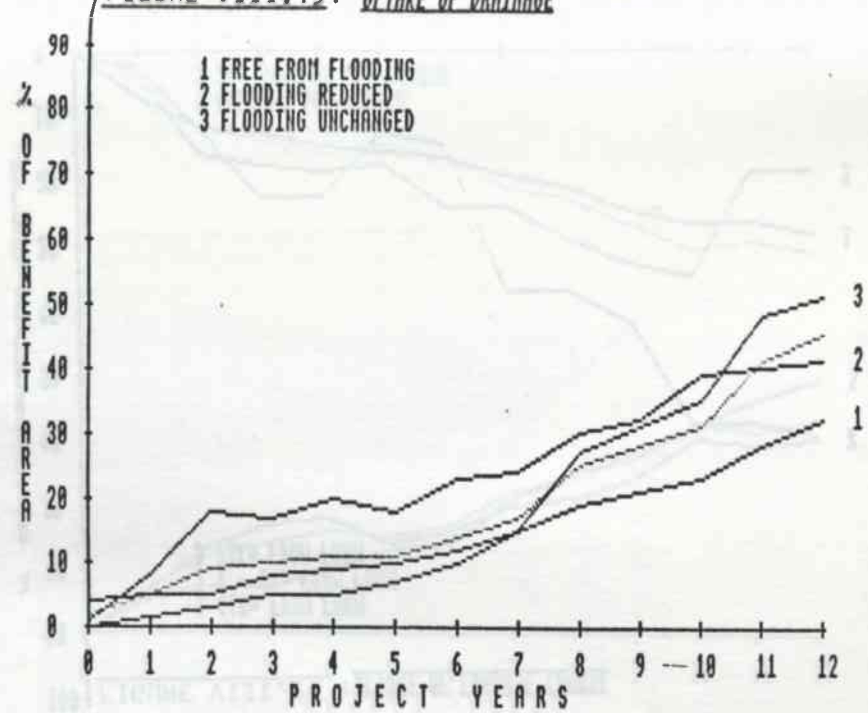


FIGURE VIII.18 : UPTAKE OF DRAINAGE

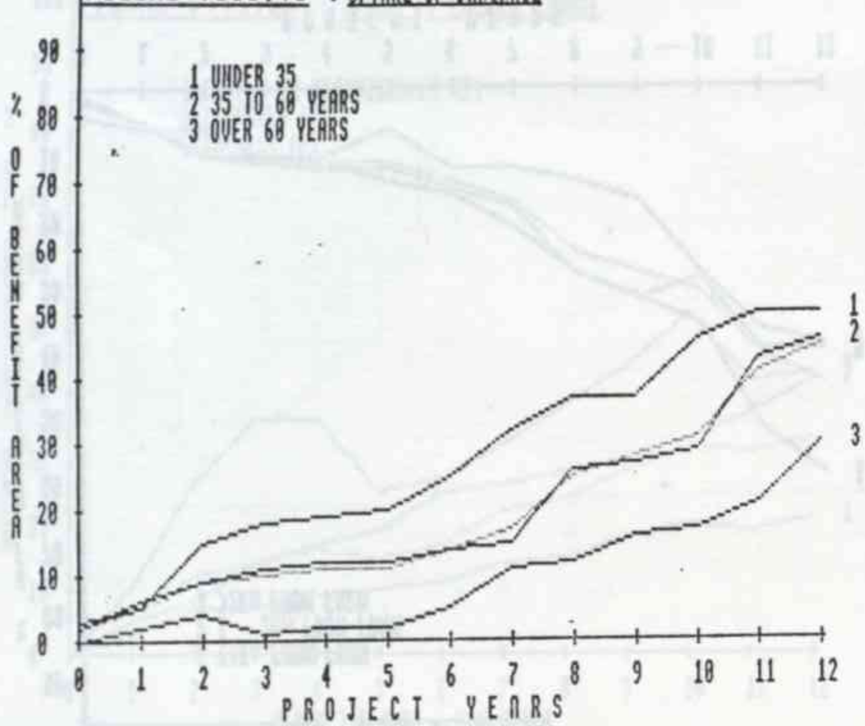


FIGURE VIII.20 : UPTAKE OF DRAINAGE

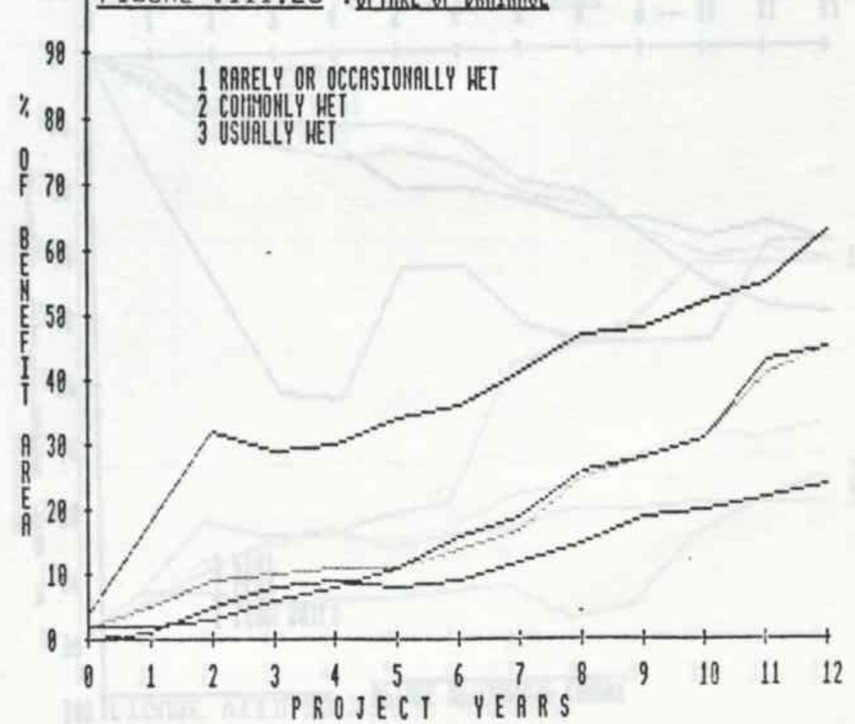


FIGURE VIII.21 : UPTAKE OF DRAINAGE

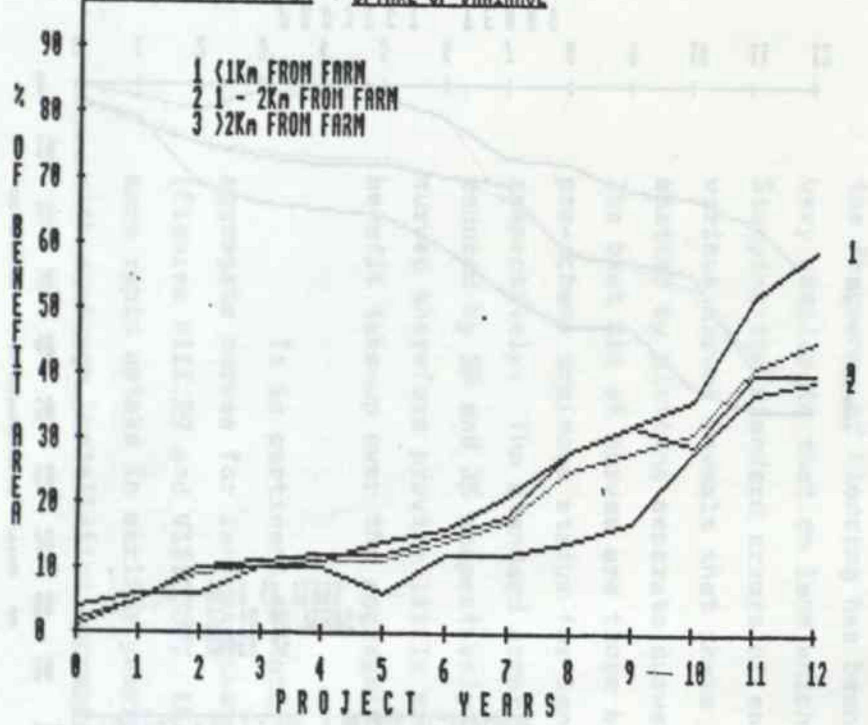


FIGURE VIII.22 : UPTAKE OF DRAINAGE

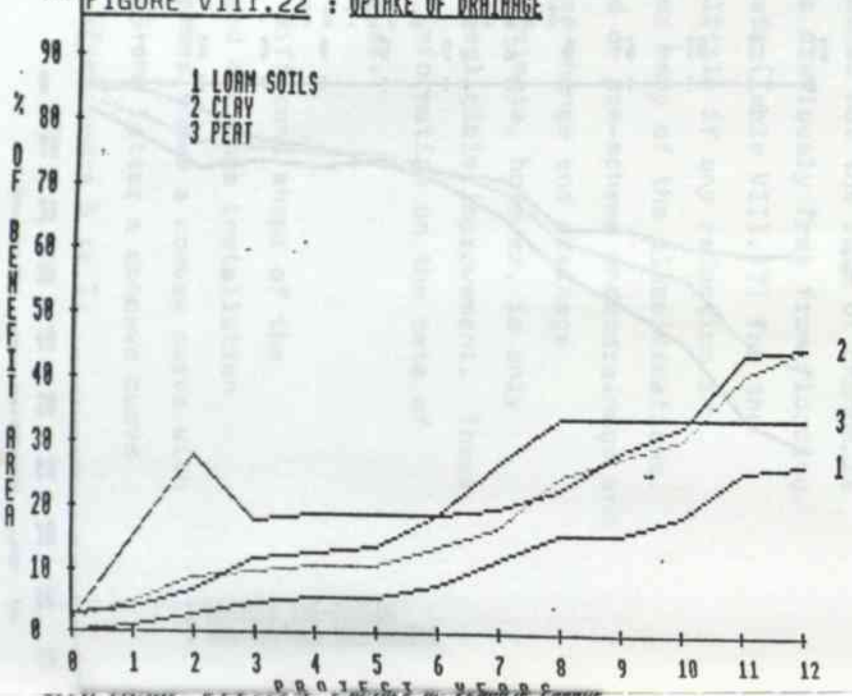


FIGURE VIII.23 : UPTAKE OF LANDUSE CHANGE

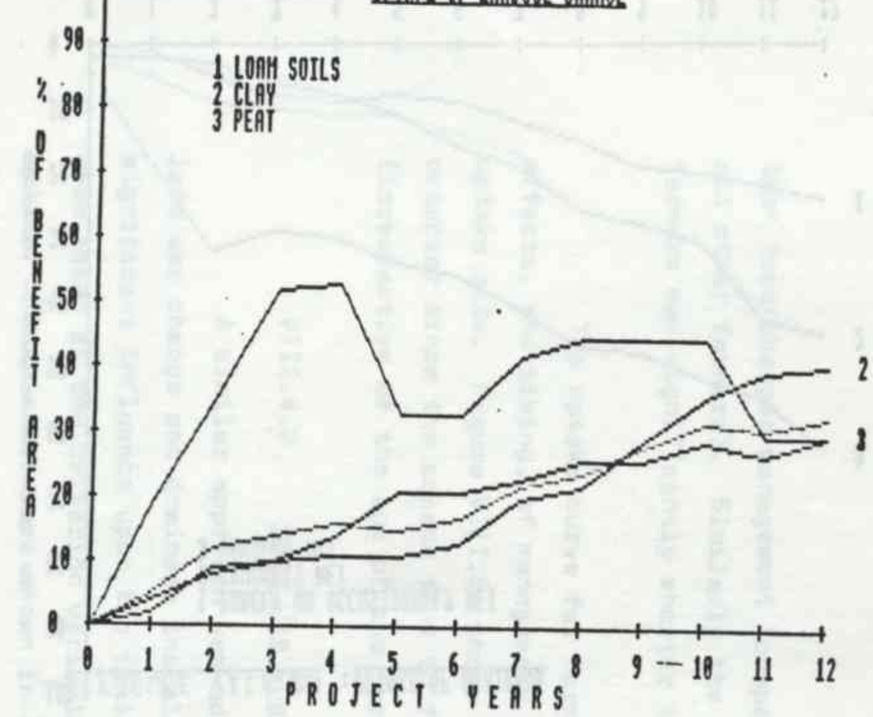


FIGURE VIII.24 : UPTAKE OF LANDUSE CHANGE

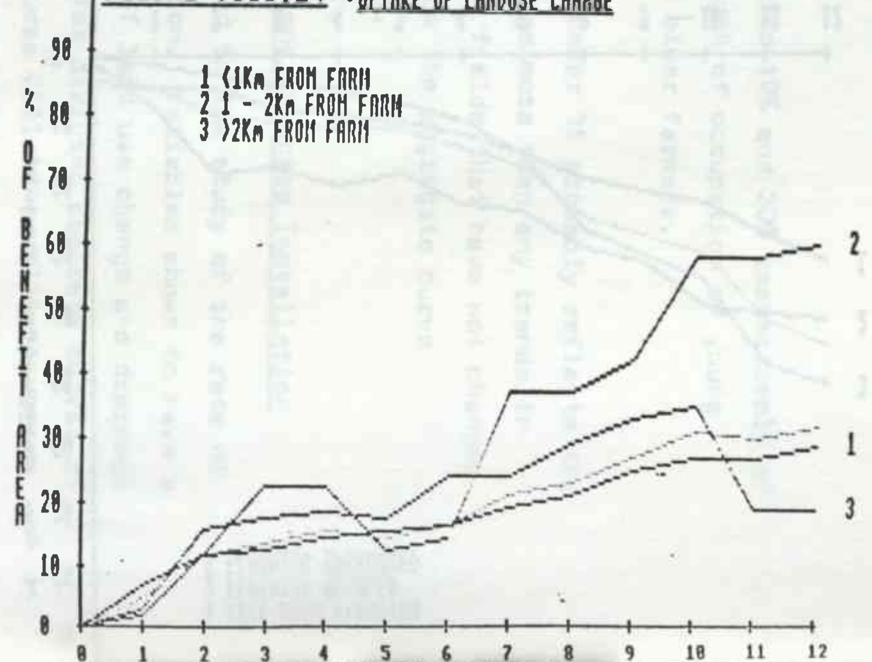


FIGURE VIII.25 : UPTAKE OF LANDUSE CHANGE

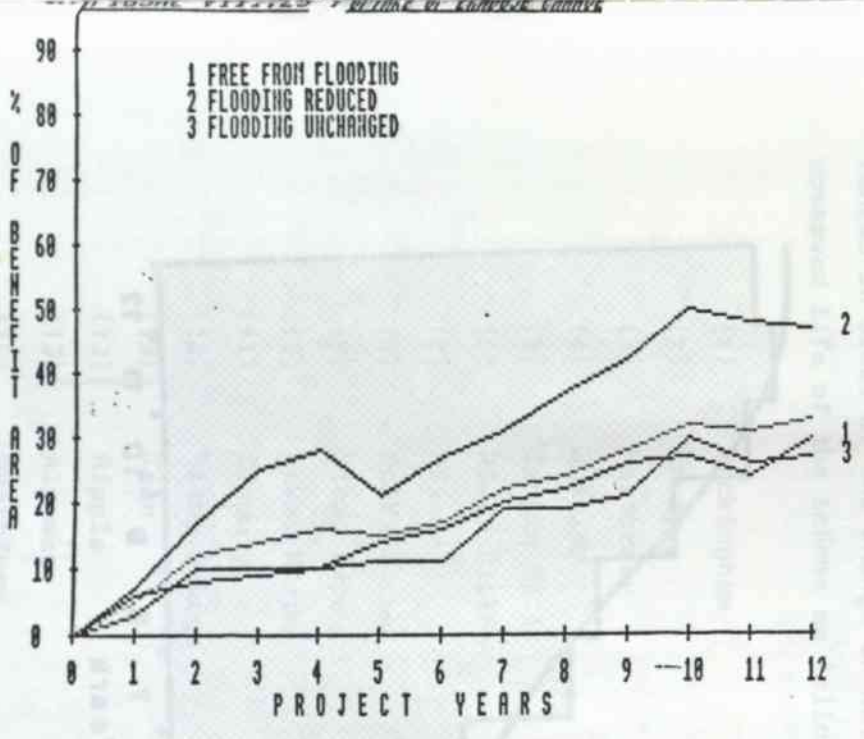


FIGURE VIII.26 : UPTAKE OF LANDUSE CHANGE

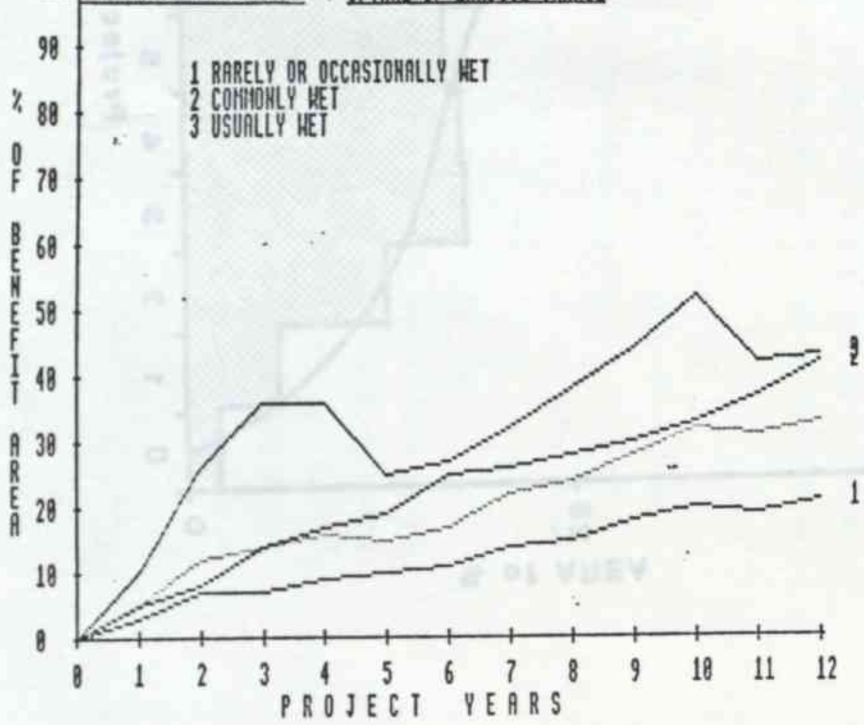


FIGURE VIII.27 : UPTAKE OF LANDUSE CHANGE

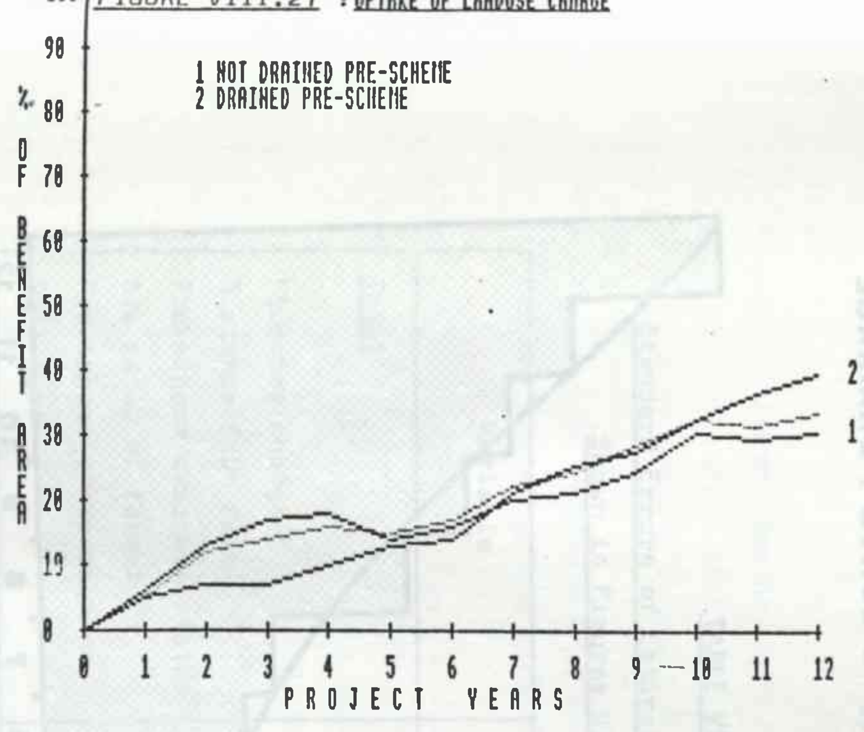


FIGURE VIII.28 : UPTAKE OF LANDUSE CHANGE

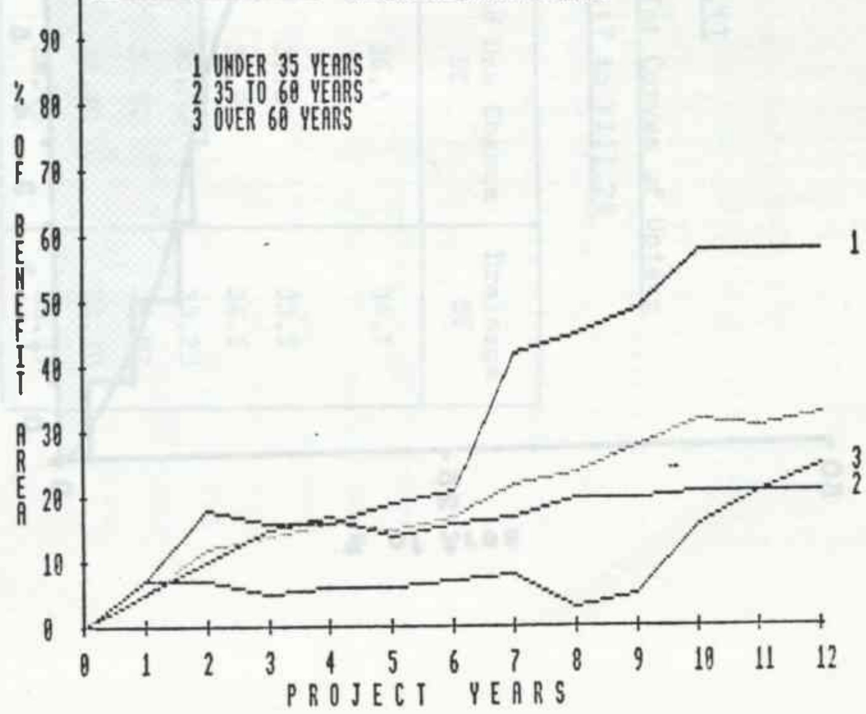


FIGURE VIII.29 : MEAN UPTAKE CURVE : DRAINAGE

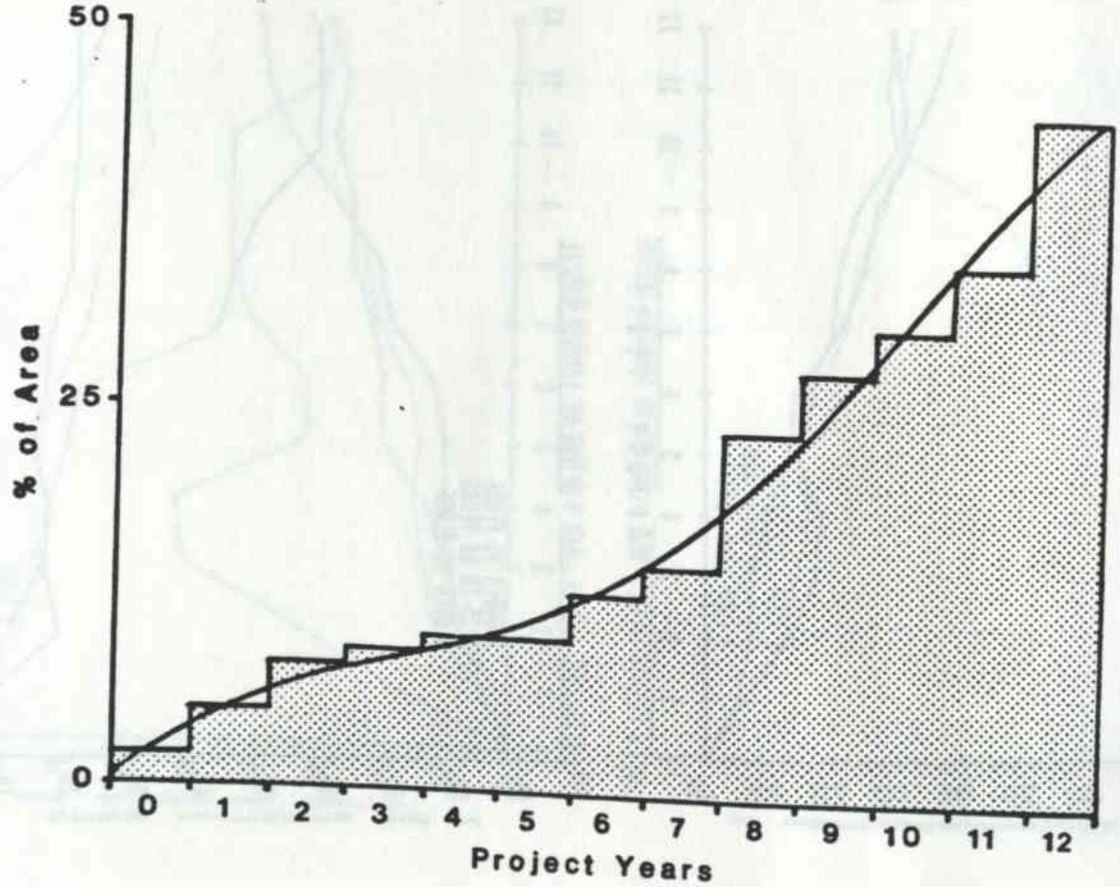


FIGURE VIII.30 : MEAN UPTAKE CURVE : LANDUSE CHANGE

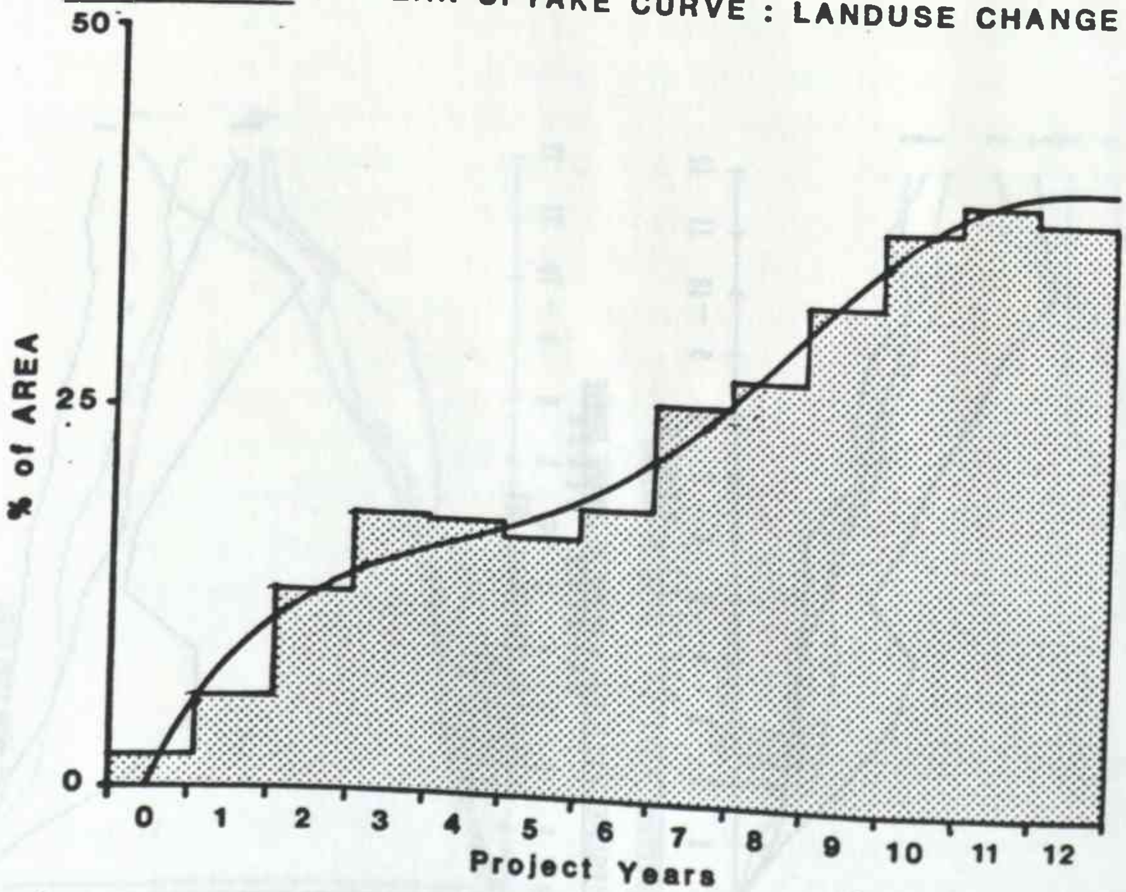


TABLE VIII.17

Standard Errors of Estimate for Curves of Uptake Shown in Figures VIII.17 to VIII.28

Variable	Land Use Change SE	Drainage SE
Total	36.1	34.1
Flooding change	37.0	33.5
Distance from farm	34.9	34.6
Pre-scheme drainage status	35.50	33.23
Age group of farmer	34.50	35.07
Pre-scheme underdrainage	34.40	34.90
Soil type	35.75	33.81

VIII.5 SCHEME SUMMARIES OF FACTORS INFLUENCING UPTAKE

The scheme by scheme appraisal (Annexe IX) compared the relative worthwhileness of the 16 schemes studied. The schemes can be ranked in order of the change in Net Returns per hectare over the observed life of the scheme as follows:

(1) Beckingham
(2) Epney
(3) Mattersey
(4) Bushley
(5) Temple Mill
(6) River Blithe
(7) Misson
(8) Doley Brook
(9) Sleap Brook
(10) River Morda
(11) Oldbury
(12) Kilby Bridge
(13) Tean
(13) Ripple
(13) Alrewas
(16) Sharnford

The scheme dates show that there is some trend for the younger schemes to be ranked lower. The uptake curves presented above suggest that the boost in uptake occurs during years 6 to 8 of the project life thus schemes that post-date 1976/77 are unlikely to have reached full benefit yet and should be interpreted with caution, particularly in view of possible occupancy and management changes.

Tables VIII.18 and VIII.19 show mean values for the variables shown to be associated with uptake of benefits. Obviously there are several exceptions to the general observations made earlier in this Annexe. However, an examination of a scheme's actual and predicted performance can reveal interesting results, particularly where there are large discrepancies. The Kilby Bridge scheme for instance, has the characteristics of a scheme likely to yield a high benefit; a large area has changed management since the scheme and the average length of occupation is lower than average; the pre-scheme gross margin was about average; a low proportion of farmers are over 60 and the scheme has the highest proportion of farmers who have attended college and are qualified in some area of agriculture; a large proportion of the farmers are members of farming groups and also represent on committees. The scheme, however, ranks 12 out of the 16 suggesting that the reason for the poor uptake lies with the physical performance of the scheme rather than any inherent apathy amongst the farmers. This was confirmed by the field survey (see Annexe IX, Appendix).

The schemes where the uptake has been rapid are associated with the largest changes in land use class (eg. Misson, Temple Mill) confirming the observation that earlier uptake is associated with more major changes.

The more successful schemes are particularly associated with large areas that were of the lowest drainage class before the scheme. With the exception of the Bushley scheme, the top 7 schemes all had over 30% of the benefit area in the 'usually wet' pre-scheme drainage class. These are sites where not only are automatic benefits high, but also land use change is more likely. Conversely, the Alrewas and Sharnford schemes, which ranked last, both had over 50% of the benefit areas

TABLE VIII.18

Summary of Field Variables

Scheme	% of Area		% of Area		% of Area Drained Pre-Scheme	Mean Shift In Land Use Class (1)	Mean Pre-Scheme Gross Margin per Ha (£)	Pre-Scheme Drainage Status		Pre-Scheme 'N' Rate On Grassland kg/ha*
	Free From Flooding Pre-Scheme	Flooding Reduced	<1 km From Farm	<2 km From Farm				% Usually Wet	% Rarely Wet	
Sharnford	52	48	94	-	86	0.14	408	4	54	143
Kilby Bridge	33	7	86	6	96	0.14	341	5	-	78
Doley Brook	84	5	91	-	62	0.36	306	22	18	69
Alrewas	60	12	67	16	11	0.04	345	3	61	61
Blithe	18	82	72	28	91	0.23	290	50	5	75
Morda	47	44	73	13	32	0.22	328	18	16	61
Sleap Brook	90	10	82	16	49	1.09	427	9	12	115
Beckingham	2	98	24	38	36	1.39	251	43	-	157
Mattersey	8	92	73	-	11	0.76	295	68	3	73
Misson	15	72	45	16	-	1.89	536	48	-	268
Tean	45	52	69	30	81	-0.04	286	14	4	61
Temple Mill	38	61	100	-	81	1.44	290	50	-	59
Ripple	14	76	88	12	20	0.4	202	10	4	21
Bushley	7	89	30	6	32	1.7	222	6	-	79
Oldbury	48	52	65	20	13	0.05	372	11	-	101
Epney	39	61	100	-	7	1.13	277	31	20	68
Total	38	36	65	17	38	0.79	345	22	13	110

* Weighted by field size.

Note:

(1) See Table VIII.1.

TABLE VIII.19

Scheme Summary of Farm/Farmer Variables

Scheme	(% Area) Farm Changed Management Since Scheme	Mean No. Years Occupied Prior to Scheme*	% of Area Farmers Aged		% of Farmers been to Agric. College* (full-time)	% of Farmers Qualified in Agric.*	% of Farmers Belonging to Farming Groups		% of Farmers Representing on Committees	% of Farms with more than one holding*	Mean View of Farming (2)	% of Area under Livestock Farms	Mean % of Farm in Benefit Area
			< 35 Years	> 60 Years			0	1					
Sharnford	10	13	10	12	-	4	16	15	14	49	2.6	21	46
Kilby Bridge	40	10	18	4	58	73	4	75	68	12	2.4	-	51
Doley Brook	42	9	-	30	-	18	42	-	40	-	3.0	30	46
Alrewas	29	31	-	25	-	-	67	18	1	56	1.1	3	32
Blithe	30	12	-	-	-	17	-	72	47	35	4.4	27	29
Morda	22	14	16	22	10	12	31	25	6	31	2.9	27	42
Sleap Brook	52	13	27	6	12	32	9	70 (1)	36	28	3.9	12	59
Beckingham	57	14	38	6	51	51	7	88 (1)	72	80	2.3	15	30
Mattersey	10	28	10	16	-	10	-	25	37	44	2.1	-	24
Misson	26	17	25	-	25	25	50	5	28	33	2.1	3	30
Tean	19	19	-	51	-	-	28	38	-	57	4.7	41	48
Temple Mill	87	-	87	-	-	-	13	-	87	87	3.6	-	19
Ripple	4	12	13	2	18	18	4	57	43	53	2.2	25	48
Bushley	41	8	17	11	-	22	-	72 (1)	1	48	3.6	28	27
Oldbury	20	19	22	28	12	12	-	46 (1)	28	31	3.4	9	60
Epney	37	2	37	-	37	37	-	100	63	63	1.4	-	35
Total	35	15	21	12	20	29	17	50	37	49	2.7	14	42

* Weighted by area in benefit area

Notes:

(1) Includes IDB or drainage group.

(2) On scale 1 to 6 - 1 = profits most important
6 = way of life most important

classified as rarely wet before the scheme. The top 7 schemes all had a mean percentage of farm in benefit area of less than 35% - the only other scheme in this class was the Alrewas scheme and, apart from the Sleap Brook scheme (which had a large benefit area anyway), all those with a mean percentage in benefit area of over 40% were in the bottom 8 schemes.

The River Tean scheme (13th) has the highest proportion of farmers over 60 years of age and the highest proportion not belonging to any farming groups. It also had a large area drained before the scheme, a low percentage in the 'usually wet' class, no farmers who had been to college or were qualified, and the highest proportion of the area who were livestock farmers.

VIII.6 FARMER ATTITUDES TO FIELD DRAINAGE

The farmers interviewed during the farm survey were asked to rank the 3 most important areas of future investment on the farm, from a list of 6. If one ignores the ranking and looks at the 3 that values included on the list, there appears to be no significant difference between farmers who have drained and those who have not (see Table VIII.20).

TABLE VIII.20

Areas of Future Investment on the Farm

Areas of Investment	Farmers Who Have Drained (%)	Farmers Who Have Not Drained (%)	Total (%)
Farm buildings and storage	45	52	49
Land purchase	37	34	35
Field drainage (in benefit area)	34	34	34
Working capital	26	38	33
Farm machinery and equipment	36	24	29
Field drainage (outside benefit area)	20	13	15
Total (no. of farmers)	86	62	148

If one looks at the rankings, similar results are shown. Nearly 50% of the farmers interviewed ranked farm buildings and storage in their top 3 areas for future investment and 33% ranked it first. Land purchase ranks second, and field drainage in the benefit area third, with 34% including it in the top 3 and 18% ranking it first. There is no difference between farmers who have, and those who have not drained, suggesting that those who have drained within the benefit area have not drained all the land that requires drainage.

Those farmers who have drained within the benefit area were asked to rank the benefits of field drainage. The resultant rankings are as follows:

TABLE VIII.21

Ranking of Drainage Benefits for Arable Use

Overall Rank	Benefit	% Ranking 1st
1	Higher yields per hectare	62
2	Earlier drilling	3
3	The ability to sow winter crops	12
4	Improved trafficability	6
5	Reduced risk of failure	3
6	Increased land value	6
7	Reduced variation across the field	6
8	Reduced risk of disease	0

TABLE VIII.22

Ranking of Drainage Benefits for Grassland Use

Overall Rank	Benefit	% Ranking 1st
1	Increased stock carrying capacity	40
	Reduced poaching risk	27
2	Earlier top dressing	13
	Longer grazing season	7
5	Improved species composition	7
6	Improved trafficability	7
7	Increased cut of conserved grass	0

Many of the factors are interdependent and eventually manifest themselves in increased productivity. This is confirmed by the results which show higher yields per hectare and increased stock carrying capacity perceived to be the most important benefits of field drainage to arable and grassland respectively, with the ability to sow winter crops and reduced poaching second. This shows the emphasis placed by farmers on 'yield' above 'trafficability' benefits. Far less emphasis is placed upon benefits such as reduced disease risk, improved species composition and increased land value.

Forty-seven percent of the area surveyed has drains (either pre- or post-scheme) that are considered adequate and a further 16% was reported as being naturally freely drained and not in need of underdrainage. Of the area that remains undrained the following reasons for not draining were reported:

TABLE VIII.23

Reasons for Not Draining

Reason	% of Undrained Area[1]
Present land use does not necessitate drainage	29
Farmer could not afford drainage	17
Insufficient outfall for drains	13
Flood frequency too great	8
Expected benefits insufficient to cover costs	5
Requires help of neighbours	3
Land is of conservation/amenity value	2
Other reasons[2]	23

Notes:

(1) Excluding naturally freely drained land.

(2) 'Other reasons' include land scheduled to be drained, recent changes of occupant, waiting to see how arterial improvements perform and personal reason.

Roughly one-third of the undrained area is unlikely to be drained as the present, and anticipated future land use does not require the land to be underdrained (this is largely grazing land). Financial constraints were significant upon 17% of the land but on 16% of the undrained area, underdrainage was not possible because the arterial outfall was insufficient or neighbours would be required to improve ditches on their land to provide a suitable outfall. This was particularly significant on the Alrewas scheme where potential benefits have not been made available to certain farmers because anticipated arterial improvements have not been carried out. This emphasises the importance of cooperation between all organizations responsible for land drainage within the benefit areas (STWA, IDB's, County Council, Riparian owners) at the planning stage. Two of the schemes found to have a negative Internal Rate of Return (see Annexe IX) had high costs:potential benefit ratios but were justified upon the grounds that non-main arterial improvements (which have not occurred) were expected to follow (Alrewas, Temple Mill).

The incidence of land which was still considered to flood too often to justify underdrainage was low (8%) and was associated mainly with the Ripple and Kilby Bridge schemes and localized areas within the Morda scheme.

APPENDIX VIII.A

CORRELATION MATRICES OF VARIABLES USED IN MULTIPLE REGRESSION EQUATIONS

Tables VIII.A.2 and VIII.A.3 show the Pearson's Correlation Coefficients for the variables used in the two multiple regression equations to explain variations in the timing of land use change and underdrainage installation. The data are presented in the format:

0.0056	correlation coefficient
(772)	number of valid cases
P = 0.877	two-tailed significance

Abbreviated names are used for the independent variables and the full definitions are given in Table VIII.A.1 below.

TABLE VIII.A.1

Abbreviated Variable Names

Variable Name	Variable Label
FLOODFQ1	Pre-scheme flood frequency
FLOODFQ2	Post-scheme flood frequency
SHIFT	Magnitude of change in land use class
MANCHNGE	Change of manager since scheme
PEAT	Peat soil
LOAM	Loam soil
EDUCQUAL	Agricultural education and/or qualification
AGEGROUP	Farmer's age group
FLDDIST	Distance of field from farmstead
DRAINED	Pre-scheme underdrainage
HOLDINGS	Number of holdings farmed
OCCTIME	Length of occupancy prior to scheme
DRSTATUS	Pre-scheme drainage status
LANDUSE2	Post-scheme land use class
OPINION	Farmer's view of farming
OWNED	Ownership of field

TABLE VIII.A.2

CORRELATION MATRIX OF SIGNIFICANT VARIABLES.
DATE OF LANDUSE CHANGE.

FILE SCHMSYS (CREATION DATE = 06/13/84) STWA BENEFITS STUDY : FARM DATA.

- - - - - - - - - - - - - P E A R S O N   C O R R E L A T I O N   C O E F F I C I E N T S - - - - - - - - - - - -

	FLOODFQ2	FLOODFQ1	SHIFT	MANCHNGE	PEAT	EDUCQUAL	AGEGROUP	FLDDIST	DRAINED	HOLDINGS	OCCTIME	DRSTATUS
FLOODFQ2	1.0000 (0) P=*****	0.6254 (771) P=0.000	0.2062 (776) P=0.000	0.0904 (764) P=0.012	0.0056 (772) P=0.877	0.1160 (715) P=0.002	-0.0726 (751) P=0.047	0.3992 (735) P=0.000	-0.1126 (739) P=0.002	0.1262 (752) P=0.001	0.0467 (743) P=0.203	0.2204 (704) P=0.000
FLOODFQ1	0.6254 (771) P=0.000	1.0000 (0) P=*****	0.1230 (779) P=0.001	-0.0372 (772) P=0.302	0.2012 (779) P=0.000	0.0016 (709) P=0.965	-0.0308 (759) P=0.397	0.1313 (743) P=0.000	-0.0931 (748) P=0.011	0.0083 (759) P=0.820	0.1083 (750) P=0.003	0.3683 (714) P=0.000
SHIFT	0.2062 (776) P=0.000	0.1230 (779) P=0.001	1.0000 (0) P=*****	0.1151 (782) P=0.001	0.1492 (803) P=0.000	0.0223 (724) P=0.550	0.0028 (769) P=0.939	0.2533 (764) P=0.000	-0.0840 (747) P=0.022	0.0427 (770) P=0.236	-0.0744 (767) P=0.039	0.1896 (713) P=0.000
MANCHNGE	0.0904 (764) P=0.012	-0.0372 (772) P=0.302	0.1151 (782) P=0.001	1.0000 (0) P=*****	-0.0328 (786) P=0.358	0.2845 (725) P=0.000	-0.4144 (775) P=0.000	0.1346 (751) P=0.000	0.0640 (747) P=0.080	0.0017 (773) P=0.962	-0.2826 (765) P=0.000	0.0456 (715) P=0.223
PEAT	0.0056 (772) P=0.877	0.2012 (779) P=0.000	0.1492 (803) P=0.000	-0.0328 (786) P=0.358	1.0000 (0) P=*****	-0.0063 (723) P=0.866	-0.0437 (773) P=0.225	0.0194 (761) P=0.593	-0.1779 (748) P=0.000	-0.0409 (774) P=0.256	0.1700 (769) P=0.000	0.1861 (716) P=0.000
EDUCQUAL	0.1160 (715) P=0.002	0.0016 (709) P=0.965	0.0223 (724) P=0.550	0.2845 (725) P=0.000	-0.0063 (723) P=0.866	1.0000 (0) P=*****	-0.3192 (718) P=0.000	-0.0362 (697) P=0.340	-0.0133 (686) P=0.728	-0.1165 (718) P=0.002	-0.1607 (703) P=0.000	0.0174 (663) P=0.655
AGEGROUP	-0.0726 (751) P=0.047	-0.0308 (759) P=0.397	0.0028 (769) P=0.939	-0.4144 (775) P=0.000	-0.0437 (773) P=0.225	-0.3192 (718) P=0.000	1.0000 (0) P=*****	-0.0785 (738) P=0.033	0.0408 (737) P=0.269	-0.1212 (762) P=0.001	0.1643 (752) P=0.000	-0.0738 (704) P=0.050
FLDDIST	0.3992 (735) P=0.000	0.1313 (743) P=0.000	0.2533 (764) P=0.000	0.1346 (751) P=0.000	0.0194 (761) P=0.593	-0.0362 (697) P=0.340	-0.0785 (738) P=0.033	1.0000 (0) P=*****	-0.1725 (713) P=0.000	0.0998 (737) P=0.007	-0.0286 (748) P=0.435	0.0995 (682) P=0.009
DRAINED	-0.1126 (739) P=0.002	-0.0931 (748) P=0.011	-0.0840 (747) P=0.022	0.0640 (747) P=0.080	-0.1779 (748) P=0.000	-0.0133 (686) P=0.728	0.0408 (737) P=0.269	-0.1725 (713) P=0.000	1.0000 (0) P=*****	0.0252 (732) P=0.495	-0.1521 (724) P=0.000	-0.1837 (700) P=0.000
HOLDINGS	0.1262 (752) P=0.001	0.0083 (759) P=0.820	0.0427 (770) P=0.236	0.0017 (773) P=0.962	-0.0409 (774) P=0.256	-0.1165 (718) P=0.002	-0.1212 (762) P=0.001	0.0998 (737) P=0.007	0.0252 (732) P=0.495	1.0000 (0) P=*****	-0.0849 (750) P=0.020	0.0130 (703) P=0.730
OCCTIME	0.0467 (743) P=0.203	0.1083 (750) P=0.003	-0.0744 (767) P=0.039	-0.2826 (765) P=0.000	0.1700 (769) P=0.000	-0.1607 (703) P=0.000	0.1643 (752) P=0.000	-0.0286 (748) P=0.435	-0.1521 (724) P=0.000	-0.0849 (750) P=0.020	1.0000 (0) P=*****	-0.0005 (694) P=0.989
DRSTATUS	0.2204 (704) P=0.000	0.3683 (714) P=0.000	0.1896 (713) P=0.000	0.0456 (715) P=0.223	0.1861 (716) P=0.000	0.0174 (663) P=0.655	-0.0738 (704) P=0.050	0.0995 (682) P=0.009	-0.1837 (700) P=0.000	0.0130 (703) P=0.730	-0.0005 (694) P=0.989	1.0000 (0) P=*****

TABLE VIII.A.3

CORRELATION MATRIX OF SIGNIFICANT VARIABLES.
DATE OF UNDERDRAINAGE.
FILE SCHMSYS (CREATION DATE = 06/13/84) STWA BENEFITS STUDY : FARM DATA.

- - - - - - - - - - - - - P E A R S O N   C O R R E L A T I O N   C O E F F I C I E N T S - - - - - - - - - - - - -

	FLDDIST	FLOODFQ1	OCCTIME	MANCHNGE	LANDUSE2	FLOODFQ2	DRAINED	OPINION	PEAT	LOAM	OWNED
FLDDIST	1.0000	0.1313	-0.0286	0.1346	0.2055	0.3992	-0.1725	0.0151	0.0194	-0.0714	-0.1491
	(0)	(743)	(748)	(751)	(766)	(735)	(713)	(715)	(761)	(761)	(702)
	P=*****	P=0.000	P=0.435	P=0.000	P=0.000	P=0.000	P=0.000	P=0.686	P=0.593	P=0.049	P=0.000
FLOODFQ1	0.1313	1.0000	0.1083	-0.0372	0.0339	0.6254	-0.0931	-0.0539	0.2012	-0.1128	0.0016
	(743)	(0)	(750)	(772)	(781)	(771)	(748)	(739)	(779)	(779)	(709)
	P=0.000	P=*****	P=0.003	P=0.302	P=0.344	P=0.000	P=0.011	P=0.144	P=0.000	P=0.002	P=0.965
OCCTIME	-0.0286	0.1083	1.0000	-0.2826	-0.0132	0.0467	-0.1521	0.1066	0.1700	0.0145	0.0476
	(748)	(750)	(0)	(765)	(769)	(743)	(724)	(730)	(769)	(769)	(699)
	P=0.435	P=0.003	P=*****	P=0.000	P=0.715	P=0.203	P=0.000	P=0.004	P=0.000	P=0.688	P=0.209
MANCHNGE	0.1346	-0.0372	-0.2826	1.0000	0.0623	0.0904	0.0640	0.0737	-0.0328	-0.0189	-0.0465
	(751)	(772)	(765)	(0)	(784)	(764)	(747)	(752)	(786)	(786)	(715)
	P=0.000	P=0.302	P=0.000	P=*****	P=0.081	P=0.012	P=0.080	P=0.043	P=0.358	P=0.596	P=0.215
LANDUSE2	0.2055	0.0339	-0.0132	0.0623	1.0000	0.1380	-0.0617	-0.0920	0.1473	0.0843	-0.2632
	(766)	(781)	(769)	(784)	(0)	(779)	(749)	(748)	(806)	(806)	(744)
	P=0.000	P=0.344	P=0.715	P=0.081	P=*****	P=0.000	P=0.092	P=0.012	P=0.000	P=0.017	P=0.000
FLOODFQ2	0.3992	0.6254	0.0467	0.0904	0.1380	1.0000	-0.1126	-0.0574	0.0056	-0.1487	-0.1909
	(735)	(771)	(743)	(764)	(779)	(0)	(739)	(728)	(772)	(772)	(707)
	P=0.000	P=0.000	P=0.203	P=0.012	P=0.000	P=*****	P=0.002	P=0.122	P=0.877	P=0.000	P=0.000
DRAINED	-0.1725	-0.0931	-0.1521	0.0640	-0.0617	-0.1126	1.0000	0.0471	-0.1779	0.0615	0.1300
	(713)	(748)	(724)	(747)	(749)	(739)	(0)	(718)	(748)	(748)	(678)
	P=0.000	P=0.011	P=0.000	P=0.080	P=0.092	P=0.002	P=*****	P=0.207	P=0.000	P=0.093	P=0.001
OPINION	0.0151	-0.0539	0.1066	0.0737	-0.0920	-0.0574	0.0471	1.0000	0.0089	0.0598	0.0712
	(715)	(739)	(730)	(752)	(748)	(728)	(718)	(0)	(750)	(750)	(679)
	P=0.686	P=0.144	P=0.004	P=0.043	P=0.012	P=0.122	P=0.207	P=*****	P=0.807	P=0.102	P=0.064
PEAT	0.0194	0.2012	0.1700	-0.0328	0.1473	0.0056	-0.1779	0.0089	1.0000	-0.2421	-0.0615
	(761)	(779)	(769)	(786)	(806)	(772)	(748)	(750)	(0)	(813)	(733)
	P=0.593	P=0.000	P=0.000	P=0.358	P=0.000	P=0.877	P=0.000	P=0.807	P=*****	P=0.000	P=0.096
LOAM	-0.0714	-0.1128	0.0145	-0.0189	0.0843	-0.1487	0.0615	0.0598	-0.2421	1.0000	0.0801
	(761)	(779)	(769)	(786)	(806)	(772)	(748)	(750)	(813)	(0)	(733)
	P=0.049	P=0.002	P=0.688	P=0.596	P=0.017	P=0.000	P=0.093	P=0.102	P=0.000	P=*****	P=0.030
OWNED	-0.1491	0.0016	0.0476	-0.0465	-0.2632	-0.1909	0.1300	0.0712	-0.0615	0.0801	1.0000
	(702)	(709)	(699)	(715)	(744)	(707)	(678)	(679)	(733)	(733)	(0)
	P=0.000	P=0.965	P=0.209	P=0.215	P=0.000	P=0.000	P=0.001	P=0.064	P=0.096	P=0.030	P=*****

ANNEXE IX

EVALUATION OF LAND DRAINAGE SCHEMES

Contents

List of Tables

List of Abbreviations

IDB	Internal Drainage Board
MAFF	Ministry of Agriculture, Fisheries and Food
MLC	Meat and Livestock Commission
MMB	Milk Marketing Board
PWNR	Public Works Non-Road index
STWA	Severn Trent Water Authority

APPENDICES TO ANNEXE IX

INDIVIDUAL SCHEME REPORTS

Appendix	STWA Division	Scheme
A	Soar	River Soar : Shanford to Croft
B	Soar	River Sence : Kilby Bridge to Wistow
C	Upper Trent	Doley Brook : Ruele Pool to Hell Hole Wood
D	Upper Trent	River Trent : Alrewas to Yoxall Bridge
E	Upper Trent	River Blithe : Blythe Bridge to Cresswell
F	Upper Severn	River Morda : Morton Bridge to Vyrnwy Confluence
G	Upper Severn	Sleap Brook : Fiddler's Bridge to Roden Confluence
H	Lower Trent	River Trent : Beckingham Marshes
I	Lower Trent	River Idle : Idle Stop to Bawtry
J	Lower Trent	River Idle : Bawtry to Mattersey
K	Derwent	River Tean : Stramshall Mill to Dove Confluence
L	Tame	River Sence : Temple Mill
M	Lower Severn	River Severn : Saxon's Lode to Mythe Hook
N	Lower Severn	River Severn : Bushley to Upper Lode
O	Lower Severn	South Gloucs. IDB : Oldbury
P	Lower Severn	South Gloucs. IDB : Epney Rhine

ANNEXE IX

EVALUATION OF LAND DRAINAGE SCHEMES

IX.1 INTRODUCTION AND SCOPE

The uptake of agricultural benefits following river or arterial watercourse improvements for agriculture can be enumerated at 3 levels of increasing aggregation, namely at field, farm and scheme level. For the purpose of the present analysis, an STWA scheme is a geographically defined land area which stands to gain agricultural benefit from capital expenditure on river and/or arterial works. The evaluation of such a land drainage improvement scheme necessarily involves the aggregation of all field and farm level benefits and costs arising within the 'benefit area' and directly attributable to the potential afforded by the scheme, together with the 'overhead' capital and running costs of the scheme itself. This evaluation process can be either 'ex-ante' or 'ex-post' depending whether appraisal occurs 'before' or 'after' the investment is made respectively.

Drawing on the assessment of benefit uptake at field and farm level, this Annexe undertakes an ex-post evaluation of selected on-going STWA drainage schemes. The Annexe describes the method of appraisal, summarises the main features of the schemes, and assesses their performance todate (and implicit performance over remaining project life).

The reports on individual schemes are contained in Appendices to this Annexe.

IX.2 SELECTION OF SCHEMES FOR APPRAISAL

Sixteen STWA land drainage improvement schemes were selected for the purpose of identifying and explaining the nature and rate of uptake of potential benefits by farmers following such improvements. It was required that the schemes had originally been justified in terms of agricultural potential, and had sufficient maturity (age or uptake) to warrant examination. The criteria and procedures for scheme selection are explained in Annexe III section 3. The schemes examined were as follows, and their reference names are underlined:

Scheme	STWA Division
River Soar: Sharnford to Croft	Soar
River Sence: Kilby Bridge to Wistow	Soar
Doley Brook (Reule Pool to Hell Hole Wood)	Upper Trent
River Trent: Alrewas to Yoxall Bridge	Upper Trent
River Blithe (Cresswell to Blythe Bridge)	Upper Trent
River Morda (Morton Bridge to Vyrnwy Confluence)	Upper Severn
Sleap Brook (Fiddler's Bridge to Roden Confluence)	Upper Severn
Beckingham Marshes (near Gainsborough)	Lower Trent
River Idle: Misson (stages 2 and 3 Idle Stop to Bawtry)	Lower Trent
River Idle: Mattersey (stage 4, Bawtry to Mattersey)	Lower Trent
River Tean (Stramshall Mill to Dove Confluence)	Derwent
River Sence: Temple Mill	Tame
River Severn: Ripple (Saxon's Lode to Mythe Hook)	Lower Severn
River Severn: Bushley to Upper Lode	Lower Severn
Oldbury: Southern Pumping Area	Lower Severn
Epney Rhine: Lapper Ditch	Lower Severn

IX.3 DATA REQUIREMENTS FOR SCHEME EVALUATION

The needs, sources and methods of collection of data for the evaluation of individual STWA schemes are discussed in Annexe III. The assessment of net agricultural benefits is derived from the survey of farmer uptake of drainage benefits at field and farm level, supported in the case of field drainage investments by reference to MAFF files. The assessment of scheme costs has been taken from relevant STWA and IDB sources.

IX.4 METHODOLOGY FOR INVESTMENT APPRAISAL

An STWA land drainage scheme can be viewed as a separately identifiable investment 'package', to which benefits and costs over time can be ascertained. Each scheme is enacted to fulfil specified objectives usually defined in terms of alleviating flooding and/or improving outfall facilities. Whilst in the early 1970's the justification for scheme implementation was often made with reference to the cost per hectare of providing a given physical improvement, usually in the context of prevailing land values or agricultural potential, more latterly, public investments in land drainage have needed to return benefits greater than costs when discounted at the Treasury's prevailing discount rate. For the schemes studied here, the general criterion for justification has been financial net return, whether implicit as in the case of most pre-1974 schemes, or explicit as in the case of post-1974 schemes for which cost:benefit appraisals were required.

Whilst the general criterion has been financial worthwhileness, the details of the calculation have varied over time. In the early 1970's, the Treasury discount rate was 10% and project lives of between 30 and 50 years were assumed. Since 1978, the Treasury discount rate has been 5%, and a 30 year life has usually been taken. Modifications and refinements have been made over time to the procedures for estimating net agricultural benefits with a view to improving the realism of predictions, particularly with respect to the fixed cost and uptake rate assumptions of scheme appraisals.

The method used here is a partial budgeting approach which compares without-project and with-project situations. The extra benefits arising from and directly attributable to a given land drainage improvement project are set against the costs of providing and maintaining that improvement over a given period, and discounted at the 5% discount rate.

The general format of the appraisal is summarised in Table IX.1.

TABLE IX.1

Format of Scheme Appraisal

Project Year	0	1	2
Calendar Year	1970	1972	1973
Agricultural Benefits			
Net Agricultural Benefits			
Flood Damage Reduction			
Less Without-Project Benefit			
Less Field Drainage Cost			
Net Agricultural Cash Flow			
Scheme Costs			
Capital			
Recurrent			
Total Costs			
Scheme Net Cash Flow			

For each year of an estimated project life of 30 years, agricultural benefits are set against scheme costs to give a net cash flow for the scheme. The benefit stream incorporates all the agricultural benefits and costs at farm level attributable to the scheme, whilst the cost stream relates to scheme level (STWA and IDB) capital and recurrent expenditure. The individual components of the cash flow and the criteria for evaluation are discussed in the following sections.

IX.4.1 Scheme Level Benefit Assessment

The agricultural benefits at scheme level include the sum of farm level net agricultural benefits and savings in flood damage costs, less without-project benefits and farm level expenditure on field drainage.

IX.4.1.1 Net Agricultural Benefits:

The estimate of net agricultural benefits attributable to a scheme is the aggregated estimated financial value of benefit uptake at field and farm level within the scheme's boundary of influence.

The derivation of financial uptake is explained in Annexe V, together with a critique of the main, largely simplifying assumptions. Financial uptake is based on physical information derived in the course of farmer interview and converted to financial values using standardised gross margin and fixed cost formulae. Financial estimates are based on estimated changes in gross margins less any changes in fixed costs which are attributed by the farmer to the changes in drainage status afforded by the scheme. Increased financial returns may arise from an increase in the productivity of existing land use activities, a move to more profitable activities and/or a reduction in production costs such as savings in bought feeds for livestock. The method uses constant 1982 prices, and implicitly the price relativities that applied at that time.

Whilst changes in price relativities have occurred over the life span of the schemes examined, it is unlikely that these would significantly affect the estimate of scheme net agricultural benefits. Perhaps more importantly there has been, particularly since the late 1970's, an increasing variance between financial farm gate prices and 'economic' prices given the occasion of farm produce surplus within the EEC. These price related issues are considered in Annexe V by way of sensitivity analysis.

The purpose of scheme evaluation is to comment on the performance of schemes todate, and not to participate in predictive estimates of what might happen over their remaining life. Estimates of uptake are based on those derived from farm survey for each year of project life up to the present time (1984) after which they are assumed constant at that level over the remaining part of a 30 year life. If it was known that some future uptake was imminent then this has been incorporated in the 1984 assessment.

If on this basis a scheme does not achieve break even returns at the 5% discount rate, the increase in agricultural benefits necessary over the remaining part of project life are identified. This required response can then be put in the context of likely latent response or scheme potential.

For most schemes, estimates of financial benefit uptake have been derived by farmer survey covering over 95% of the benefit area. In most cases, the balance has been found to be not in productive agricultural use. Where the surveyed area does not fully cover the area deriving benefit, it has been assumed that the average observed financial uptake per hectare can be applied to the scheme as a whole. A grossing-up factor is used to estimate expected scheme level returns based on the ratio total area of benefit: total area covered by farmer survey. In the case of 4 schemes this factor has been between 1.07 and 1.23. For the remainder there has been 100% coverage by farmer survey, and the aggregated estimate of farmer uptake provides the scheme level estimate of net agricultural benefit.

For most schemes, the area deriving potential benefit was defined at the feasibility stage, usually with reference to the Medway Letter line. For some schemes, farmer survey and ground checks have made it necessary to redefine the benefit area where it is apparent that potential benefits are not provided. This redefinition does not exclude areas where farmers are not afforded improved opportunities because, say, follow-up work on road culverts has not been done, but excludes areas which derive no drainage benefit from the scheme because of, say, topographical features, or because they simply are not within the drainage catchment of the scheme. In this context, a number of instances have arisen where the benefit areas have been drawn beyond the Medway Letter line, eg. Doley and Blithe. The lowest level of enumeration is the field such that, generally, the benefit area includes the total areas of fields which run along the boundary of scheme influence.

IX.4.1.2 Flood Damage Reduction:

Benefits accrue to farmers at scheme level in terms of the reduced incidence and/or duration of flooding and consequent savings in losses to standing crops, livestock, property, and time spent clearing litter and debris from land and watercourses.

Flood damage costs vary according to the frequency, duration and particularly timing of flooding. Winter flooding on grass causes little damage and some argue it to be beneficial, whereas on winter sown cereals it can at least depress yields, and at most require reseeding. Summer floods can devastate hay and arable crops. There were few site specific hydrologic data on which to estimate flood return periods, or areas of inundation, particularly by time of year.

Where the scheme involves a flood alleviation component, scheme files refer to pre-scheme flood risk and post-scheme design flood return periods. This information, combined with farmer estimates of the extent and physical impact of given flood events can be used to estimate the likely average annual cost of flooding for the pre- and post- scheme situations.

For most pre-scheme flood prone situations, the land was down to grass and the cost of winter flood events was confined to fence repair, and debris collection charged at standard rates. Summer floods are expensive and unforgettable. Post-scheme flood damage cost will depend much on land use. On arable cropping, it has been assumed that winter/spring flooding will cost about £200 per hectare in terms of either reduced yields (by 20-30%) on winter cereals, recultivation and reseeding costs, reduced gross margins on spring sown cereals, or the yield penalties imposed on delayed planting on spring sown crops. In the case of a summer flood, the entire standing crop is assumed lost. The loss is equivalent to expected gross revenue less the value of uncommitted variable costs (eg. direct harvesting expenses). For the purpose of analysis the gross margin value of the standing crop is taken as a proxy for this cost.

The savings in flood damage costs will depend on the relative changes of flood risk and flood event costs for the pre-scheme and post-scheme conditions. In most cases there will be an average annual reduction in flood damage costs. On flood prone schemes on which uptake has been considerable, the lower risk of a more expensive flood event serves to reduce the real savings in flood damage costs.

IX.4.1.3 Without-Project Benefits:

It can be reasonably assumed that, notwithstanding drainage constraints, farmers in the benefit areas would have participated in the general improvement in physical productivity enjoyed by the farming sector over the last 20 years or so. During this period (see Annexe VII), farm productivity has increased by an average 2-3% per year, both in livestock and arable systems. It is likely that by improved methods, better stock or varieties, farmers could have achieved some productivity improvements on fields in the benefit areas in the absence of a change in drainage regime. In the main, however, pre-scheme land use was mainly confined to extensive grass systems for fatstock and dairy, and productivity improvements in these sectors have usually been associated with fairly radical changes in grassland and enterprise management which require that land is adequately drained. It is likely therefore that without-project productivity improvements would be substantially below the national average. Furthermore, without-project benefits should only be charged against those areas for which benefits attributable to the scheme have been identified. Some farmers have not changed their farming practices and derive only the automatic benefits associated with flood damage reduction or extended grazing. Other farmers may have made changes not related to the drainage improvement. Given that these farmers have not contributed to 'with-project' benefits it is reasonable to exclude them from the assessment of 'without-project' benefits.

An assessment was made of the usefulness of secondary data for assessing likely without-project returns, particularly agricultural census based data in the form of parish returns. On examination this data proved to be too general to reflect site specific conditions in the benefit areas which often comprise river corridors which cut across parish boundaries. It had been anticipated that a selected survey of farmers outside the benefit area would provide a 'control' to compare against 'with-project' conditions. This proved unnecessary because in most cases there was at least one farmer in the benefit area who had not significantly changed his farming methods since scheme inception.

The basic assumption is made that, on the area for which positive benefit uptake has been identified, without-project benefits are levied at 1% compound per year of the average pre-scheme net returns (gross margins less semi-fixed costs) up to 1984, after which, like the estimate of with-project benefits, they remain constant. So where uptake has been low, without-project charges are low, and vice versa. The sensitivity of a scheme to this assumption is tested.

IX.4.1.4 Field Drainage Costs:

The costs of field drainage installations by farmers made possible by the scheme and involving underdrainage, and the cutting or improvement of farmer watercourses, has been charged for the year in which the investments were made. Data on field drainage details have been obtained from farmer survey, supported by reference to MAFF files on grant aided investments. Where actual cost information was not available, these have been estimated by reference to installations of the same type within the same benefit area, or by using the cost formulae derived in Annexe IV. All drainage costs are in 1982 prices, before grant. Unless specifically stated, no incremental maintenance costs for drainage have been assumed, although in some cases there is evidence of higher post-scheme maintenance standards. Where schemes involve privately operated pumping, estimates of annual operating costs for fuel and repairs are based on farm specific data. The capital costs of private pump stations are included in the initial investment and a nominal sinking fund charge has been made per hectare to cover pump replacement. Low lift private pumping costs ranged between £22 and £34 per hectare in 1982 prices.

In some instances, particularly on the River Idle schemes, farmers used irrigation to exploit the potential for root crop production, especially potatoes and sugar beet. A standard cost of £2/ha mm has been assumed at average annual application rates of 100 mm where relevant.

IX.4.2 Scheme Level Costs

IX.4.2.1 Capital Costs:

In most cases, it has been possible to obtain actual records of capital expenditure at outturn prices for each scheme and these have been charged accordingly for the year in which they were incurred, adjusted to 1982 values using the Public Works Non-Road (PWNR) price index.

The capital costs of a drainage scheme are the initial costs of labour, materials and services used in providing the land drainage improvement, and cover the cost of river or watercourse regrading, re-sectioning, embanking and revetting, the construction of water control structures such as outfalls, penstocks and pumping stations, and expenditure on ancillary works such as underpinning or rebuilding access bridges or providing cattle drinking places. In some instances they include costs associated with environmental protection or enhancement. Where compensation is paid to farmers to cover temporary or permanent loss of output arising from the works this cost is charged to the scheme. Contributions may be received where works result in a higher order of service to third parties, eg. contributions towards road bridge or culvert improvements from Local Authorities. These are deducted from the capital cost of the scheme.

Where the scheme involves capital expenditure by non-farmer third parties, such as Local Authority and Internal Drainage Board improvements, these too are charged to the scheme. In some cases STWA have undertaken such work on their behalf.

In a number of cases, schemes are part of larger catchment improvement projects and share the benefits of the flood protection or improved drainage opportunities afforded by highland carriers or large scale pumping schemes. In these circumstances, a proportion of these 'overhead' capital costs have been apportioned to a given scheme according to the relative share of total benefit provided. In most cases these joint costs are apportioned on a per hectare of total benefit basis. In others, notably the Idle schemes, capital costs are absorbed on the basis of the estimated degree of benefit afforded to particular sub areas at the feasibility study stage.

Where new capital investments have been made during project life (eg. new pumping station) the residual values of such items have been valued in year 30.

IX.4.2.2 Recurrent Costs:

Expenditure on repair and maintenance of river and watercourse works is needed to secure scheme design standards.

At the time of the enquiry little reliable information was available on maintenance expenditure which could be segregated to given scheme benefit areas.

By definition, the improvement schemes require that a higher order of maintenance be provided compared to the pre-scheme situation and where maintenance schedules have been lacking there has been evidence of declining yields or reduced potential. For the purpose of analysis, and according to accepted convention, post-scheme maintenance expenditure is assumed at 1½% of the gross capital cost per year.

Where schemes involve arterial pumping, recurrent expenditure for fuel and repairs and maintenance has also been charged. Observed pump operating costs (excluding pump replacement) varied between £5 per hectare and £12 per hectare per year, depending on the proportion of total drain water in need of lifting as opposed to release through penstocks.

IX.4.3 Measuring Scheme Performance

The main criterion for scheme evaluation is that benefits must exceed costs at the relevant discount rate. For schemes enacted before October 1978 this was 10% and since October 1978 5%, although various interpretations were made regarding scheme life.

The justification for the change in discount rate is difficult to determine, and the argument that such a high discount rate (and at times higher than the commercial interest rate) encouraged a myopic viewpoint inconsistent with public sector investments aimed at improving long term productive capacity.

Theoretically, schemes implemented before 1978 should be evaluated at the 10% discount rate, and later schemes at 5%, and to be correct, the evaluations would need to adjust for the real changes in price relativities that have occurred, and will occur, over time. As an expedient compromise, it is assumed that the present 5% discount rate is generally applicable to all existing schemes over a 30 year life, on the basis that what was justifiable in the late 1970's from an agricultural output viewpoint would have been more justified in the early 1970's.

IX.4.4 Uptake as a Percentage of Potential

An estimate has been made of post-scheme farming potential expressed in gross margin terms, against which actual uptake can be measured. This estimate of potential is based on a combination of land capability assessment and local farming practice, essentially adopting the perspective that would be taken at the planning stage of a land drainage scheme. An assessment has been made of post-scheme climate, soil, drainage status and farming system characteristics and from this a reasonably achievable average 'target' gross margin per hectare has been derived. Thus, for grassland, site class and drainage status (see Annexe IV) are combined 'target' nitrogen application rates. For livestock rearing and fattening systems and for dairy systems these are mainly based on MLC and MMB recommended levels respectively which in turn reflect the top 25% producers in their enterprise costing. Hence for fatstock and dairy systems target nitrogen rates are 250 and

300 kg N/ha respectively. In some scheme areas there are farmers applying more nitrogen (and achieving higher stocking rates) and this, but they remain the exception, yet show that the potential is achievable.

For cropping systems, potential gross margins are based on average regional yield levels and the highest yields regularly obtained within the scheme. Attention has been given to rotational requirements to both sustain yields and suit the needs of local farming systems.

The estimate of potential was made in terms of gross margins because of the difficulties of estimating the extent or extra capital investments required on individual farms. Consequently the estimate of potential does ignore fixed cost implications of change and the fact that average fixed costs vary between enterprises. Intensive dairying and high winter cereal yields can offer similar gross margins (£700+, 1982 prices), but average fixed costs are higher in the case of the former.

Whereas uptake as a percentage of potential is taken here to be the observed incremental benefit as a proportion of the potential increment afforded by a scheme, a more correct measure should adjust for the fact that pre-scheme benefit levels may have been below pre-scheme potential. If this were so, expressing actual post-scheme uptake as a proportion of a nominal 100% uptake may unfairly prejudice the assessment of actual uptake response. That is if pre-scheme uptake was 70% of potential, then the measure for comparing post-scheme response should also be 70% of potential. For instance, there may have been scope for nitrogen use in spite of poor drainage but none was applied. Post-scheme levels may similarly be constrained due to non-drainage factors.

Thus there would be a case for reducing theoretical potential by a ratio of pre-scheme uptake to pre-scheme potential, and expressing post-scheme uptake as a percentage of this. The fact that some 44% of farmers did not positively respond to the schemes may suggest that these were operating below pre-scheme potential and were not unduly constrained by pre-scheme drainage status. However, shortage of reliable and detailed data on pre-scheme potential makes the assessment of pre-scheme potential difficult.

The assessment of uptake as a percentage of potential therefore needs to be interpreted with caution. It is used here mainly as an indicative measure of the relative exploitation of potential benefits for comparing between schemes.

IX.4.5 Predicting Uptake Over Remaining Project Life

A 30 year project life has been assumed for scheme evaluation, and all schemes have varying proportions of their lives remaining. In the first instance, assessments of financial performance have been made assuming that current levels (1984) of uptake prevail over remaining project life. Such an assumption could prejudice schemes which are immature or have demonstrated little uptake todate. In such cases, it is justifiable to predict likely uptake over the relevant part of remaining project life to derive an assessment of worthwhileness which allows for project immaturity. These adjustments have been made only for projects which generate negative net present values using observed benefit uptake and which are less than 12 years old.

The aggregate uptake curve derived from the farm survey and presented in Figure VIII.1 has the following polynomial function:

$$y = 26.11515 - 6.802319x + 2.229537x^2 - 0.1017094x^3$$

where y = total uptake in £/ha

x = project year

Differentiating gives:

$$dy/dx = -6.802319 + 4.459074x - 0.3051282x^2$$

where $dy/dx = 0$, and y = maximum

x = 13 years

Given the third degree polynomial, uptake peaks in year 13.

TABLE IX.2

Factors for Weighting Net Agricultural Benefits Over Remaining Project Life

Project Year	% of Maximum y	← Age of Project as at 1983 → 1	2	3	4	5	6	7	8	9	10	11	12
1	23.5	1.0											
2	22.6	1.0	1.0										
3	25.3	1.1	1.1	1.0									
4	30.8	1.3	1.4	1.2	1.0								
5	38.6	1.6	1.7	1.5	1.3	1.0							
6	47.9	2.0	2.1	1.9	1.6	1.2	1.0						
7	58.1	2.5	2.6	2.3	1.9	1.5	1.2	1.0					
8	68.5	2.9	3.0	2.7	2.2	1.8	1.4	1.2	1.0				
9	78.4	3.3	3.5	3.1	2.5	2.0	1.6	1.3	1.1	1.0			
10	87.2	3.7	3.8	3.4	2.8	2.3	1.8	1.5	1.3	1.1	1.0		
11	94.1	4.0	4.2	3.7	3.1	2.4	2.0	1.6	1.4	1.2	1.1	1.0	
12	98.6	4.2	4.4	3.9	3.2	2.6	2.1	1.7	1.4	1.3	1.1	1.1	1.0
13	100.0	4.2	4.4	4.0	3.2	2.6	2.1	1.7	1.5	1.3	1.1	1.1	1.0

This cumulative frequency based on the aggregate uptake observed for all schemes can provide a means of estimating likely uptake over remaining project life.

For example, uptake has been observed over 5 years on the Sharnford scheme up to 1983 (year 1984 was a normalised year incorporating likely adjustments immediately underway). If it is assumed that the slope of the uptake curve at individual scheme level is consistent with the slope of observed aggregate curve, the observed uptake at year 5 can be weighted according to the factors shown in Table IX.2 to give a prediction of uptake between years 6 and 13, after which benefits will remain constant. As in the case of the Sharnford scheme, uptake has been both low and slow, the predicted increases in likely response are similarly modest.

On some of the poor performing schemes, uptake as a percentage of potential has been very low, suggesting much scope for potential response in time. However, in most instances these potentials are based on intensive livestock systems, which though practiced by a minority of farmers are unlikely to be taken up by the greater majority. In such cases farmers may not be aware of the potential benefits afforded by a scheme because these are relevant only to intensive farming systems. Furthermore, pre-scheme uptake as a percentage of potential often appeared low, suggesting that post-scheme uptake as a percentage of potential would be similarly limited.

The effect of breaking into the uptake curve to predict uptake over remaining project life is to improve the performance of schemes, but not to the extent that previously unprofitable schemes at the 5% discount rate now become profitable.

Considerable reservations are held about these predictive estimates. There is little statistical justification for the method used, but it has been applied in recognition of the fact that some potential does exist which could be taken up within the relevant time horizon.

A confident prediction of likely uptake over remaining project life would require more data than that collected for ex-post evaluation. In some cases, poor performing schemes are in need of additional river or arterial works, such that predicting future uptake would necessitate a pre-investment appraisal.

IX.5 SUMMARY OF SCHEME CHARACTERISTICS

The findings of the evaluation of individual schemes can be summarised in terms of drainage status, farm characteristics, land use and financial performance.

IX.5.1 Drainage Status

Table IX.3 summarises the pre- and post-scheme situation on the 16 selected schemes with respect to flood risk, drainage status, and installation of field drains. For the schemes as a whole, on average over 60% of the benefit areas were flood prone, 43% with at least one event per year. Flood risk was highest on River Severn Bushley and Ripple schemes, in the Idle washlands, on the Blithe and the Sence at Kilby Bridge. Post-scheme flooding has not occurred on 68% of the area and has reduced on a further 9%. Pre-scheme flood risk shows a high positive correlation with poor drainage status. More than 55% of the total areas were described as 'commonly' or 'usually' wet. Overall, some 19% (over 1,000 ha) of the benefit areas have had new underdrainage installed post-scheme, and a further 13% have been redrained. Forty-two percent remains undrained and 26% has underdrains which pre-date the scheme. Most post-scheme field drainage has been associated with schemes with the greatest land use change such as Beckingham Marshes, the Idle schemes, Temple Mill and Bushley. In many cases, the schemes have reinstated outfalls for old drainage systems which farmers regard as adequate for grassland management purposes.

IX.5.2 Farm Characteristics

Livestock farmers predominate in the benefit areas. Of the 170 farmers interviewed, 46% of the farms in the benefit areas were specialist or mainly dairy farmers (with more than 75% of labour inputs and total output attributable to dairy production). A further 18%

TABLE IX.3

SCHEME SUMMARY : LAND DRAINAGE STATUS

Scheme	Pre-Scheme Flood Risk – % of Area					Pre-Scheme Drainage Status – % of Area				Under-Drainage – % of Area				Change in Flood Frequency – % of Area			
	Did Not Flood	< 1 in 5	1 in 2 to 1 in 5	One per Year	> One per Year	Rarely Wet	Occasion-ally Wet	Commonly Wet	Usually Wet	Un-drained	Drained Pre-Scheme	Drained Post-Scheme	Re-drained	No Floods	Reduce	Same	Increase
Snarnford	52	-	-	3	44	54	36	7	4	14	66	-	21	100	-	-	-
Kilby Bridge	33	-	-	1	65	-	59	36	5	4	79	-	18	36	4	54	6
Doley Brook	63	-	-	13	24	18	26	35	22	39	43	-	19	84	5	10	-
Airewas	57	-	-	17	27	61	18	17	3	89	11	-	-	56	17	27	-
Blithe	19	6	-	-	75	5	-	45	50	5	64	5	27	100	-	-	-
Morda	47	-	2	4	47	16	34	33	18	54	23	13	9	90	1	-	9
Sleap Brook	91	-	1	1	7	12	43	36	9	40	35	11	14	99	1	-	-
Beckingham	2	98	-	-	-	-	35	22	43	13	13	45	29	2	-	98	-
Mattersey	7	2	-	12	79	3	16	13	68	41	11	46	-	100	-	-	-
Misson	15	-	2	27	56	-	25	26	48	67	-	33	-	84	6	7	2
Tean	46	-	23	-	31	4	64	18	14	15	78	4	3	83	14	3	-
Temple Mill	39	-	-	-	61	-	19	31	50	20	11	-	70	100	-	-	-
Ripple	14	1	-	2	83	4	22	63	10	80	10	-	10	24	65	-	10
Bushley	8	-	-	24	69	-	31	63	6	15	33	63	-	7	89	4	-
Oldbury	48	13	-	14	25	-	20	69	11	84	13	3	-	94	6	-	-
Epney	39	14	-	-	47	20	18	31	31	45	3	49	4	100	-	-	-
Total	39	17	1	7	36	13	31	33	22	42	25	19	13	68	9	21	2
Valid Cases (%)	←		95		→	←	87		→	←	89		→	←	93		→

were livestock mainly cattle producers. These dairy and fatstock farmers accounted for a total 56% of the benefit areas. These farm type assessments are based on the post-scheme survey. The pre-scheme situation, before land use change, would have been more heavily oriented to livestock farming. About 22% of farms accounting for 31% of the total benefit areas are mainly cropping farms, occurring mainly in the IDB areas of the Idle, Beckingham and Epney schemes.

Table IX.4 summarises farm size, tenure, percentage of the farm area in benefit, and stocking rates at grass. The overall average size of farm was 105 hectares (compared to a national average of 118 hectares) with an average 42% of farm area (30 hectares) in the benefit area. The larger farmers are predominantly cropping farms. Average standard man days per farm were 926 equivalent to nearly 4 persons. Standard man day estimates generally exceeded standard man day availability based on recorded family and regular hired workers, implying that the workforce works longer or harder than the standard man day, or the need to employ casual labour.

Some 56% of fields in the benefit area were owner-occupied, and 34% tenanted, but with large variation between schemes. Overall 59% of farms with land in the benefit area were mainly owned, and 38% mainly tenanted, similar to the national average.

IX.5.3 Land Use

Table IX.5 summarises the pre-scheme and post-scheme land use for individual schemes. Overall, the pre-scheme situation was 81% down to grass, 75% accounted for by permanent pasture. Sixteen percent was arable or arable/ley. The overall post-scheme situation is characterised by a decline in the area of permanent grass to 47% of the total, and the increase of arable and arable/ley to 43%. If rough grazing is arbitarily ascribed the lowest land use rating, with permanent pasture, temporary grass, arable/leys, and continuous cropping representing an increasing order of land use intensity, then land use moved to a higher category on 32% of the total area, and declined on 2% (mainly attributable to retiring farmers) of the area. The schemes which record the greatest improvement in land use are notably the ones which generate the best financial performance.

TABLE IX.4

SCHEME SUMMARY : FARM TENURE, STOCKING RATE & PERCENTAGE IN BENEFIT AREA

Scheme	Mean* Farm Size (ha)	Mean SMD Requirement	Farm Tenure : % of Farms					Mean Grass Stocking Density LU/ha	Mean Grass* Stocking Density (Weighted by area in BA) LU/ha	Mean % of Farm in Benefit Area	Field Tenure : % of Area			
			All Tenanted	Mostly Tenanted	Mostly Owned	All Owned	No Data				Owned	Tenanted	Summer let	Other
Sharnford	56	581	7	14	14	64	–	1.81	2.33	46	77	21	1	–
Kilby Bridge	100	989	33	22	11	33	–	2.12	1.76	51	73	25	2	–
Doley Brook	107	1873	50	20	10	20	–	1.44	1.73	46	50	50	–	–
Alrewas	81	958	38	15	31	15	–	1.59	1.68	33	34	63	3	–
Blithe	44	488	–	14	14	72	–	1.51	1.55	29	96	–	4	–
Morda	58	607	13	17	30	39	–	1.92	1.83	42	53	23	1	23
Sleap Brook	83	892	11	11	6	72	–	1.85	1.92	59	81	6	2	11
Beckingham	174	640	–	43	50	–	7	1.71	3.04	30	14	86	–	–
Mattersey	171	1230	60	20	20	–	–	1.62	1.92	24	41	59	–	–
Misson	353	2227	30	30	20	10	10	1.04	1.26	30	44	6	–	50
Tean	42	422	–	11	33	56	–	1.96	1.82	48	100	–	–	–
Temple Mill	172	1672	100	–	–	–	–	2.36	2.20	19	–	100	–	–
Ripple	70	267	–	12	38	50	–	0.93	0.74	48	85	14	–	1
Bushley	93	473	–	29	–	71	–	1.71	1.58	27	58	–	–	42
Oldbury	49	1064	14	14	21	36	14	1.78	1.80	60	74	23	4	–
Epney	182	1648	50	–	50	–	–	1.71	1.77	35	50	37	12	–
Total	105	926	19	19	22	37	2	1.73	1.97	42	56	34	1	9
Valid Cases (%)	93	88	←		93		→			93			93	

TABLE IX.5

SCHEME SUMMARY : LAND USE

Scheme	Pre-Scheme Land Use – % of Area						Post-Scheme Land Use – % of Area						Land Use Change – % of Area		
	Rough Grass	Permanent Pasture	Temporary Grass	Arable /Ley	Crops	Non Agric.	Rough Grass	Permanent Pasture	Temporary Grass	Arable /Ley	Crops	Non Agric.	Decline	No Change	Improved
Sharnford	–	63	14	19	4	–	–	56	15	25	4	–	–	93	7
Kilby Bridge	5	87	–	–	–	8	–	86	–	5	–	8	–	82	10
Doley Brook	8 [1]	55	2	26	–	9	8 [1]	50	6	19	13	4	5	73	20
Alrewas	–	57	34	–	9	–	–	56	34	–	10	–	–	99	1
Blithe	8	92	–	–	–	–	–	84	16	–	–	–	–	77	23
Morda	–	86	5	8	1	–	–	73	12	13	2	–	7	73	20
Sleap Brook	–	63	–	7	17	14 [2]	–	31	7	22	34	5 [2]	6	48	43
Beckingham	3	68	1	–	28	–	–	18	–	–	82	–	–	46	54
Mattersey	–	62	–	5	33	–	–	30	6	8	56	–	–	70	30
Misson	6	83	–	–	6	4	–	25	–	5	64	5	–	33	65
Tean	–	91	8	–	–	1	–	66	8	12	–	14 [4]	–	75	10
Temple Mill	–	81	–	–	–	19 [3]	–	10	–	72	–	19 [3]	–	10	72
Ripple	–	86	–	2	7	4	–	73	–	4	19	4	–	82	14
Bushley	–	95	–	5	–	–	–	31	–	31	38	–	–	34	66
Oldbury	–	93	1	2	1	4	–	89	4	3	1	4	–	95	4
Epney	–	87	13	–	–	–	–	39	–	57	4	–	–	39	61
Total	2	75	4	5	11	4	1	47	7	12	31	3	2	64	32
Valid Cases (%)	←			98		→	←			99		→	←	99	→

1. Doley Common
2. Sleap Airfield
3. Sibson Wold
4. A50 By-pass

IX.5.4 Degree of Benefit Uptake

Table IX.6 summarises the uptake of agricultural benefits by individual schemes, and distinguishes between automatic benefits (such as extended grazing) and positive uptake derived from an intensification or change of land use. Overall, a positive uptake response was recorded on 51% of the total benefit area, with a further 6.7% reporting automatic benefits only. No benefits occurred on 42% of the area. In terms of farmers deriving benefit, uptake was perceived on 66% of all surveyed farms. At individual scheme level, some measure of positive uptake was recorded on 100% of the benefit area in the case of the Blithe scheme, whereas in the case of Sharnford a positive response occurred on only 12% of the benefit area.

TABLE IX.6

Uptake of Agricultural Benefits by Scheme

Scheme	% of Total Scheme Benefit Areas		
	No Benefits Perceived	Automatic Benefits Only	Positive Benefit Uptake
Sharnford	82.0	6.3	11.7
Kilby Bridge	60.2	6.5	33.2
Doley Brook	47.2	10.9	41.9
Alrewas	62.5	0.0	37.5
Blithe	0.0	0.0	100.0
Morda	49.6	4.0	46.4
Sleap	61.5	1.8	36.8
Bekcingham	21.6	0.0	78.4
Mattersey	12.0	0.0	88.0
Misson	28.1	34.0	37.8
Tean	75.4	2.3	22.3
Temple Mill	18.4	0.0	81.5
Ripple	50.1	11.0	38.9
Bushley	5.2	0.0	94.8
Oldbury	26.8	19.2	53.9
Epney	0.0	0.0	100.0
Total	42.3	6.7	51.1

IX.6 SCHEME FINANCIAL PERFORMANCE

IX.6.1 Net Present Values and Internal Rates of Return

Table IX.7 summarises the financial performance of the 16 STWA schemes.

On the basis of observed performance todate extrapolated over the remainder of project life, 7 of the 16 schemes recover costs and appear profitable at the 5% discount rate. These are the Doley, Morda, Sleap, Mattersey, Misson, Bushley and Epney schemes. One further scheme, Beckingham Marshes, is sufficiently marginal to justify satisfying the 5% rule. Five of these schemes are wholly or partly within IDB areas, and 2 others have informal farmer drainage groups.

On 3 schemes, Kilby Bridge, Blithe and Temple Mill, the internal rate of return is between 0% and 5%, and present levels of uptake would need to more than double over remaining project life for them to break even. The remaining schemes: Sharnford, Alrewas, Tean, Ripple and Oldbury, produce negative rates of return. The increase in net agricultural returns over remaining project life needed to break even varying between two-times present levels in the case of the Alrewas to more than ten-times in the case of Sharnford.

Some of the poor performing schemes are immature such that further uptake beyond the 1984 level could be anticipated. Using the method described in section IX.4.6 above, the derived uptake curve which peaks in year 13 of project life was used to predict uptake over remaining project life.

This prediction of full development performance does not significantly affect the overall outcome. The Kilby Bridge scheme joins those with positive net present values at 5%, although this scheme is especially sensitive to assumptions regarding the savings in flood damage costs which were a major justification for the scheme.

TABLE IX.7

Summary of Scheme Performance

Scheme	Capital Cost £ per ha of Benefit Area[1]		Field Drainage Investment £ per ha of Benefit Area	Performance Todate[2]			Projected to Full Development[3]		Remarks
	Estimated	Actual		NPV at 5% £'000	IRR %	Switch Value	NPV at 5% £'000	IRR %	
Sharnford	1080	1331	90	-482	-∞	8.5	-422	-8.0	23% increase in costs.
Kilby Bridge	541	740	84	-54	2.2	1.5	60	5.5	Includes anticipated increased flood damage in without-project benefits. 37% increase in costs.
Doley Brook	970	368	161	16	6.7	0.88	16	6.7	62% saving in costs (incl. bridge not rebuilt).
Alrewas	548[4]	532[4]	0	-175	-4.0	2.5	-124	0.1	Anticipated arterial works on non-main river not carried out.
Blithe	683	799	82	-24	1.75	1.75	-24	1.75	
Morda	511	522	122	61	7.4	0.82	61	7.4	Part in IDB.
Sleap	203[4]	178[4]	125	81	8.3	0.8	81	8.3	Excluding benefits to Sleap Airfield. Local Drainage Group.
Beckingham	-	1877	275	-27	4.6	1.02	-27	4.6	IDB.
Mattersey	-	653	188	325	16.0	0.57	-	-	IDB.
Misson	-	513	135	54	6.7	0.9	-	-	IDB.
Tean	1323	1452	27	-253	-11.4	7.0	-217	-3.9	25 ha out of production during road construction.
Temple Mill	619	1296	525	-29	2.7	1.25	-29	2.7	Anticipated arterial works on non-main river not carried out. 109% increase in costs.
Ripple	660	1134	56	-182	-3.9	3.75	-167	-1.9	72% increase in costs.
Bushley	673	567	240	78	11.3	0.63	78	11.3	Local Drainage Group.
Oldbury	692[5]	1208[5]	15	-427	-4.8	2.9	-140	3.0	75% increase in costs. IDB.
Epney	905[5]	1013[5]	130	66	8.0	0.75	66	8.0	IDB.

1. Capital costs brought to 1982 levels using PWNR index.
2. Observed performance todate with benefits continuing at their 1984 level for remainder of project life.
3. Projected of full development (see Annexe IX, section 4.6).
4. STWA costs per ha of direct benefit only.
5. Whole project costs.

IX.6.2 Capital Costs per Hectare

Average capital costs per hectare of benefit were £882 in 1982 prices, ranging from £178 in the Sleap to £1,877 in the Beckingham. Capital costs vary according to the nature of the drainage problem and the engineering solution, such that simple relationships say between benefit area and capital cost per hectare, or between capital cost and actual or potential net returns are easily discernible.

In 5 schemes there were significant increases in real capital costs beyond those estimated before commencement of works, in 3 cases by more than 70%. Four of these schemes failed to break even at the 5% discount rate. It is not possible at this stage to say whether inadequate attention to design and costing, supervision, or bad luck during implementation were at fault, but higher costs were a contributary factor to poor scheme performance.

IX.6.3 Field Drainage Investments per Hectare

Field drainage investments averaged £141 per hectare of the benefit area, ranging from nil in the case of Alrewas to £525 in the Temple Mill where 70% of the area has been redrained since the scheme.

IX.6.4 Increased Gross Margins and Net Returns

A summary of benefits by scheme is contained in Table IX.8.

Overall net returns increased by £93 per hectare in 1982 prices, generally being associated with the nature of uptake response. At Ripple where the majority of benefits have been associated with marginal improvements to grassland management, gross margins and net returns have risen by 20% and 16% respectively. In the case of Epney where uptake has meant a move to arable and intensive ley systems gross margins and net returns rose by 109% and 91% respectively from a similar baseline to those at Ripple. The degree of improved drainage provided was greater in the case of the Epney, however.

TABLE IX.8

Summary of Benefits by Scheme

Scheme	Date of Commencement of Works	No. of Farmers in Benefit Area	No. of Farmers Taking Up Benefits	Benefit Area (ha)[1]	Extra Net Returns (£/ha)	Flood Damage Reduction (£/ha/year)	Increase in Gross Margin (%)	Increase in Net Returns (%)	Extra GM/ha as % of Potential	Ranking (based on extra net returns/ha)
Sharnford	1978	14	4	370	13	1.49	4	5	6	16
Kilby Bridge	1974	9	7	256	40	22.41	28	19	29	12
Doley Brook	1973	10	8	198	70	0	24	29	29	8
Alrewas	1976	13	2	464	22	2.48	15	11	n/a	13
Blithe	1971	7	7	77	90	2.39	56	53	37	6
Morda	1972	23	10	431	62	2.44	26	37	26	10
Sleap	1973	17	12	945	66	0.14	30	30	20	9
Beckingham	1960	14	10	919	231	-4.88	123	168	70	1
Mattersey	1982	10	8	309	166	11.55	96	89	65	3
Misson	1980	10	9	480	84	0	n/a	53	n/a	7
Tean	1977	8	3	138	22	5.94	13	29	12	13
Temple Mill	1972	2	2	73	142	3.83	80	73	69	5
Ripple	1975	8	6	244	22	20.10	20	16	10	13
Bushley	1972	7	5	129	148	5.81	67	119	47	4
Oldbury	1978	14	12	448	50	8.59	17	24	22	11
Epney	1971	2	2	145	183	7.72	109	91	73	2

1. The Area used for investment appraisal which may not be the same as the benefit area defined at feasibility stage nor the area covered by the farm survey.

Average actual increments in gross margin have varied between 6% and 73% of what might be regarded as a potential increment for local conditions and farming practice (see section IX.4.5 above). This measure of relative uptake does not, of course, allow for the fact that much of pre-scheme farming practice was below the potential offered by pre-scheme drainage status.

IX.6.5 Distribution of Benefits

Of the 164 farmers who were identified as potential beneficiaries of the schemes, 109 (66%) reported deriving benefits which could be expressed in financial terms. In the majority of schemes, however, the distribution of benefits is skewed in favour of a small number of beneficiaries often but not always in proportion to the percentage of the benefit area they farm, as shown in Table IX.9.

Larger farms, accounting for a larger proportion of the benefit area, derived a proportionately larger share of total gross margin and net revenue increment. Average increments in financial benefits were greatest for larger farms, but variation about the average was considerable.

Cropping farms derived the greatest average per hectare financial benefit of all farm type, and a share of total benefit increment proportionately greater than their share of total benefit area. Dairy farms and 'other' types were the other major beneficiaries.

IX.7 FACTORS INFLUENCING INDIVIDUAL SCHEME PERFORMANCE

The factors which influence the nature and rate of uptake of agricultural benefits at field, farm and scheme level are discussed in detail in Annexe VIII. In financial terms, the factors influencing overall scheme performance are the relative sizes and timing of net agricultural benefits and scheme costs.

Sensitivity analysis of individual scheme performance confirms that it is net agricultural returns (rather than without-project benefits, flood damage reduction, or field drainage costs) that is the critical factor in the benefit stream. In the main, at

TABLE IX.9

Distribution of Benefits by Type and Size of Farm

Farm Size:

Classes ha	% of Total Benefit Area	Gross Margin		Net Return	
		Average Increment £/ha	% of Total Increment	Average Increment £/ha	% of Total Increment
0-20	2.0	26 (69)	0.5	18 (33)	0.4
20-40	10.2	68 (148)	6.0	40 (74)	4.8
40-80	22.4	55 (104)	10.5	37 (70)	9.8
80+	65.4	149 (219)	83.0	111 (138)	85.0

Farm Type:

Dairy	39	112 (149)	36.2	66 (87)	29.4
Livestock	13	42 (135)	4.5	35 (97)	5.3
Cropping	33	189 (260)	51.0	154 (155)	57.6
Mixed	10	29 (71)	2.3	24 (68)	2.7
Other	5	133 (202)	5.9	78 (111)	5.0

Figures in brackets show standard deviation.

field level net agricultural returns, whether arising from improved productivity or land use change, have been greatest where the scheme has provided a significant improvement in potential drainage status, and physical conditions, particularly soils, have been conducive to farming improvement or change.

This has been the case particularly on the Idle Washlands, where in a traditional potato and sugar beet area farmers have found it attractive to grow root crops on peats and sands with irrigation. The potential for arable or arable/ley cropping has been greatest and most fully exploited on the less heavy soils of the Sleap, Bushley, Beckingham and Epney schemes.

At farm level, the degree of uptake has been associated with a change of farm management during the life of the scheme, such as a new farmer coming in, or an heir taking over from or joining in partnership with a father. By way of examples, on the Morda, the greatest degree of uptake was associated with one farmer who acquired a farm in the benefit area in the year preceding the scheme, and he alone accounts for 35% of the total net returns to the scheme. Two other major beneficiaries on the Morda involved the sons joining fathers in partnership and resultant pressures to intensify. On the Bushley, the major beneficiary involves a partnership formed between 2 farmers shortly after the scheme was implemented. On the Misson, one farming company acquired a large part of the benefit area immediately prior to, and largely in anticipation of, the scheme, and subsequently changed farming methods radically.

At scheme level the main factors influencing the uptake of benefits, in addition to field and farm level factors found within the confines of a particular benefit area, relate to the presence of formal or informal organisations providing drainage services within the benefit area. Seven of the 8 schemes which break even at 5% involve such organisations, 5 are in IDB areas (3 of which are pumped) and 2 contain informal drainage groups which collectively undertake watercourse improvement and in one case emergency pumping when necessary. It is in these schemes that farmers are aware of the potential afforded by improved drainage particularly by the demonstration effect on adjoining IDB areas, where there is much pressure exerted by farmers and land drainage committees for improvement, where drainage contractors are more readily available, and where follow-up work on arterial drains or pumping is done quickly to satisfy a latent demand.

With respect to scheme costs, it is perhaps fortuitous that the 7 schemes with the highest financial performance generally displayed the lowest capital cost per hectare, but more importantly they also offered the greatest potential benefit per £ capital cost. As previously mentioned, significant increases in inflation-adjusted scheme costs over estimated costs prejudiced 5 schemes. In some instances more detailed site investigation and design would have concluded that original cost estimates were unrealistic.

IX.8 CRITIQUE OF METHODOLOGY

Criticisms may be levelled at the preceding methodology in terms of the assumptions built into the analysis, and those factors which have been left out.

The evaluation of schemes depends on the reliability of the estimates of costs and benefits and the sensitivity of performance to these. Scheme level and field drainage cost data have mainly been derived from financial records. Benefit assessment is largely based on farmer interview whereby physical data has been converted to gross margin and fixed cost values using standardised procedures. The greatest uncertainty must lie with the estimate of fixed costs, and particularly the assumption regarding additional labour requirements. A critique of benefit assessment procedures is contained in Annexe V, and the sensitivity of estimates to varying assumptions is examined.

The analysis adopts a quasi-financial viewpoint which values all inputs and outputs at prevailing market prices, except for drainage expenditure which is costed before grant. In the present context of agricultural surpluses in major food commodities in U.K. and Europe measuring extra output at support prices is likely to overstate the real value of extra production to the economy. However, up until 1984, agricultural policy has been expansionist and support prices have been consistently defended at Government level, for justifying productivity and output improvements in the agricultural sector. It is important to consider the implications of an alternative, more economically rational price base and this is done in Annexe V.

The financial analysis adopts a 1982 constant price base and the price relativities that applied at that time. This implies that inflation affects all inputs and outputs equally over the scheme lives. The justification for this assumption is explained in Annexe V and its effect examined.

The evaluation of schemes is production and monetary oriented. In the course of interview farmers related what they say as the (mainly beneficial) intangible effects of the scheme which are by definition difficult if not impossible to quantify in money terms, particularly the reduced threat of flooding.

The method does not incorporate the external, largely non-agricultural impacts of the land drainage improvements, particularly the environmental impact of changes in water regimes and subsequent farming practice on conservation, amenity and recreation. Where substantial impacts have been identified, whether beneficial or detrimental, these are referred to in the individual scheme reports. Other external benefits associated with the multiplier effects of increased farming activities, employment and incomes within the rural economy have also not received direct attention although consideration has been given to the distributional effects of additional net returns arising from the schemes.

APPENDIX A

Soar Division

River Soar : Sharnford to Croft

SILSOE COLLEGE

STWA SOAR DIVISION - RIVER SOAR SCHEME (1978)

Report on the background to, and development of, the scheme and the nature and rate of uptake of agricultural benefits.

1. Physical Background

The River Soar flows in a northerly direction from the Warwickshire border near Hinckley, through Leicestershire and part of Nottinghamshire, to join the River Trent at Long Eaton in Derbyshire. The present scheme relates to the upper most reach of the River Soar from upstream of Sharnford to Croft (9.5 km).

The catchment area of 72.5 sq. km is fairly steep longitudinally with pre-scheme bed gradients ranging from 1 in 250 to 1 in 900. The valley sides rise steeply from the floodplain which itself is fairly flat and shows signs of the river having had several courses over it (Ref. 1). The water-course shows evidence of considerable human interference. Several sections have been straightened and improved at various stages in the past. The reach between Sharnford and Soar Mill has been modified to provide a suitable head for the Mill and the Soar flowed along a man-made leat rather than the valley bottom.

2. Soils and Land Capability

The soil of the area is predominantly clay (Ref. 1), but the soils of the floodplain appear to be very mixed with pockets of 'running sand' and gravel. The National Soils Map (Ref. 6) classifies the soils of the entire area as surface water gleys of the Salop Association. The soils have a clayey subsoil that is slightly porous and coarsely structured that holds up percolating drainage waters. They are generally imperfect to poorly drained unless underdrained. The land quality was classified by MAFF (Ref. 2) as grade 3 with the exception of the immediate floodplain which was classified as grade 4, presumably because of its poor drainage.

3. Land Drainage History

Prior to the STWA scheme the County Council improved a length of ditch that runs parallel to the Soar along the valley floor upstream of Stoney Bridge (see Fig 1). This watercourse is in fact lower than the Soar and its improvement gave great benefit to the adjoining fields, some of which were subsequently underdrained in response.

4. Pre-Scheme Land Drainage Status

The lower valley was poorly drained due to its flatness and the relatively high water level in the main river (Ref. 1). The drainage had deteriorated to the state that the river would flood with every major storm and the farmers of riparian land would expect their fields to be under water 2 or 3 times every year. The farm survey identified 140 ha (equal to 38% of the benefit area) as liable to flooding. The 'flashy' nature of the river meant that water levels would rise and fall quickly so the river would only be in spate for one to 3 days.

Flooding usually occurred in winter causing little disruption of agricultural practices (as most of the riparian land was under grass). However, the occasional summer flood had caused damage to, and in some cases complete loss of, the hay crop. Flooding of property was rare although in 1955 and 1968 approximately 3 houses, a public house, and the main road in Sharnford were flooded (Ref. 3).

Most riparian land (equal to 87% of the benefit area) had been underdrained at some time, either into the Soar or tributary brooks, although with low freeboard and frequent surcharging few systems could have been working efficiently. However, the farm survey (see 10 below) found that 54% of the area surveyed was reported as being 'Rarely or Seldom Wet' prior to the scheme. Thirty-six percent was reported to be 'Occasionally Wet', 7% 'Commonly Wet' and 4% 'Usually Wet'.

5. The Impact of Pre-Scheme Drainage Status on Land Utilisation

Immediately prior to the scheme the land use of the benefit area (see section 7) was as follows (from farm survey):

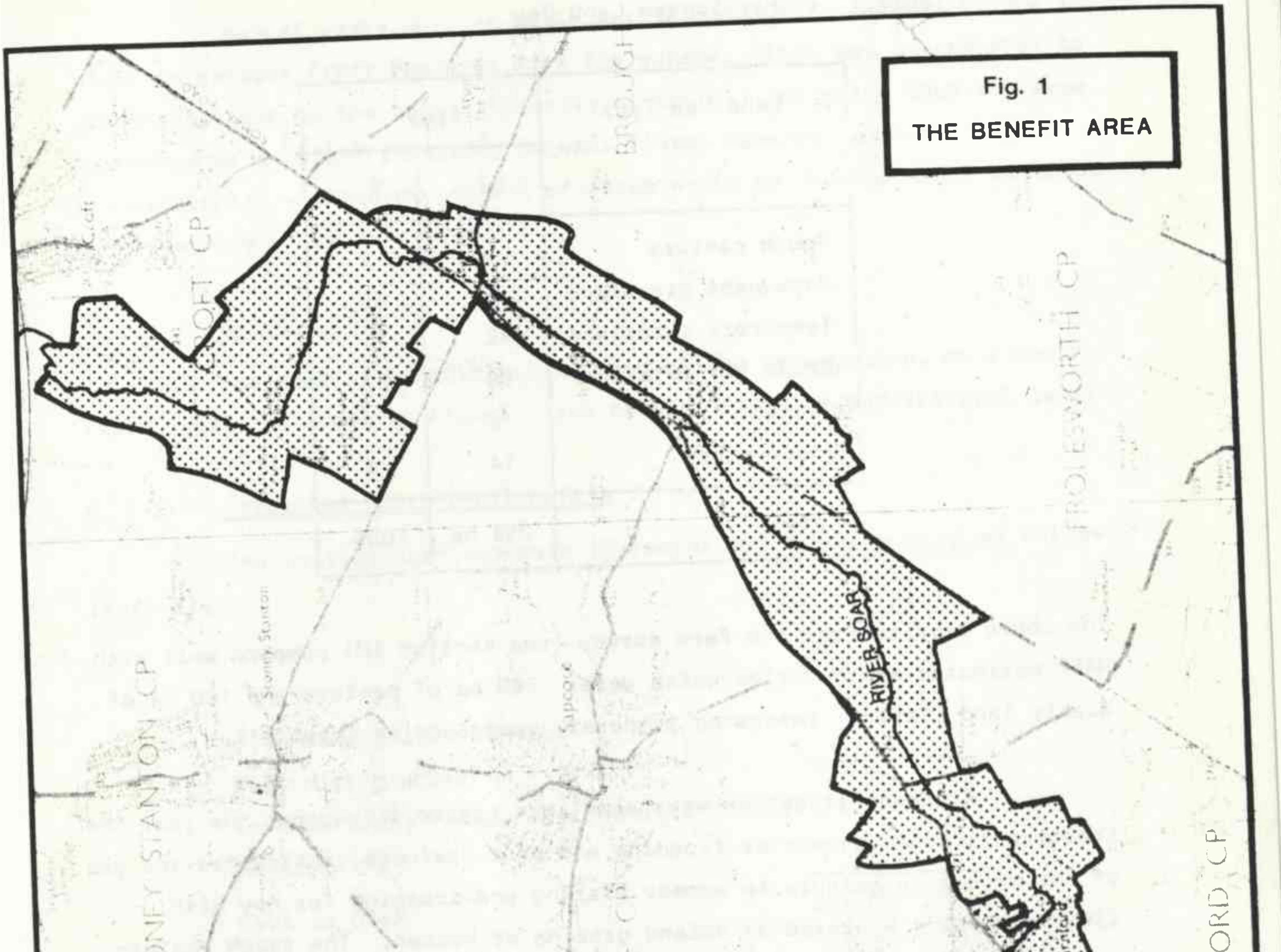


Fig. 1
THE BENEFIT AREA

Table 1 : Pre-Scheme Land Use

Land Use Type	Area	
	Ha	%
Rough pasture	9	2
Permanent grassland	219	60
Temporary grassland	42	11
Crops (in rotation)	80	22
Unused	4	1
Unsurveyed	14	4
Total	368 ha	100%

The above results from the farm survey (see section 10) compare well with MAFF estimates at that time which were: 240 ha of pasture and 120 ha of arable land (Ref. 1) (assuming temporary grassland is 'arable').

Although livestock were sometimes grazed throughout the year the constraints posed by winter flooding and poor drainage, restricted the use of the riverside pasture to summer grazing and cropping for hay with livestock being wintered on upland grazing or housed. The rough pasture and wetter areas of permanent grass suffered from infestation by rushes and other poor quality species, particularly in the reach between Sharnford and Soar Mill. The land used for crops was almost exclusively away from the river where there was little or no flood risk and better field drainage conditions.

6. Scheme Design

The scheme was designed in 1975 in collaboration with ADAS who recommended design standards required for agricultural purposes. The river channel was to be deepened and regraded to ensure a minimum freeboard of 1.5 m throughout the length and a minimum design return period for bankfull discharge of one in 3 years, for agricultural land, rising to one in 10 years through Sharnford (Ref. 4). Following consultations with the Regional Engineer of MAFF, return periods of one in 5 years and one in 7 years were chosen for the reaches Croft to Soar Mill and Soar Mill to Sharnford respectively (relating to discharges of 11.96 and 10.74 cumecs).

Channel works were to begin upstream of Croft railway bridge in order to exclude Croft Pastures from the scheme. This was in response to recommendations by the Nature Conservancy Council who noted that the area (proposed as an SSSI) contained several floral species, rare in Leicestershire - although not all of these would be detrimentally affected by a lowering of water levels.

7. Benefit Area

The area of benefit, as defined by the Medway Line, on a whole field basis, is shown on Figure 1 and covers 367 ha of agricultural land.

8. Predicted Costs and Benefits

The initial cost estimate (December 1976) was made up as follows (Ref. 4):

	£,000	
Preliminary investigation	3.0	
Engineering works	169.5	
Land purchase, compensation, etc.	11.5	
Other costs	21.0	
Cost to STWA	205.0	205.0
Infield drainage	55.0	
Drainage Cost to Farmers	55.0	55.0
TOTAL COST		260.0*

* 1977 prices

This was to be financed by STWA with grant aid from MAFF. STWA applied for a FEOGA grant from the EEC but no financial support was forthcoming. There were no other contributions towards the cost. Channel excavation work was to be carried out by contracted labour.

The Benefit Assessment provided by MAFF related to 360 ha of agricultural land (Ref. 4). It was anticipated that pasture would be improved on 140 ha, arable improved on 120 ha and that 100 ha would change from pasture to arable as a result of the improvement scheme. A net benefit of £220-£230,000 was quoted (Ref. 4). Revised figures were quoted in the Engineers Report (Ref. 1) derived as follows:

Table 2 : Value of Benefits

Improvement	Area (ha)	Increase in annual gross margin/ha (£)	Total (£)
Improved pasture	140	55	7,700
Conversion to arable	100	150	15,000
Improved arable	120	65	7,800
	360		30,500*

* 1977 prices

This figure was discounted at a rate of 10% over an anticipated life of 30 years to derive a present value of £287,520, ie. a benefit/cost ratio 1.11.

No allowance was made for the rate of change to arable or installation of infield drains after the completion of channel works. The assessment is based upon the assumption that all benefits are realised immediately.

9. The Scheme

The scheme was carried out in two phases:

(a) Phase I:

Croft to Sutton Hill Bridge (2.4 km). Channel excavation works began upstream of Croft railway bridge in February 1978. The oxbow at the lower end was cut off and filled and the channel deepened by 0.5 m-1 m. The river was diverted around Soper's bridge but the bridge was left as an archaeological feature.

By September 1978, work on Phase I was almost complete, however, a thick gravel formation encountered during excavation meant that virtually treble the quantity of top-soil had to be stripped, piled and respread. The additional expenditure incurred (approximately £23,000) caused a delay in the commencement of Phase II, pending a technical and financial appraisal. Three options were considered:

(i) Complete Phase I and abandon further work;

(ii) Complete Phase I and extend works as far as Stoney Bridge;

(iii) Proceed as originally envisaged.

The costs and benefits of each option were appraised by STWA on the following basis:

(i) Design and supervision costs were included in the cost to the Authority.

(ii) The expected life of the scheme was extended from 30 years to 50 years.

(iii) Costs were phased according to the year of expenditure.

(iv) Benefits were phased, assuming that any underdrainage would be installed in the year following completion of channel works and the benefits would accrue the year after that.

(v) Costs and benefits were discounted at 5% and 10% to test the sensitivity to varying discount rates.

Option three was found to be most worthwhile but benefit/cost ratios were shown to be very sensitive to the choice of discount rate. The costs and benefits were revised as follows (Ref. 5):

	£,000 (Sept '78)	
Cost:		
Phase I	107.5	
Thrust Bore	17.5	
Phase II	158.5	
Total Expenditure	283.5	283.5
Design and Supervision	24.0	24.0
Cost to STWA		307.5
Infield drainage	62.0	62.0
TOTAL COST		369.5

Benefits:

Phase I only one year @	12.4 pa
Phases I and II 48 years @	36.6 pa

NB: No further details were given.

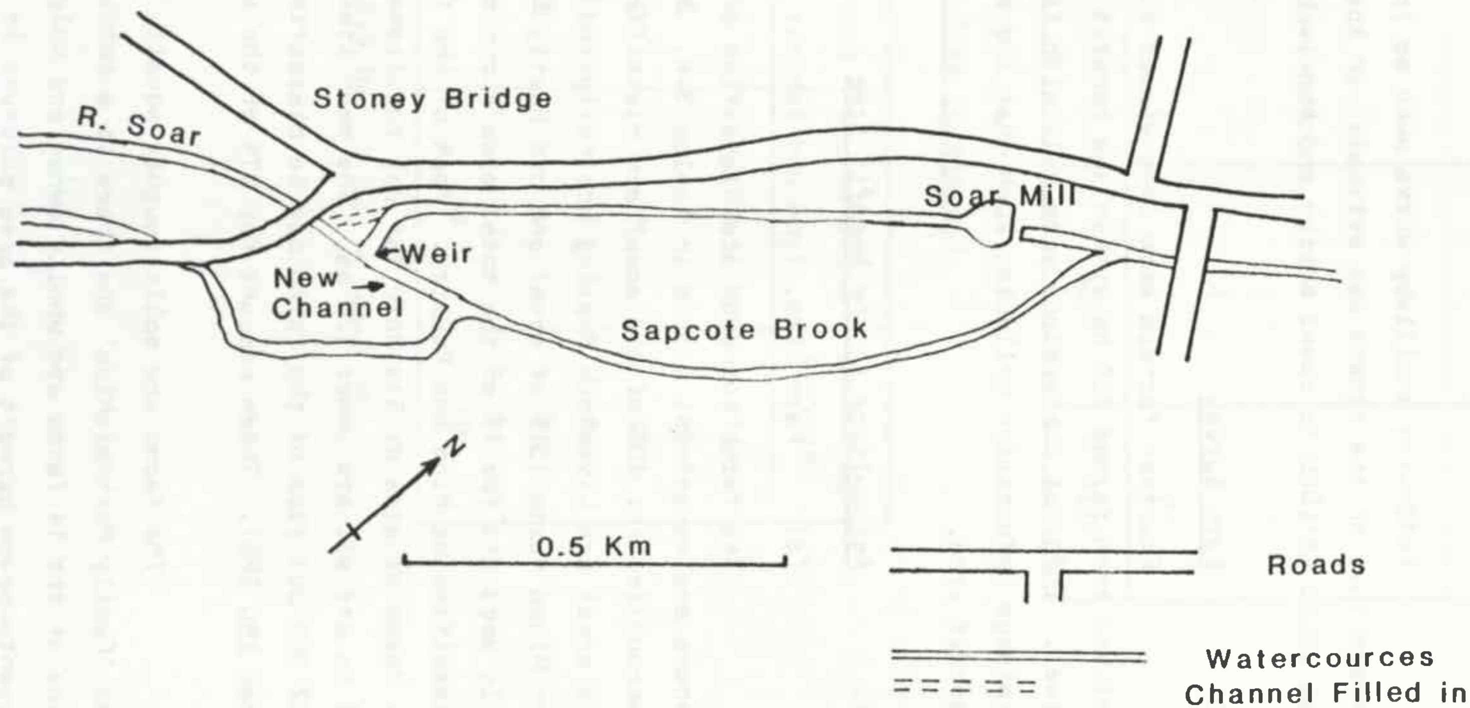
Benefit/Cost Ratio:

	Discount Rate	
	5%	10%
Cost (PV) £	359,000	348,800
Benefits (PV) £	610,400	309,600
Ratio	1.70	0.89

(b) Phase II:

Sutton Hill Bridge to end of main river (7.1 km). Following approval by the Technical and Financial Appraisal Group, work commenced on Phase II. Below Stoney Bridge, a channel was cut to by-pass Soar Mill, however, to maintain the mill pond as an amenity feature a weir was installed to divert normal flow through the leat. Flood flows would pass over the weir, through the new channel into the Sapcote Brook which was improved as far as its confluence with the Soar below the Mill (see Figure 2).

Fig. 2 DIVERSION WEIR BELOW STONEY BRIDGE



Throughout Phase II bed levels were lowered by 0.5 m-1 m although works through the village of Sharnford (between Sharnford weir and Aston Lane - 0.5 km) were of maintenance standard only. Works extended up to the end of main river just below Hogue Hall Spinney.

Following ancillary works such as fencing and stoning the total expenditure on the scheme was estimated in April 1982 at £344,000. To this was added £51,000 to cover design and supervision costs.

10. Farm Survey

Fourteen farmers were interviewed during June and July 1982 who between them farmed 300 ha within the benefit area (ie. 81% of the benefit area). Informal discussions were held with five others and land use and drainage information collected such that the survey covered 96% of the benefit area.

11. Agriculture in the Benefit Area

(a) Farm Size, Type and Tenure:

The farms surveyed are classified according to size, type, tenure and management status in Tables 3-6. Six of the farms surveyed, (accounting for 40% of the area) are classified as Dairy and four (21% of the area) are Livestock Rearing and Fattening - Mostly Cattle. There are two Mixed farms (31% of area) and one Mostly Cereals farm although this only accounts for 1% of the total area surveyed. One farm (7% of area) is classified as Pigs and Poultry. Most of the farms are small when measured in terms of area or Standard Man Day requirement. The average size is 56 ha and all are under 120 ha. The mean Standard Man Day requirement is 582 SMD but five of the farms can be classified as 'part-time' (ie. less than 250 SMD). These account for 27% of the area surveyed.

The farms are split roughly equally between 'Sole Proprietorships' and 'Family Partnerships' and there is a tendancy towards owner-occupation. Nine of the 14 farms are wholly owned and only one wholly tenanted. Seventy-seven percent of the area surveyed is owner-occupied.

Table 3 : Farm Type

Farm Type	No. of Farms	% of Area Surveyed
Specialist Dairy	4	33
Mainly Dairy	2	7
Livestock - Mostly Cattle	4	21
Poultry and Pigs	1	7
Mostly Cereals	1	1
Mixed	2	31
Total	14	100

Table 4 : Farm Size (hectares)

Farm Size (ha)	No. of Farms	% of Area Surveyed
20- 30	2	11
30- 40	3	22
40- 50	3	22
50-100	5	19
100-200	1	26
Total	14	100

Mean = 55.9 ha SD = 28.6 ha

Table 5 : Farm Size (Standard Man Days)

Farm Size (SMD)	No. of Farms	% of Area Surveyed
100- 174	1	2
175- 249	4	25
250- 499	2	7
500- 999	5	34
1000-1499	1	26
1500-1999	1	6
Total	14	100

Mean = 582 SMD   SD = 486 SMD

Table 6 : Farm Management and Tenure

	Management		
Tenure	Sole Proprietor	Family Partnership	Total
100% owned	4	5	9
75-99% owned	0	1	1
50-74% owned	0	1	1
25-49% owned	1	0	1
1-25% owned	0	1	1
100% tenanted	1	0	1
Total	6	8	14

(b) Dairy Enterprises:

Dairying is the most important enterprise within the benefit area. Although there are only 6 farms classified as Dairy, one of the Mixed farms and the Poultry and Pig farm also have dairy herds. Farms with dairy herds account for 73% of the land surveyed.

Herd size averages 1.2 dairy cows per hectare of grass plus 0.6 followers. All breed their own replacements and most sell some cattle at up to 2 years for beef (average 0.6 beef cattle per hectare of grass). Total stocking rates average 2.25 Livestock Units per hectare of grass on farms with dairy cattle. The cattle are grazed on the floodplain land in summer, usually after a cut of hay has been taken. Permanent pasture dominates the land use although, on the more intensive farms, some pasture is regularly ploughed and reseeded and silage making replaces hay. Most farms with dairy enterprises also grow some cereals on upland fields outside the benefit area. Two farms not classified as 'Dairy' kept small dairy herds.

(c) Beef Suckling Enterprises:

Beef suckling is the second most important enterprise. The four Cattle farms and the Mixed farm with beef cattle account for 26% of the area surveyed. All the farms with suckler herds were small, when measured by Standard Man Day requirements and most were classified as part-time (ie. less than 250 SMD). Herd sizes average 1.11 Livestock Units per hectare of grass on farms with suckler herds, although some farms were operating single, and others double or multiple, suckling systems. Most also carried some sheep. Floodplain land use is dominated by permanent pasture, most of which is cropped for hay in summer and then grazed. Some cereals are grown away from the river or outside the benefit area.

(d) Cereals:

One farm is classified as Mostly Cereals, but one of the Mixed farms has a large area in rotation within the benefit area. Winter and spring barley, wheat or oats are grown on the more freely drained land away from the river. Yields are variable, depending upon management techniques but are clearly related to drainage status. Only one farm surveyed kept no livestock and this had very little land within the benefit area (accounting for only 1% of the total area surveyed) and none adjacent to the river.

12. Effects of the Scheme on Flooding and Land Drainage

The works carried out successfully reduced the frequency of flooding such that upto the time of the farm survey the river had not flooded even after the severe conditions of the winter of 1981/82. However, there have been allegations that the scheme has enhanced flooding elsewhere, especially on Croft Glebe land (below the lower end of the scheme). It has been claimed that silt brought with the floodwaters was deposited on the land rendering it ungrazeable for long periods. This may, however, have been a temporary phenomenon resulting from the channel excavation works upstream.

The improved channel is now able to cope with higher discharges, conveying water very much quicker to lower end of the scheme. As the reach through Croft Pastures has not been improved it acts as a constriction to flow causing floodwaters to back-up at the lower end of the scheme over a length of about ½ km.

More serious problems have been caused by the deterioration of field drainage following the completion of the scheme. This was caused by two factors: firstly, the bank of spoil excavated from the channel acted as a physical barrier to surface water preventing it from reaching the channel. Thus water has been ponded at the base of the bank creating drainage and trafficability problems. Secondly, the surface beneath the spoil bank was hardened and compacted due to the weight of vehicles used in the execution of the works, restricting the natural drainage into the brook. Both of these factors were confirmed by ADAS.

In order to reinstate the field drainage, STWA have been paying for, or contributing towards, the cost of underdrainage of the land affected. Todate, roughly 35 ha of the land recorded as having been drained since the scheme, has been carried out with aid from the Authority and much that will be drained within the next few years will be paid for by STWA.

The change in the hydraulic characteristics of the channel has led to significant erosion problems. In at least two reaches STWA have had to stone meanders to stabilize the banks and work on this was still proceeding at the time of the farm survey. It should be noted that where stoning has taken place the effect has often been to divert the problem rather than solve it. Where erosion has been severe the banks have been steepened to the extent that one farmer claims he has had to insure his cattle against falling into the river.

High rates of bank erosion have led to increased suspended sediment loads and slumping of unstable banks and meanders. This has been exacerbated by a lack of maintenance following the scheme, and the improvement potential of the scheme has been gradually declining. At least one farmer has delayed investment in field drainage due to fears of the channel form deteriorating within a few years. The lack of maintenance is now receiving attention from STWA.

Three instances have been identified within the benefit area where full benefits cannot be realized until a certain amount of ancillary ditch improvement is carried out. In each case the farmers wished to install field drains but were unable to obtain a suitable outfall. The farmers themselves were unwilling to invest in the ditching work either because the main problem was not on their property, or because they believed it was the responsibility of the County Council or STWA (NB: None is main river). The watercourses in question are at Sutton Hill Bridge, Sharnford, and the Aston Flamville Brook (noted in section 24(5) survey (Ref. 3), page 23).

Cereal yields do not appear to have been affected by the scheme except occasionally where arable land abuts the river. On one field (where there have been no subsequent drainage problems) yields at the bottom of the field are reported to have been roughly doubled and brought into line with yields on cereal land outside the benefit area as a direct response to the scheme.

13. The Agricultural Benefits of the Scheme

(a) Improved Production from Existing Land Use:

The reduction of flooding and improvement of drainage has undoubtedly improved the condition of the grazing. Sward composition has improved as rushes have died back or been ploughed out, and the risk of poaching at either end of the grazing season has been reduced. The reduction of flood risk has removed the need to keep a careful eye on livestock, which previously had to be moved when the river rose. The farmers interviewed, however, were not able to perceive the benefits in terms of improved production (eg. better grass cuts or longer grazing seasons). In a number of cases this was due to the deterioration of field drainage following the scheme (see Section 12), but few automatic benefits were recorded largely because the main pre-scheme drainage problem was winter flooding and field drainage was in many parts reasonably good (see Section 4).

(b) Change of Land Use:

The pre- and post-scheme land use data are given in Table 7 below:

Only 7.8% of the area surveyed has changed land use since the scheme. Some rough grazing has been improved to permanent grass status and a small area of permanent grass has been ploughed and reseeded as a temporary ley. 18.2 ha of permanent grass have been ploughed and brought into an arable rotation of temporary grass and winter cereals. This change was accompanied by field drainage in each case and was carried out in direct response to the river improvement scheme. The land use data are shown in Figure 3.

(c) The Installation of Field Drains:

Figure 4 shows the rate of installation of field drains following the completion of the scheme. The areas quoted refer to the whole field although often only part of the field was drained. Todate 16 fields have received underdrainage treatments, covering 69.5 ha of which nearly 8 ha could, and would, have been drained even if the river had not been improved. Several farmers indicated that they intend to install field drains after this harvest year, such that by 1983 80 ha should have been drained, (22% of the benefit area). Half of this will have been wholly or partly financed by STWA (see section 12).

(c) The Rate of Benefit Uptake:

A financial assessment of the Sharnford to Croft scheme has been undertaken by identifying, on the basis of farmer interview, the change in farm enterprise gross margins attributable to drainage improvements, net of any additional fixed costs, and including the benefit of extended grazing if relevant. The procedures used for this purpose are described in Annexe V.

A summary of benefits by farm (before field drainage costs) is given in Table 8. Four out of 14 potential beneficiaries reported actual benefits attributable to the scheme. These four farmed 56% of the benefit area. The greatest extra net benefits per hectare are associated with changes in land use, from permanent pasture to temporary grass or arable/ley rotations. Such changes involved field drainage.

Table 7 : Change of Land Use (areas in hectares)

Post-scheme / Pre-scheme	Rough Grazing	Permanent Grass	Temporary Grass	Arable/Ley Rotation	Crops	Pre-Scheme Total
Rough Grazing		3.6				3.6
Permanent Grass		167.2	1.6	18.2		187.0
Temporary Grass			41.0			41.0
Arable/Ley Rotation				57.4		57.4
Crops					10.0	10.0
Post-Scheme Total	0	170.8	42.6	75.6	10.0	299.0

Fig 3 : LANDUSE CHANGE

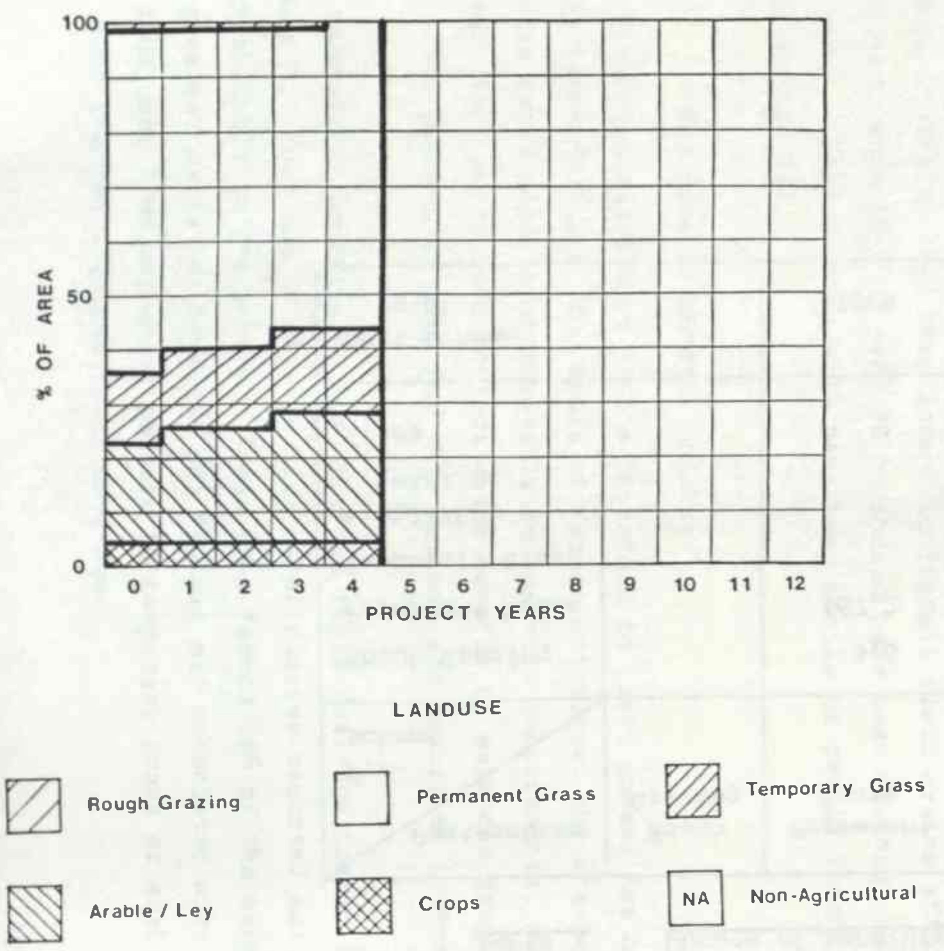
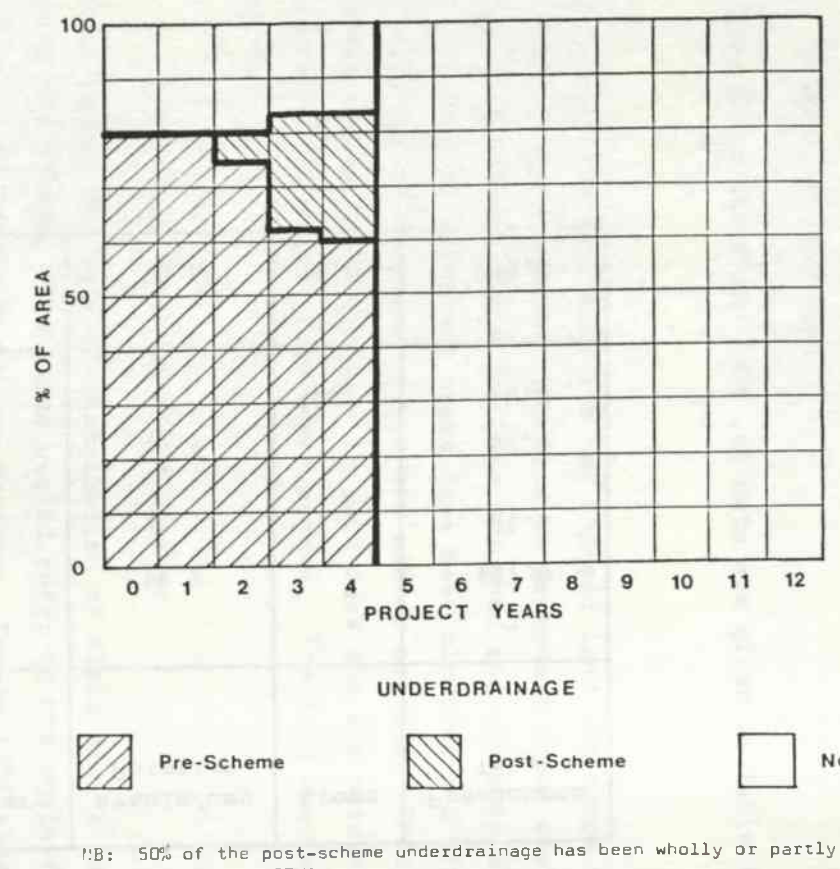


Fig 4 : INSTALLATION OF UNDERDRAINAGE



NB: 50% of the post-scheme underdrainage has been wholly or partly financed by STWA.

FIGURE 5 : Degree and Rate of Financial Uptake

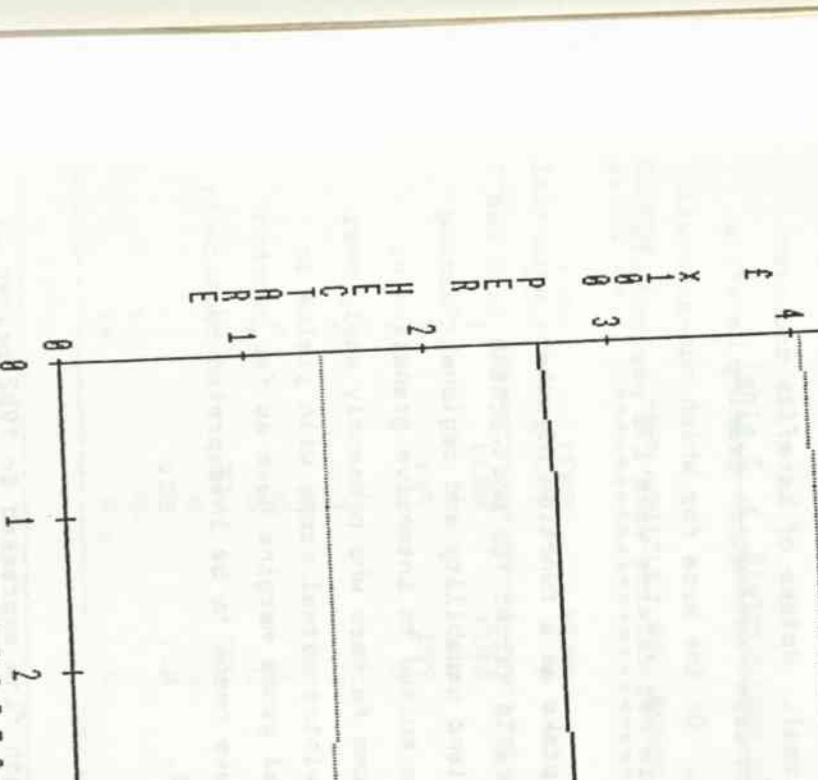
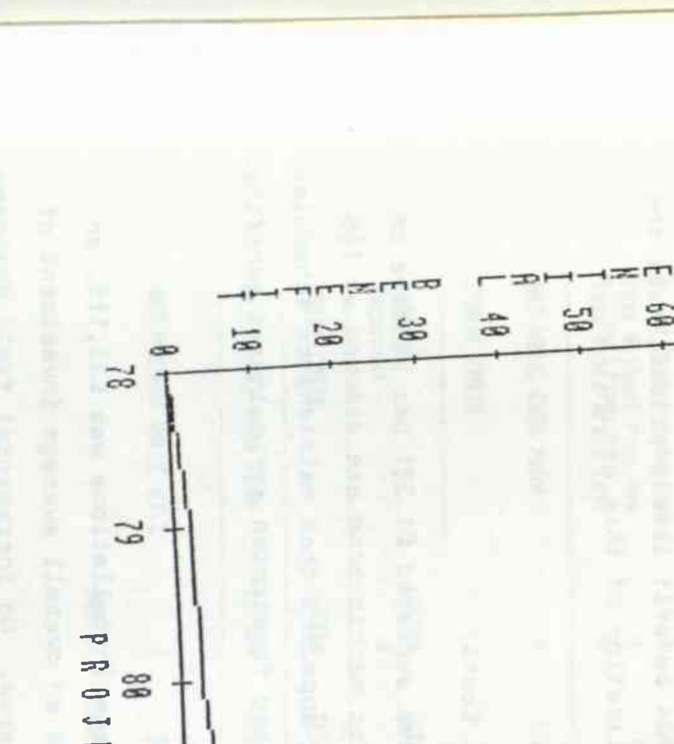


FIGURE 6 : Uptake as a Percentage of Potential



POTENTIAL GROSS MARGIN = £610/Ha.
PRE-SCHEME GROSS MARGIN = £347/Ha.

POTENTIAL BENEFIT = £263/Ha.
FINAL UPTAKE = 6%

The rate of uptake of financial net benefits attributable to the scheme is apparent from Figure 5 and Table 9. Averaged over the total 297 ha benefit area, the estimated increase in net returns obtained by 1984 was £13 per hectare (in 1982 prices). Uptake of benefits occurred on 18% of the total area, 35% of which were 'automatic' grazing benefits and the remainder was positive uptake. On the area for which non-automatic benefits were ascertained average extra net returns were £70 per hectare.

Figure 6 expresses actual uptake as a function of scheme potential which is taken as a reasonably achieveable target for post-scheme land use and farming practice: that based on land capability and regional farming practice. Most of the benefit area is suited to intensive grassland or arable/ley systems, as evidenced by some farmers who presently apply over 350 kg N/ha on grass and grow 3 to 4 winter cereal crops with yields in excess of 5 t/ha. On this basis actual gross margins have so far reached 6% of potential. This measure of uptake needs to be interpreted cautiously as discussed in Annexe IX, section 4.4.

14. Financial Analysis

A summary of the scheme's cash flow expressed in 1982 prices is given in Table 9.

(a) Net Agricultural Benefits:

The estimate of net agricultural benefits attributable to the scheme are based on the net returns shown in Figure 5, multiplied by a factor of 1.23 to reflect the fact that 81% of the benefit area was surveyed. Land use observations were made on the remainder and it is considered reasonable to assume that the same order of benefits have been obtained. The analysis assumes that 1984 benefit levels prevail over the remainder of project life, and the implication of this assumption is considered in the sensitivity analysis.

(b) Capital and Recurrent Costs:

The capital costs of the scheme averaged £1,331 per hectare of potential benefit. Incremental costs for maintenance are assumed at 1½% of gross capital costs, although it was apparent that maintenance schedules had not been kept, which in some cases had frustrated agricultural benefits.

(c) Field Drainage Costs:

The total cost of field drainage installations was £33,115, an average of £705 per hectare drained, and an overall average investment of £90 per hectare for the total benefit area. No incremental field drainage maintenance costs have been assumed.

Table 8 : Distribution of Benefits by Farm

SCHEME 11 NET AGRICULTURAL BENEFIT
********* **************************

FARM CODE	YEAR FIRST	YEAR 1	YEAR 4	YEAR LAST	% OF BENEFITS	% OF AREA
1	1188	1188	1188	1188	31	26
2	0	0	0	0	0	5
3	109	109	292	781	21	15
4	0	0	0	0	0	8
5	0	0	0	0	0	3
6	0	0	0	0	0	5
7	0	0	0	0	0	4
8	0	0	0	0	0	6
9	0	0	0	0	0	4
10	720	720	720	720	19	10
11	0	0	-10	-10	0	2
12	128	128	973	1102	29	5
13	0	0	0	0	0	6
14	0	0	0	0	0	1
TOTAL				3783	100	297

Table 9 : Summary of Cash Flows and NPV

RIVER SOAR SHARNFORD TO CROFT

PROJECT YEAR	0	1	2	3	4	5	6 TO 30
CALENDAR YEAR	1978	1979	1980	1981	1982	1983	1984 TO 2008
AGRICULTURAL BENEFITS							
Net Agric Benefits	0	2651	2810	3760	3908	4668	4668
Flood Damage Reduction	0	550	550	550	550	550	550
less Without Proj Ben	0	91	182	275	368	463	558
less Field Drain Cost	0	0	12020	19462	1633	0	0
NET AGRIC CASH FLOW	0	3110	-8842	-15427	2457	4756	4660
SCHEME COSTS							
Capital	165384	21342	196196	84801	24875	0	0
Recurrent	0	0	0	0	0	7389	7389
TOTAL COSTS	165384	21342	196196	84801	24875	7389	7389
SCHEME NET CASH FLOW	-165384	-18232	-205038	-100228	-22418	-2633	-2729
NET PRESENT VALUE AT %	0	2.5	5	7.5	10	12.5	15
	-582153	-525342	-481852	-446752	-417310	-391931	-369630

(d) Flood Damage Reduction:

Flooding has not occurred post-scheme. Pre-scheme losses of hay crops (once in an estimated 15 years) were recorded on two farms (total 19 ha), together with miscellaneous damage to fencing and hedges, and debris collection costs arising from winter floods on 4 other farms. The saving in agricultutal flood damage cost is estimated at £550 per year.

(e) Without-Project Benefits:

A basic assumption of 1% compound per year is used to account for likely improvements in farming performance achieveable without the project (see Annexe V). Without-project benefits are charged for those areas for which there has been some observed post-scheme benefit uptake, 11.7% in the case of the scheme. Without-project benefits are therefore taken at 1% compound per year of the pre-scheme net return (£77,529) multiplied by 11.7%, ie. £9,070 x 1% compound.

(f) Project Worthwhileness:

Assuming benefits continue at their 1984 level over a 30 year project life, the net present value of the scheme at 5% discount rate is -£493,906 in 1982 prices, implying a negative internal rate of return. The scheme demonstrates a combination of high capital cost and low uptake. Unless further improvements are made to ancillary ditches, scheme performance is unlikely to improve.

(g) Sensitivity Analysis:

Table 10 examines the sensitivity of the scheme to selected benefit and cost parameters. For the basic assumptions, net agricultural benefits would need to be at least ten times higher for the scheme to break even at the 5% discount rate, or benefits would need to increase by a factor of 13 from their present level over the remainder of project life; equivalent to additional net benefits of £130 per hectare. Damage reduction would need to be 65 times assumed levels to break even. Even with capital costs assumed at £0, present levels of agricultural uptake would need to increase by 2.5 times to cover the cost of field drainage and scheme maintenance.

Using the aggregate uptake curve to predict benefits over remaining project life, uptake would peak in year 13 at 2.6 times its observed year 5 levels, resulting in a net present value of -£422,718, and a negative internal rate of return (-8%).

15. Discussion

In terms of meeting its design objectives, the scheme has been an unqualified success - water levels have been lowered considerably to provide a good outfall for field drains and the river has not flooded since the improvement scheme was carried out. The works have been carried out with due regard to conservation and environmental factors and attempts have been made to maintain the visual appearance: old bridges have been modified to lower bed levels whilst retaining the structural character or left as amenity features where this has not been possible (eg. Soper's Bridge). The pond at Soar Mill has been retained which is not only an attractive feature but also added considerably to the market value of the property (especially important to the owner who has just sold it!). Attempts were made to save and replant the River Water Dropwort which occurred in the lower reach, although this appears to have been unsuccessful. Also tree-planting schemes were carried out under the guidance of STWA's Landscape Architect.

However, in terms of agricultural benefit, the scheme has not so far satisfied its objectives. Todate only 20 ha of permanent pasture have been ploughed (20% of that predicted) and much of the field drainage installation has been reinstatement rather than improvement. Most farmers have been keen to install field drains where they have perceived a need and many have reacted quickly to the opportunity to do so, others have been held up due to arterial drainage problems or conflict with STWA over who should pay for the work. The scheme has been plagued with problems which have not only prevented full benefits from being realized but have also alienated the farmers of the area whose perception of the scheme is easily tainted by wranglings over fencing, compensation payments, bridges and so on. Once these problems are effectively dealt with further benefits should accrue but these, as least in the next few years, will be realized in terms of improved production from grassland rather than any change to arable.

TABLE 10

River Soar : Sharnford to Croft - Sensitivity Analysis

Run No.	Agricultural Benefits Factor	Without Project Benefits Compounding Factor	Flood Damage Reduction Factor	Capital Works Cost Factor	NPV at 5% £	IRR %	Switching Value
1	1.0	1	1	1	-493900	-∞	11.0
2	1.0	1	1	0.5	-276100	-∞	6.5
3	1.0	0	1	1	-486900	-∞	10.5
4	1.0	1	1	0	-58300	-∞	2.5

* The factors show the weights applied to the original estimates eg a factor of 1.5 for the without-project benefits indicates that the new value is 1.5 x 1% compound per year (the original value) ie 1.5% compound.

* Switching value : change in agricultural net benefits needed to make the project breakeven at 5% discount rate eg a 1.5 switch value shows an increase of 1.5 x the original estimated is required.

At £1,331/ha of benefit, the Sharnford to Croft scheme was very expensive. Part of this was due to overexpenditure on phase I (see Section 9 above) and final costs were 23% above the original estimate. Additionally, field drainage costs have been high in relation to the benefits as much of the drainage has been reinstatement (rather than improvement) and no direct benefits have been perceived.

16. References

(1) STWA Soar Division River Soar - Sharnford to Croft Improvement Scheme. Engineers Report, January 1977.

(2) MAFF Agricultural Land Classification.

(3) STWA Soar Division Land Drainage Survey, section 24(5), Water Act 1973, p. 3. January 1978.

(4) STWA Soar Division River Soard - Sharnford to Croft Improvement Scheme. Scheme File (1975-82).

(5) STWA Soar Division Report by the Technical and Financial Appraisal Group. September 1978.

(6) Soil Survey National Soils Map at 1:250,000. Soil Survey, 1983.

APPENDIX B

Soar Division

River Sence : Kilby Bridge to Wistow

SILSOE COLLEGE

STWA SOAR DIVISION - RIVER SENCE : KILBY BRIDGE TO WISTOW

Report on the background to and development of the scheme and the nature and rate of uptake of agricultural benefits.

1. Physical Background

The River Sence is a tributary of the River Soar in Leicestershire. It rises near Billesdon (Leics.) and flows south west, then west to join the Soar at Glen Parva. The predominantly rural catchment measures 133 sq. km, and is geologically characterized by alluvium overlying Boulder, and Upper Lias Clays. From source to confluence the Sence falls 150 metres.

The scheme under consideration relates to 8.25 km of Main River between Kilby Bridge (SP610969) on the A50 Welford Road, and the point where the Sence passes under the Grand Union Canal near Wistow (SP655959). Through this length the river flows south of the canal, following a tortuous course in a flat valley. The catchment to Kilby Bridge measures 82.66 sq. km.

2. Soils and Land Capability

The soils in this area are dominated by Fladbury Series silty clay derived from the calcareous Boulder Clay of the surrounding uplands (Ref. 1). Borehole investigations have shown the presence of blue clay and gravel deposits along the channel. The land adjacent to the river is liable to flooding was classified as grade 4 by MAFF (Ref. 3). The remainder was grade 3 (see Figure 1).

3. Land Drainage History

19 km of the Sence, from the Soar confluence to just north of Great Glen, were designated as Main River in 1959. An improvement scheme was planned for 17.5 km of the river up to Wistow in the late 1960's to be carried out in three stages. This would tie in with works already carried out in the Great Glen area designed to provide urban flood alleviation.

By 1969, farmers in the Kilby area had become so concerned about the condition of the river (see 4 below) that a petition was organized and finally a meeting arranged between local farmers, the Trent River Authority and the local Member of Parliament. They were assured that an improvement scheme was being prepared, yet, despite persistant pressure from individual farmers and the MP, works could not commence until stages 1 and 2 had been completed.

Work commenced on the first stage; Soar confluence to Blaby Mill; in October 1969, and the second in September 1971.

4. Pre-Scheme Land Drainage Status

The existing channel was subject to shoaling in numerous locations and the banks were liable to severe erosion and slipping along the entire length. The land adjoining the river suffered from frequent inundation (Ref. 2). According to the farm survey (see 9), 184.6 ha were liable to flooding which would occur two to three times each year although surface water would only remain on the land for a matter of days. The flooding situation was likely to worsen due to continuing urban development in the vicinity of Great Glen and Fleckney, and the new Fleckney Sewage Works.

Four bridges on the river had particularly narrow openings and inverts above the proposed bed level producing unacceptably high affluxes.

Ninety-five percent of the benefit area had old drainage systems although these were largely shallow (about 0.6 m) and the average freeboard (drain to water level) was only 0.3 m. Thirty-three percent was described as being 'commonly wet' and 5% as 'usually wet', (from Farm Survey data).

5. The Impact of Pre-Scheme Land Drainage Status on Land Utilization

Prior to the scheme the use of all of the land within the benefit area was restricted to grass. Roughly 5% of the area was so wet as to be classified as rough pasture. Over most of the area flooding was the major constraint upon agriculture. Winter flooding would restrict the grazing season but otherwise cause little damage to the grassland. The occasional spring or summer flood however could cause the complete loss of a hay crop.

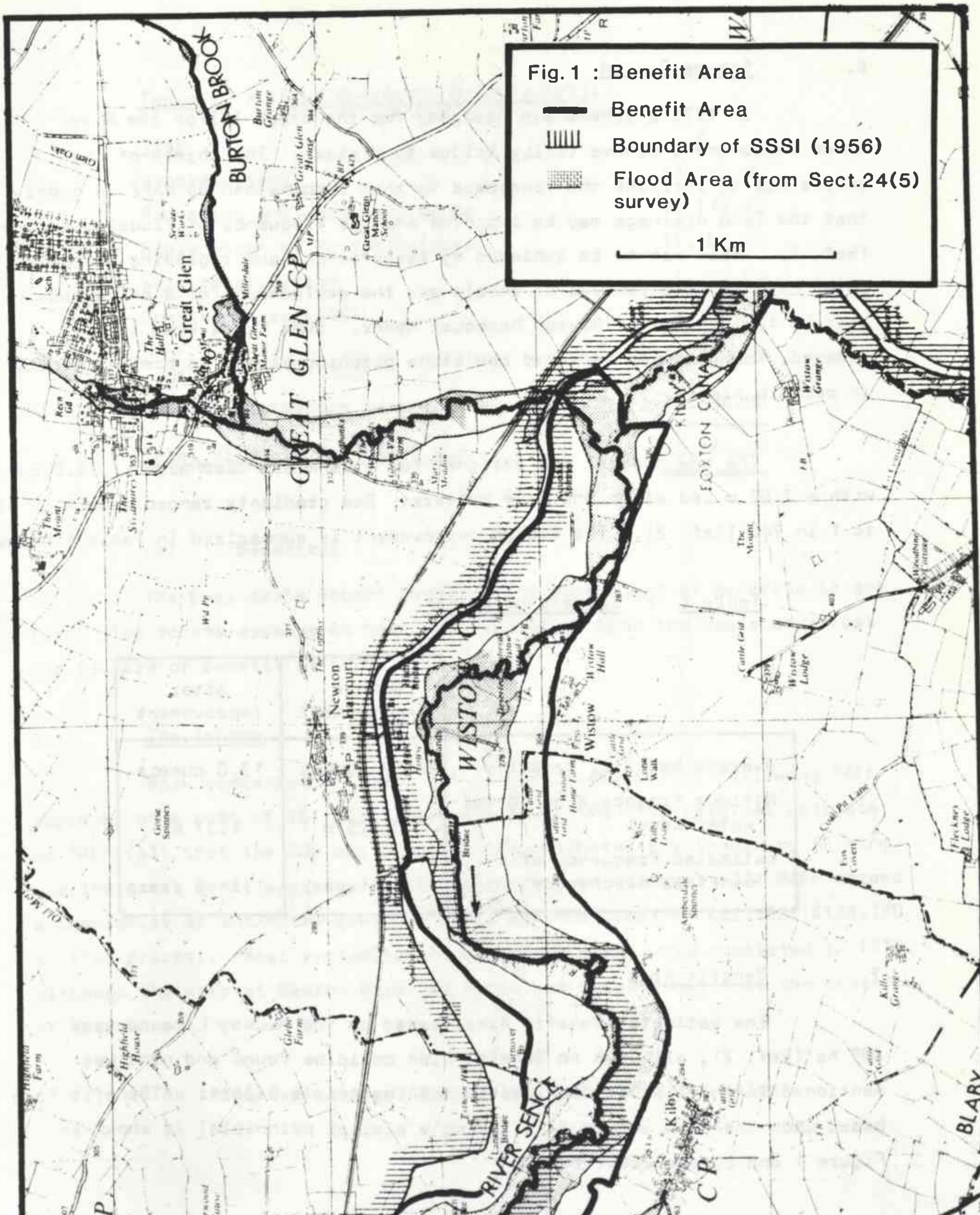


Fig. 1 : Benefit Area

6. Scheme Design

In 1973 a scheme was designed for the Stage III of the River Sence improvement scheme (Kilby Bridge to Wistow). The object of the scheme was to increase the freeboard to that recommended by MAFF in order that the land drainage may be improved and the frequency of flooding reduced (Ref. 2). This was to be achieved by resectioning and regrading of the river channel, the removal of shoals and the replacement of a collapsed weir in the grounds of Newton Harcourt Manor. Some trees were to be cleared, four bridges replaced and stone pitching placed to prevent erosion in certain places.

The new channel was designed for a bankfill discharge of 13.0 cumecs with a 3.05 m bed width and 1:1½ batters. Bed gradients ranged from 1 in 483 to 1 in 740 (Ref. 2). The design improvement is summarized in Table 1 below.

Table 1 : Summary of Design

	Before Improvement	After Improvement
Average bankfull capacity	8.23 cumecs	13.0 cumecs
Minimum freeboard at normal water level	0.925 m	1.37 m
Estimated frequency of bankfill discharges	2 in 1 year	1 in 5 years

7. Benefit Area

The estimated Benefit Area, based on the Medway Line covered 309 ha (Ref. 2), although no Benefit Plan could be found and none was mentioned in the list of drawings in the Engineer's Report. A Benefit Area based upon the Farm Survey data (using a similar principle) is shown in Figure 1 and covers 280.1 ha.

8. Predicted Costs and Benefits

(a) Costs:

The original cost estimate totalled £64,860 before contributions, made up as follows:

Table 2 : Cost Estimate (October 1973)

Item	£
General items	13,895.00
Regrading and ancillary works	32,172.85
Replacement of Access Bridges	11,104.08
Weir construction	1,790.00
Contingencies (10%)	5,898.07
Total	64,860.00
Less: Contribution towards weir	1,500.00
Total eligible for grant aid	£63,360.00

(b) Benefits:

The Engineer's Report contained no assessment of benefits in any form. The scheme appears to have been justified upon the basis of a cost per hectare of benefit of £205.

9. The Scheme

Work commenced on Stage III on 1st December 1973 following MAFF approval of a cost of £61,845. This was lower than the original estimate as MAFF felt that the 60p per linear metre estimated for temporary fencing was too great so it was reduced to 40p/metre. In November 1974 MAFF agreed a compromise at 50p/metre giving a total approval cost of £62,452 (£138,780 in 1982 prices). Most regrading and ancillary works were completed in 1977, although the weir at Newton Harcourt Manor was never rebuilt at the request of the owner.

The total expenditure to June 1979 is summarized below:

Table 3 : Expenditure to June 1979

Financial Year	Eligible for Grant (£)	STWA Staff Costs (£)
1973/74	5,664	-
1974/75	35,940	-
1975/76	10,586	1,567
1976/77	24,139	4,093
1977/78	2,662	747
1978/79	1,670	-
	80,661	6,407

The final account for £80,661 was submitted and approved by MAFF in June 1979, this is equivalent to £176,489 in 1982 prices (ie. an overexpenditure of £37,709). The inclusion of STWA staff costs directly attributable to the scheme brings the total cost to £190,098 in 1982 prices.

10. Farm Survey

Nine farmers were interviewed during May 1983 who between them farmed all of the agricultural land within the Benefit Area. Only four of the farms are farmed today by the same occupiers as before the scheme. Five of the farms have changed management although in only one case has this been to a newcomer. One County Council farm has changed hands twice since the scheme.

11. Agriculture in the Benefit Area

(a) Farm Size, Type and Tenure:

The farms are classified according to type, size, tenure and management in Tables 4-7 below.

Table 4 : Farm Type

Farm Type	No. of Farms	% of Benefit Area
Specialist dairy	5	26
Mainly dairy	1	15
Mixed	1	47
Other	2	12
Total	9	100

Table 5 : Farm Management and Tenure

Management Status	% of Farm Owned						
	0	1-25	26-50	51-75	76-99	100	Total
Sole proprietor	2	1				1	4
Partnership	1		1		1	1	4
Other						1	1
Total	3	1	1	-	1	3	9

Table 6 : Farm Size by Area

Size Class	No. of Farms	% of Benefit Area
10- 20 ha	1	5
20- 30 ha	3	19
30- 40 ha	-	-
40- 50 ha	1	4
50-100 ha	1	4
100-200 ha	2	21
200-300 ha	-	-
300-500 ha	1	47
Total	9	100

Mean 99.9 ha, St. Dev 138.2 ha (of 9 valid cases)

Table 7 : Farm Size by Standard Man Days

Size Class	No. of Farms	% of Benefit Area
250- 499 SMD	1	8
500- 999 SMD	2	8
1000-1499 SMD	2	21
1500-1999 SMD	2	51
No data	2	12
Total	9	100

Mean 989.4, St. Dev 501.0 (of 7 valid cases)

Six of the farms surveyed are dairy farms, 5 being specialist and one mainly dairy, however the one mixed farm accounts for the largest proportion of the Benefit Area (47%). Two farms (accounting for 12% of the Benefit Area) were not classified according to the MAFF farm type classification. Until recently both had been let out to other farmers within the Benefit Area and are presently in a transitional state. Part of one is scheduled to be used as a stud farm.

Table 5 shows an even distribution between tenure and management status. Three of the farms are wholly tenanted and are County Council smallholdings. A fourth County Council farmer also owns some land elsewhere. Three of the farms are wholly owned. Many of the farmers rent land on an annual basis, some of which is within the Benefit Area.

68% of the land within the Benefit Area is farmed by farms in excess of 100 ha in size and one farm of 453 ha accounts for 47%. The average size is 100 ha, but the standard deviation is high. The mean Standard Man Day requirement is 989 SMD (St. Dev 501 SMD). Two farms were not classified by SMD for the reasons outlined above.

(b) Dairy Enterprises:

Six farmers have dairy herds ranging from 45 to 200 milking cows (mean 91, St. Dev. 56) and milk yields range from 5,000-7,000 litres per cow (mean 5840, St. Dev. 853). The average grass stocking rate on dairy farms is 2.03 livestock units per hectare.[1]

(c) Beef Enterprises:

Four of the dairy farms and one mixed farm keep cattle for beef. The dairy bred calves are either sold at two years as finished cattle or are sold at one year - 18 months old as stores. On the mixed farm, store cattle are finished.

(d) Arable Enterprises:

Only the mixed farm has any arable enterprises - growing wheat, barley, oats, spring beans, oil seed rape and grass seed in rotation with grass for hay or silage and grazing. Very little of this is within the benefit area which is presently 96% grass.

12. Effects of the Scheme on Flooding and Land Drainage

The effects of the scheme on flood frequency and duration are summarized below:

Table 8 : Effects of the Scheme on Flooding

Effect	Area (Ha)	% of Benefit Area
Did not flood	95.5	34
Flooding eliminated	7.6	3
Frequency and duration reduced	12.1	4
Frequency unchanged. Duration reduced	55.5	20
" " Duration unchanged	92.4	33
Flooding increased	17.0	6
Total	280.1	100

It appears that the performance of the scheme has not matched the design criteria. The farm survey suggested that on only 7% of the area has the risk of flooding been reduced. Eighty percent of the land that used to flood is reported to still flood as often although on one third of this farmers noticed that the flood waters recede quicker. On 17 hectares the frequency of flooding has increased, reported to be due to the relatively low level of the new bridge decks causing water to back up at times of high flow.

Most farmers noted that the river rises and falls quicker since the scheme, but that flooding has not been alleviated. This seems to suggest that urban development in the catchment of the Sence since the scheme is leading to more rapid runoff after heavy storms.

In terms of providing increased freeboard for field drainage, the scheme appears to have been more successful (although no data are available to support this observation). Where field drains have been installed, the farmers believe that they would not have been able to do so were it not for the scheme.

Two significant drainage problems remain on other watercourses that affect land within the benefit area:

(i) Kilby Brook

The Kilby Brook drains from the village to the Sence, joining about 3/4 km upstream of Kilby Bridge. The brook floods frequently, especially when the Sence is high and there is insufficient freeboard for field drainage. Since the scheme the more rapid lowering of the Sence after flood allows the Kilby Brook to recede a little sooner, but generally there has been little improvement. The brook requires resectioning and regrading to provide benefit to 37 ha of agricultural land and alleviate flooding of two properties in Kilby (Ref 5).

(ii) Grand Union Canal

The length of the Canal between Newton Harcourt and Kilby Bridge stands at least 5 m higher than field level by the river. Since the drought of 1976 when this section of the Canal dried up, there has been a significant seepage problem. Despite attempts by the British Waterways Board to prevent seepage by sheet-piling, much of the adjacent land is persistently waterlogged. Some farmers have attempted to pipe water from the wettest parts directly to the Sence but this has not been entirely successful. The Waterways Board are paying compensation to some farmers although they would prefer the Board to pay for a complete field drainage system to alleviate the problem.

13. <u>Agricultural Benefits of the Scheme</u>

(a) Land Use Change:

The land use data are shown in Table 9.

Table 9 : Land Use (Hectares)

Pre-Scheme \ Post-Scheme	Non-Agric	Permanent Grass	Grass/Crop Rotation	Woodland	Total
Non-Agric	10.9	-	-	-	10.9
Rough Grazing	-	13.0	-	-	13.0
P Grass	-	232.4	11.3	1.2	244.9
Woodland	-	-	-	11.3	11.3
Total	10.9	245.4	11.3	12.5	280.1

In 1974, 8% of the Benefit Area was under woodland or other non-agricultural uses. The rest was all under grass although 5% was described as being rough grazing. Since the scheme, the rough grazing has been plouged and reseeded as permanent grass (NB This was an area previously designated as a Site of Special Scientific Interest - see 14), and 11.3 ha of the permanent grass has been ploughed and brought into an arable rotation. 83% of the Benefit Area has remained permanent grass.

Fig 2 shows that all land use change has taken place between 1979-1981.

(b) Field Drainage Installation:

Table 10 : Field Drainage Installation

Date of Drainage	Area (ha)	Land Use		
		Pre-Scheme	Post-Scheme	Date of Change
1977	17.0	P Grass	Rotation	1979
1977	18.2	P Grass	Permanent Grass	-
1982	13.0	Rough Grazing	Permanent Grass	1981

Fig 2 : LANDUSE CHANGE

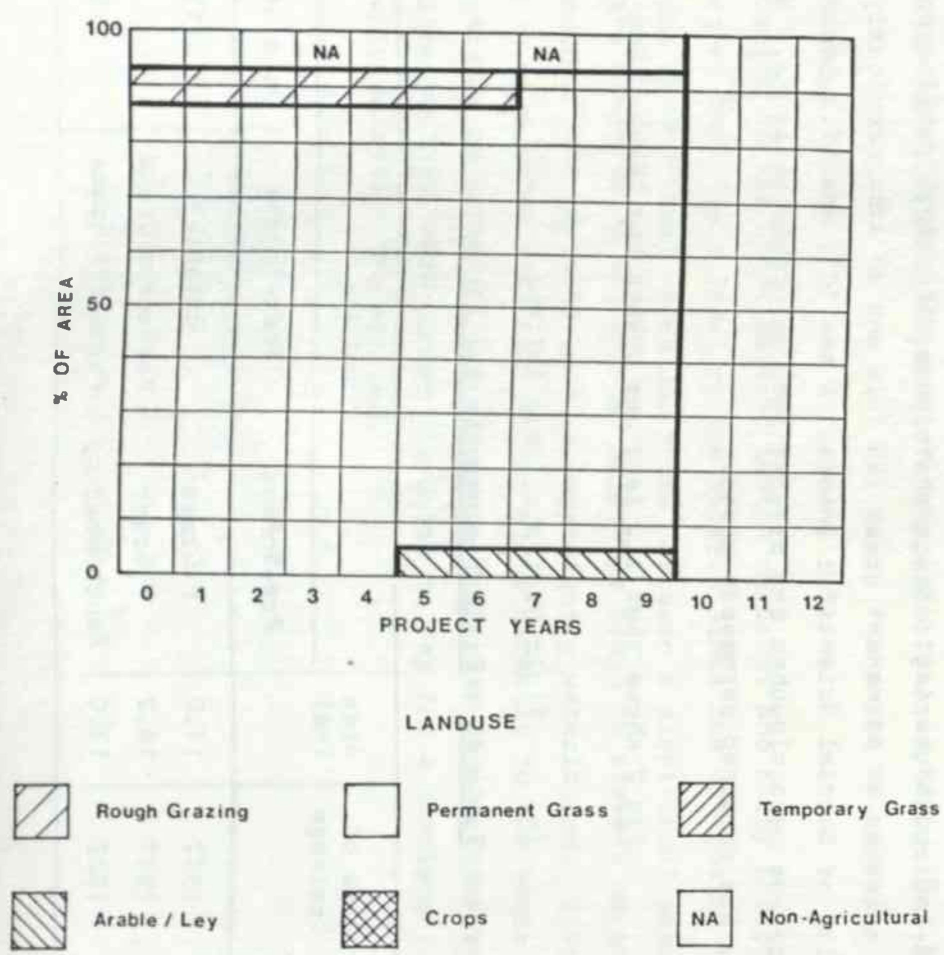
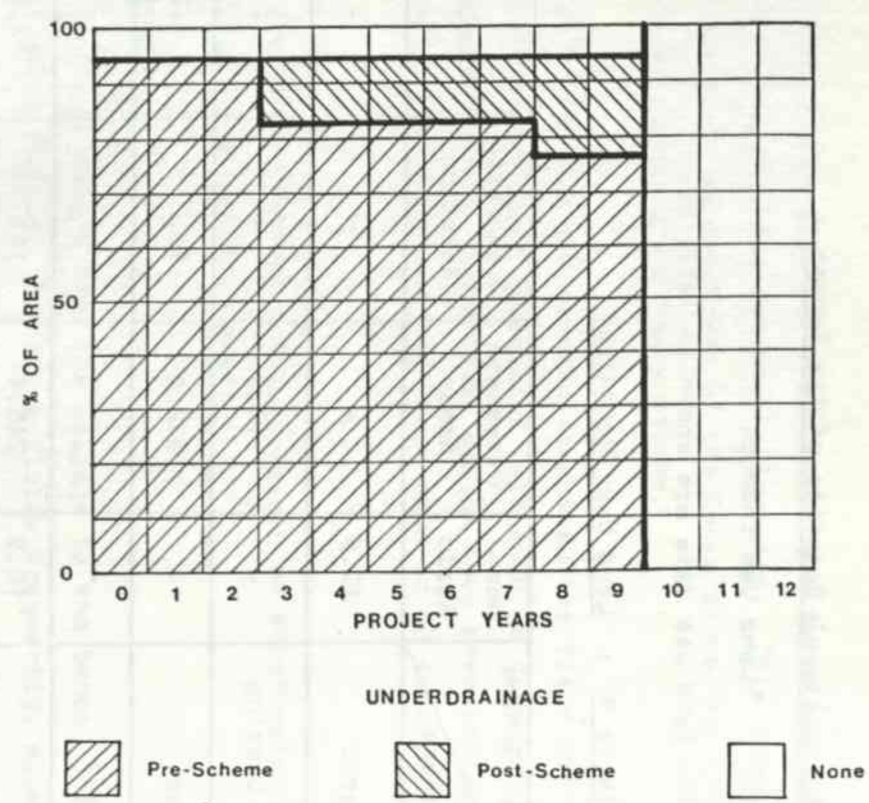


Fig 3 : INSTALLATION OF UNDERDRAINAGE



Since the scheme only 48.2 ha have been underdrained (17% of the benefit area). In each case this has been on land with old drainage systems and has largely been associated with a change of land use. Some other attempts have been made to drain land affected by seepage from the Canal but this has not been associated with the scheme (see 12).

(c) Improved Production from Existing Land Uses:

On the 7.6 ha where flooding has been eliminated, the occupier has noticed an improvement in the quality of the sward and a reduction in the risk of animal disease. Elsewhere, however, there has been little improvement in the productivity of the grassland. Approximately 31 ha of the permanent grass have been reseeded and in some cases the new grass has been undersown under barley.

Much of the grassland still retains ridges and furrows which present a severe constraint on improvement. Many farmers see the ploughing out of ridges and reseeding of swards as being more pressing than drainage improvement.

(d) The Rate of Benefit Uptake:

A financial assessment of the Kilby Bridge to Wistow scheme has been undertaken by identifying, on the basis of farmer interview, the change in farm enterprise gross margins attributable to drainage improvements, net of any additional fixed costs, and including the benefit of extended grazing if relevant. The procedures used for this purpose are described in Annexe V.

A summary of financial net benefits (before field drainage costs) by farm in the benefit area is given in Table 11. Seven out of nine potential beneficiaries reported perceived benefits. Three out of these farmers accounted for 86% of total scheme benefits. The rate of uptake of financial benefits is illustrated in Figure 4. Over a farmed benefit area of 256.7 hectares, the average extra net return attributable to the scheme was £40 hectare (in 1982 prices) for the 1983/4 season.

Figure 5 expresses actual take-up as a percentage of a reasonably achieveable target*, that is, based on land capability and local farming practice. The silty clays of the benefit area make the land best suited to grassland, with some limited scope for cereal cropping between grass leys with field drainage. The greatest potential is for intensive dairy with grass cut for silage. Some farmers in the benefit area are presently applying in excess of 350 kg N/ha with 2/3 cuts of silage.

Figure 5 shows that todate, actual gross margins have reached some 29% of potential**.

14. Financial Analysis

A summary of the financial cash flow of the scheme is contained in Table 12, expressed in 1982 prices.

Table 11 : Distribution of Benefits by Farm

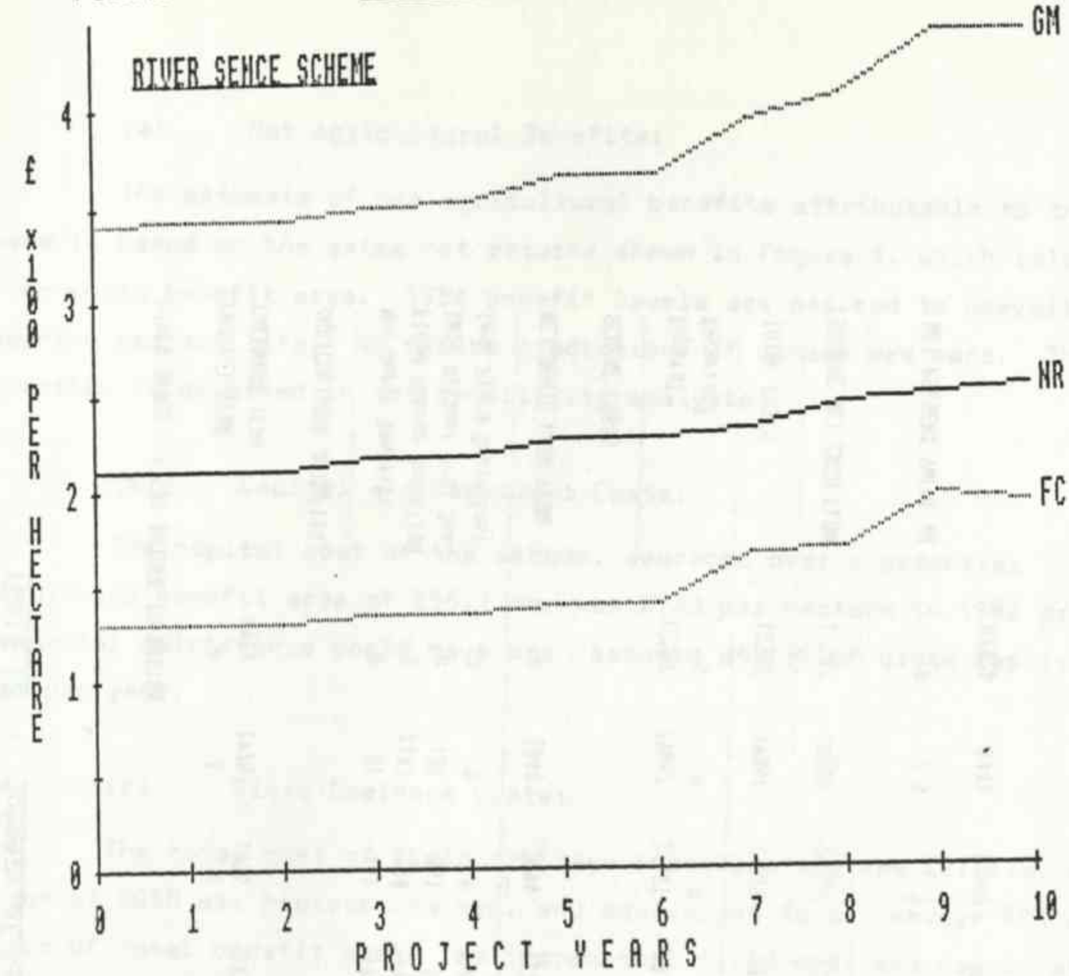
SCHEME 12 NET AGRICULTURAL BENEFIT
********* *************************

FARM CODE	YEAR FIRST	YEAR 3	YEAR 6	YEAR LAST	% OF BENEFITS	% OF AREA
1	0	0	0	131	1	17
2	0	0	0	1854	18	5
3	34	104	204	312	3	4
4	0	0	0	4373	42	9
5	0	0	0	0	0	2
6	45	137	275	413	4	3
7	0	0	0	0	0	4
8	0	144	583	583	6	3
9	0	[illegible]	2729	2723	[illegible]	46
TOTAL				10277	100	256

* Given the drainage conditions specified in the scheme design.

** It should be noted that given the reported post-scheme flood frequency the potential offered by the scheme may be considerably less than that described above.

FIGURE 4 : Degree and Rate of Financial Uptake



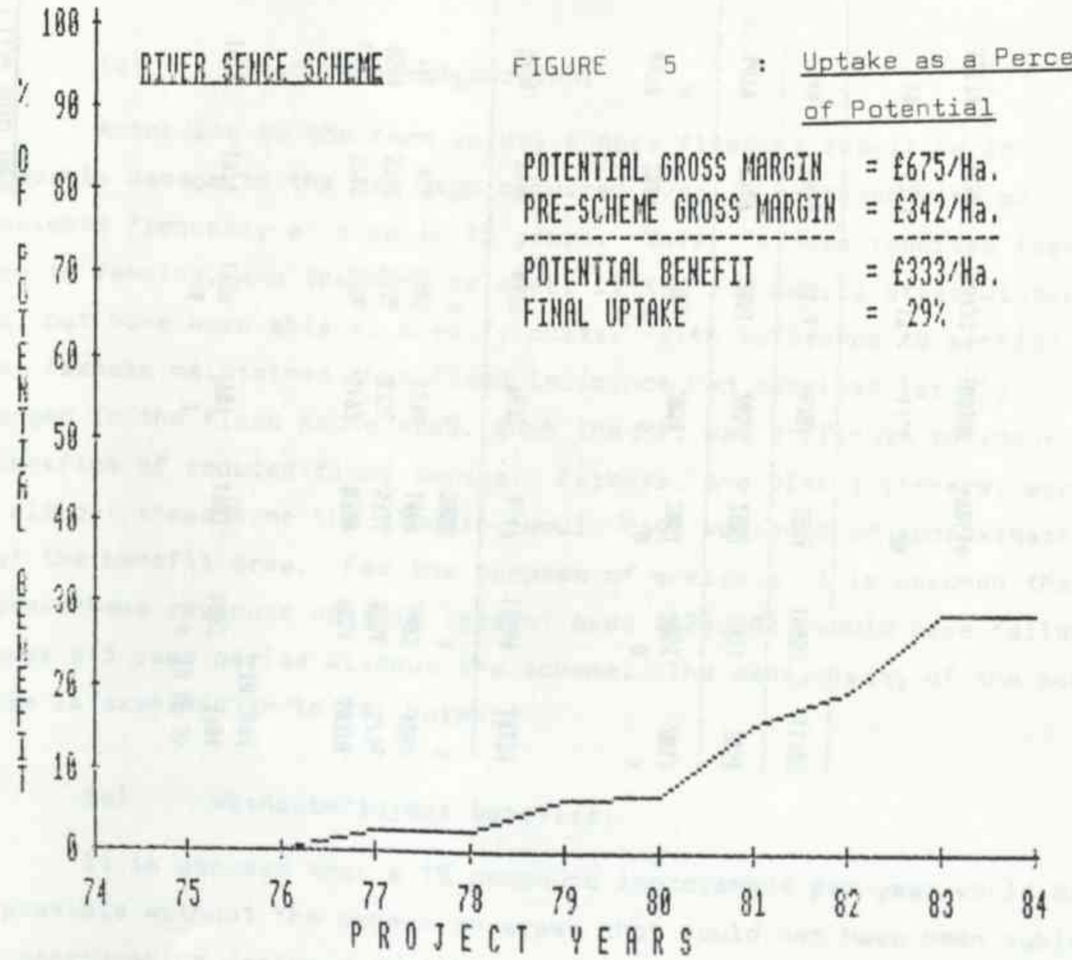


FIGURE 5 : Uptake as a Percentage of Potential

Table 12 : Summary of Cash Flow and NPV

RIVER SENCE KILBY BRIDGE TO WISTOW

PROJECT YEAR	0	1	2	3	4	5	6	7	8	9	10 TO 30
CALENDAR YEAR	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984 TO 2004
AGRICULTURAL BENEFITS											
Net Agric Benefits	0	81	161	1492	1572	3715	3796	5192	8350	9651	10378
Flood Damage Reduction	0	1147	2294	3442	4589	5736	5736	5736	5736	5736	5736
less Without Proj Ben	0	180	361	544	730	916	1105	1296	1489	1683	1880
less Field Drain Cost	0	0	0	15629	0	0	0	0	5850	0	0
NET AGRIC CASH FLOW	0	1049	2094	-11240	5431	8535	8427	9632	6747	13704	14234
SCHEME COSTS											
Capital	12587	79867	27621	61374	6079	2569	0	0	0	0	0
Recurrent	0	0	0	0	0	0	2851	2851	2851	2851	2851
TOTAL COSTS	12587	79867	27621	61374	6079	2569	2851	2851	2851	2851	2851
SCHEME NET CASH FLOW	-12587	-78818	-25527	-72614	-648	5966	5576	6781	3896	10853	11383

NET PRESENT VALUE AT %	0	2.5	5	7.5	10	12.5	15	17.5	20
	81926	6441	-54000	-79445	-92574	-98683	-100723	-100380	-98644

(a) Net Agricultural Benefits:

The estimate of net agricultural benefits attributable to the scheme is based on the extra net returns shown in Figure 4, which relate to the whole benefit area. 1984 benefit levels are assumed to prevail over remaining project life. No future predictions of uptake are made. This assumption is examined in the sensitivity analysis.

(b) Capital and Recurrent Costs:

The capital cost of the scheme, averaged over a potential agricultural benefit area of 256.7 ha, was £740 per hectare in 1982 prices. Incremental maintenance costs have been assumed at 1½% of gross capital costs per year.

(c) Field Drainage Costs:

The total cost of field drainage installations was £21,479, an average of £650 per hectare drained[1], and equivalent to an average £84 per hectare of total benefit area. No incremental field drainage maintenance costs have been assumed.

(d) Flood Damage Reduction:

According to the farm survey summer flooding resulting in irreparable damage to the hay crop occurred over 38 hectares with an approximate frequency of once in 15 years. Seven farmers reported frequent damage to fencing, and the need to clear litter and debris after winter flood, but none were able to specify costs. With reference to section 12 above, farmers maintained that flood incidence had remained largely unchanged in the flood prone area, such that it was difficult to identify any benefits of reduced flood damage. Farmers, and STWA engineers, agreed that without the scheme the flooding would have worsened on approximately 53% of the benefit area. For the purpose of analysis it is assumed that net pre-scheme revenues on this (grass) area (£28,682) would have fallen by 20% over a 5 year period without the scheme. The sensitivity of the scheme to this is examined in 14 (f) below.

(e) Without-Project Benefits:

It is assumed that a 1% compound improvement per year would have been possible without the scheme on areas that would not have been subjected to a deteriorating drainage condition. Without-project benefits have been

1. Although fields totalling 48.2 ha were drained, the actual area of underdrainage was 33.0 ha.

charged on those areas where some uptake of benefits attributable to the scheme have been ascertained, 33.2% of the total area in this case. Without-project benefits are therefore taken as 1% compound per year of the pre-scheme net return (£54,118) multiplied by 33.2%, ie. £17,967 x 1% compound.

(f) Project Worthwhileness:

On the basis of the aforesaid assumptions, and that agricultural net benefits remain at their 1984 level for the remainder of a 30 year project life, the net present value of the scheme at the 5% discount rate is -£54,000 in 1982 prices, with an internal rate of return of 2.3%. A 50% increase in estimated net benefits would be needed to make the project break even at 5%.

Using the derived uptake curve to predict uptake over remaining project life, and allowing for the fact that works were only completed in year 3 of project life (1977) uptake would peak in year 16 (13 + 3) at 2.08 times its 1983 (year 9) level. This would generate a net present value of £13,264 and an internal rate of return. This estimate remains sensitive to flood damage reduction benefits which if assumed zero would reduce net present value at 5% to -£60,800 and internal rate of return to 2.5%.

(g) Sensitivity Analysis:

Table 13 examines the sensitivity of the scheme to selected cost and benefit parameters. The project is sensitive to assumptions regarding flood damage reduction cost. To break even, without-project grass productivity losses on the flood liability area would need to be 35% of pre-scheme levels total, rather than the 20% assumed. At the 5% discount rate, the scheme is likely to recover 70% of capital costs.

15. Non-Agricultural Aspects of the Scheme

The land immediately adjacent to the Grand Union Canal between Kilby Bridge and Foxton was designated as a Site of Special Scientific Interest in 1956 upon the basis of its flora. Also included was an area of meadow between the Canal and the River Sence between Kilby Bridge and Newton Harcourt (see Figure 1).

TABLE 13

River Sence : Kilby Bridge to Wistow - Sensitivity Analysis

Run No.	Agricultural Benefits Factor	Without Project Benefits Compounding Factor	Flood Damage Reduction Factor	Capital Works Cost Factor	NPV at 5% £	IRR %	Switching Value %*
1	1.0	1	1	1	-54000	2.3	1.50
2	1.0	0.5	1	1	-43482	2.9	1.33
3	1.0	1.5	1	1	-64938	1.4	1.60
4	1.0	0	1	1	-33370	3.4	1.29
5	1.0	1	0	1	-128056	-ve	2.25
6	1.0	1	1	0.7	0	5.0	0

* The factors show the weights applied to the original estimates eg a factor of 1.5 for the without-project benefits indicates that the new value is 1.5 x 1% compound per year (the original value) ie 1.5% compound.

* Switching value : change in agricultural net benefits needed to make the project breakeven at 5% discount rate eg a 1.5 switch value shows an increase of 1.5 x the original estimated is required.

The Trent River Authority duly informed the NCC of the proposal to improve the River Sence in June 1973. In July, NCC replied, stating that:

> "...the Sence is one of the few remaining streams in Leicestershire that is relatively unpolluted and retains plant and animal populations typical of a small midlands stream."

In particular, they requested that the River Authority should:

(i) Work from one bank only (bank to be decided following consultation with NCC),

(ii) Leave the meanders and as many trees as possible and recreate new pools and shallows to replace those lost.

NCC also identified a number of sites along the river where rare plants had been identified, including Spiney Restharrow (Ononis spinosa) and Wood Club-rush (Scircus sylvaticus). It was recommended that TRA worked from the opposite bank to leave these undisturbed. NCC pointed out that the meadow south east of Kilby Bridge was a designated SSSI - its marshy vegetation containing several rare plants (including Carex echinata) and supporting unusual breeding wading birds. The TRA agreed to work from the opposite bank but pointed out that the proposed scheme would affect the water-table within the SSSI. NCC stressed that any lowering of the water-table would adversely affect the SSSI and it was agreed to build a small stone weir 5 m upstream of Kilby Bridge to preserve normal water levels adjacent to the meadow. The cost of the weir (£100) was approved by MAFF as eligible for grant aid.

During 1974 the scheme received a great deal of criticism for its environmental effects. An article in a Sunday Colour Supplement (Ref 6) stated that:

> "This charming natural river has been turned into an efficient drainage ditch with animals, birds and vegetation scraped out of existence."

One local resident felt strongly enough to write to his local MP complaining about the 'destruction of the river' and especially the removal of the old stone bridges.

In 1981 the NCC surveyed the Kilby and Foxton Canal and found that the grassland SSSI within the Benefit Area of the Sence scheme had been drained and the grassland resown. The rare species were no longer present and the site was de-notified in November 1981 (Ref 7). Today there is no sign of the stone weir built at Kilby Bridge.

16. Discussion

It is apparent that this scheme has fallen short of its design objectives and there has been little improvement potential presented. In the light of this it is unsurprising that there has been very little land use change or field drainage installation. Whilst it is not possible to account for the flooding without a detailed analysis of hydrograph data, it appears that the channel is carrying a lot more water now than it used to and that it has become more 'flashy'.

Most farmers did not realize that they were supposed to have had any benefit from the scheme and most, apart from those whose land now floods more often than it used to, are quite satisfied with its performance. They feel that, were it not for the scheme, they would be in a much worse position now, given the changes in the hydrological regime of the river.

Some deficiencies in the design of ancillary works, such as the inadequate bridges and stone pitching that washed away after the first flood, have angered the farmers, and the environmental impacts have disappointed others. The destruction of the SSSI does not seem to be related to the scheme rather, it was due to the change of management status of the land.

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7. Dr M. Vincent. NCC. E. Midlands Div. Grantham. (Personal communication)

APPENDIX C

Upper Trent Division

Doley Brook : Ruele Pool to Hell Hole Wood

SILSOE COLLEGE

STWA UPPER TRENT DIVISION - DOLEY BROOK SCHEME (1973)

Report on the background to, and development of, the scheme and the nature and rate of uptake of agricultural benefits.

1. Physical Background

The Doley Brook is the name given to the upper reach of a tributary to the River Penk in W. Staffordshire. It is one of a series of watercourses that flow in a south-easterly direction from the Trent-Severn Watershed.

The length of the brook presently under consideration runs for four miles from its source as an agricultural drainage ditch at Hell Hole Wood (SJ807225 c. 100 m AOD) to the pools at Ruele Mill (SJ842188). Physiographically and hydrologically the brook can be divided into two distinct reaches:

(i) Upstream of the Gnosall (A518) road bridge the brook flows through a narrow valley known as the Gnosall depression. This is a glacial overflow channel that has been infilled by undifferentiated organic soils. In cross-section the valley is steep sided with a flat floor 250-300 m in width. In longitudinal section the valley is notable for its shallow gradient - the average gradient over the 1.9 miles (3.06 km) between Hell Hole Wood and Gnosall road bridge is 1 in 5000. Before the 1973 river improvements there were only 10 inches (25 cm) fall on this reach.

(ii) Below Gnosall (A518) road bridge the valley opens out, having a wider, more undulating floor with less steep sides. The longitudinal gradient steepens to 1 in 2000.

2. Soils and Land Capability

The soils of the upper reach of the Doley have been surveyed in detail by the Soil Survey (Ref. 2) and the whole area is covered at a small scale by the Soil Survey (Ref. 3). The main features of the area, the Gnosall Depression is filled with fibrous peat and undifferentiated alluvial soils (see fig. 1). The soils of the valley sides are either lighter sandy and loamy brown calcareous earths of the Newport and Arrow series, or typical stagnogleys of the Salop and Clifton series. These are described in detail in Appendix I.

Two land evaluation surveys have been carried out in this area. The whole area is covered by the MAFF Agricultural Land Classification (ALC) and the upper reach by the Soil Survey's more detailed Land Use Capability Classification (LUCC). Although there are many similarities between these two surveys they are not exactly comparable and in many areas ALC grade and LUCC class differ (see figs. 2 and 3).

The unconsolidated soils of the valley floor upstream of Gnosall have been classified as class/grade 5 in both surveys as a result of the very high groundwater table and high risk of flooding. The surface soil has a high retained water capacity and low bearing strength, thus poaching is a serious problem and grazing seasons are short. Land use is restricted to permanent pasture and rough grazing as these soils are not normally ploughed. Below Gnosall the valley floor has been classified as grade 4 (ALC) due to the reduction in the extent of peat and better drainage conditions.

The valley sides are generally classified as grade/class 3. The clayey soils of the Salop and Clifton series suffer from wetness limitations due to the very slightly porous subsoil. Careful timing of cultivations is important, and timeliness critical if these areas are to be ploughed. Underdrainage can be effective if there is a suitable outfall facility and grass or cereals can be grown.

Where sandy soils occur, and on the upper slopes the land has been classified as class/grade 2. Although the Newport and Arrow soils are liable to slaking and capping after repeated cultivation, they are suitable for cereals, root crops or grass and generally require no underdrainage treatments.

There is no class/grade 1 land in the area. Details of the Land Capability units are given in Appendix II.

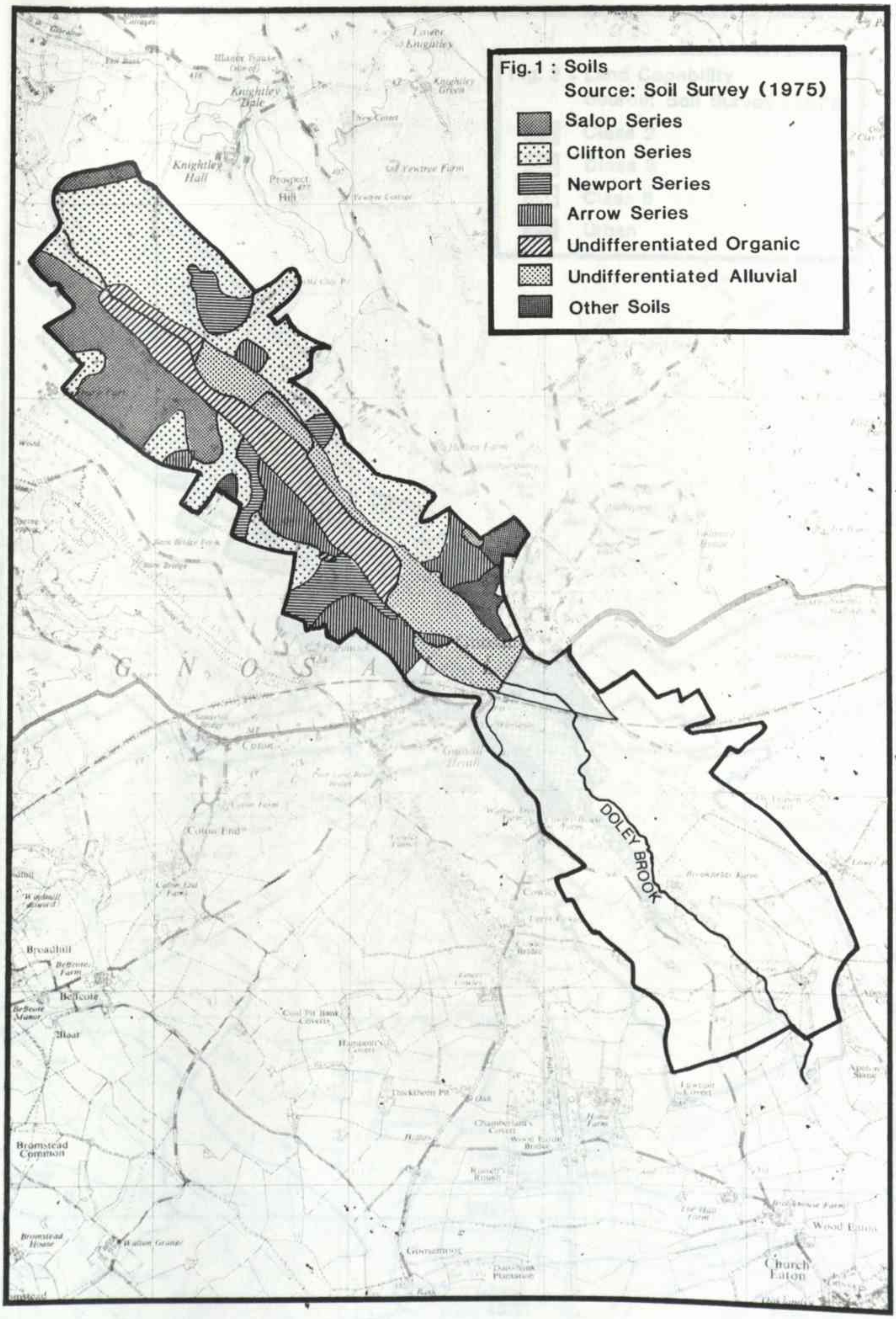


Fig.1 : Soils
Source: Soil Survey (1975)
Salop Series
Clifton Series
Newport Series
Arrow Series
Undifferentiated Organic
Undifferentiated Alluvial
Other Soils
DOLEY BROOK
Knightley Dale
Knightley Hall
Prospect Hill
Broadhill
Bromstead Common
Church Eaton
Wood Eaton

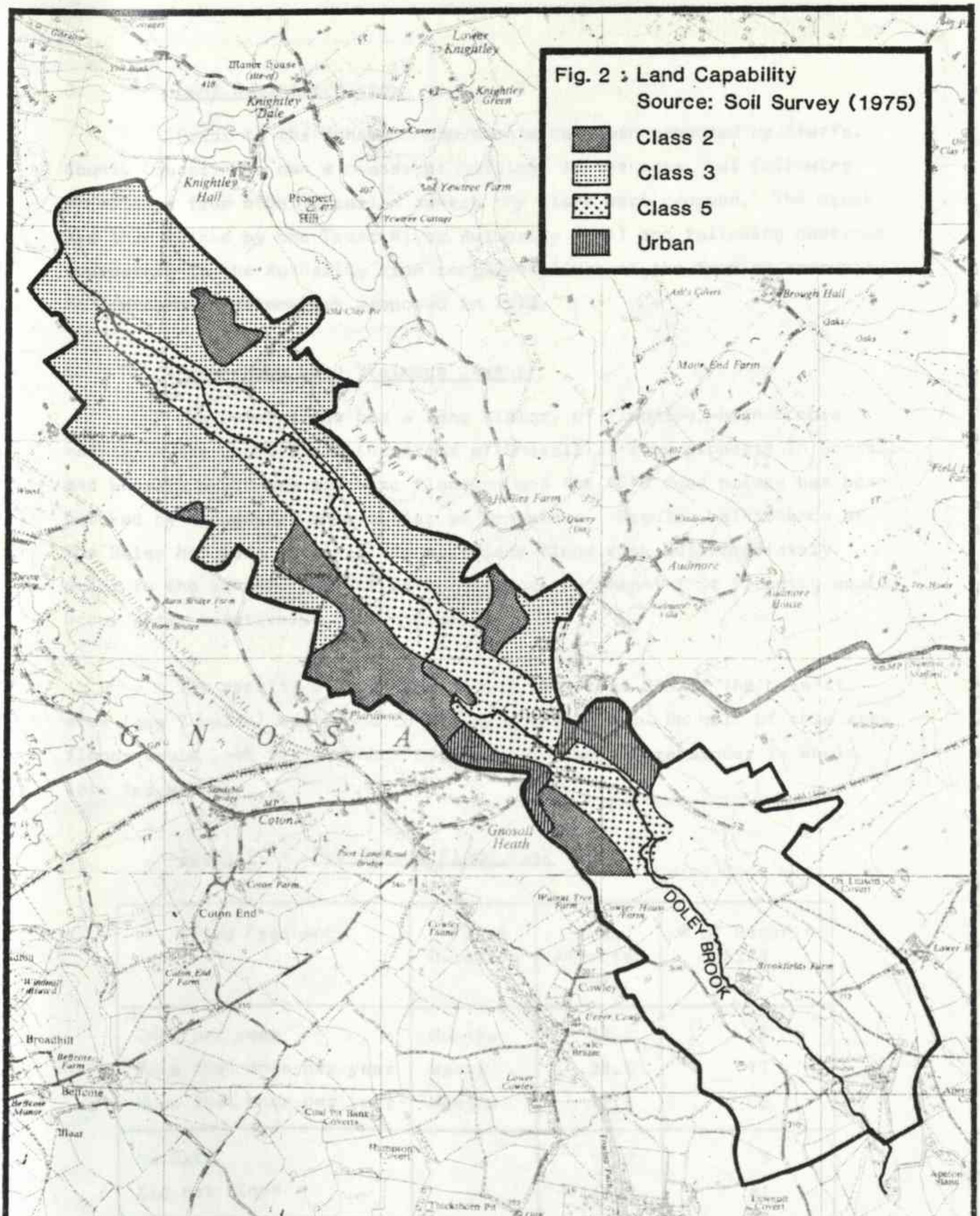


Fig. 2 : Land Capability
Source: Soil Survey (1975)

3. <u>Land Drainage History</u>

Prior to the scheme, improvements had been proposed by Staffs. County Council who own a number of holdings in the area, but following objections from other riparian owners the plans were dropped. The brook was then mained by the Trent River Authority (TRA) and following numerous approaches to the Authority from representatives of the farming community an improvement scheme was proposed in 1973.

4. <u>Pre-scheme Land Drainage Status</u>

The Doley Brook has a long history of flooding which occurs mainly in the upper reach (upstream of Gnosall). Some property in Gnosall and Gnosall Heath was prone to flooding and the A518 road bridge has been blocked by floodwater on a number of occasions. Regular maintenance of the Doley has been essential to alleviate flood risk but immediately prior to the scheme, neglect of the channel had meant that flooding would occur after relatively minor storms.

The results of the farm survey show that 34% of the benefit area (see 7 below) was prone to flooding (Table 1). On half of this area floods would last for a number of months and on the remainder it would last for weeks.

Table 1 : Pre-Scheme Flood Risk

Flood Frequency	Flood Duration	Area Affected (ha)	% of Benefit Area
Once per year	Months	27.4	12
More than once per year	Weeks	38.8	17
More than once per year	Months	12.4	5
No Data	-	11.2	5
Did not flood	-	141.0	61
Total		230.8	100

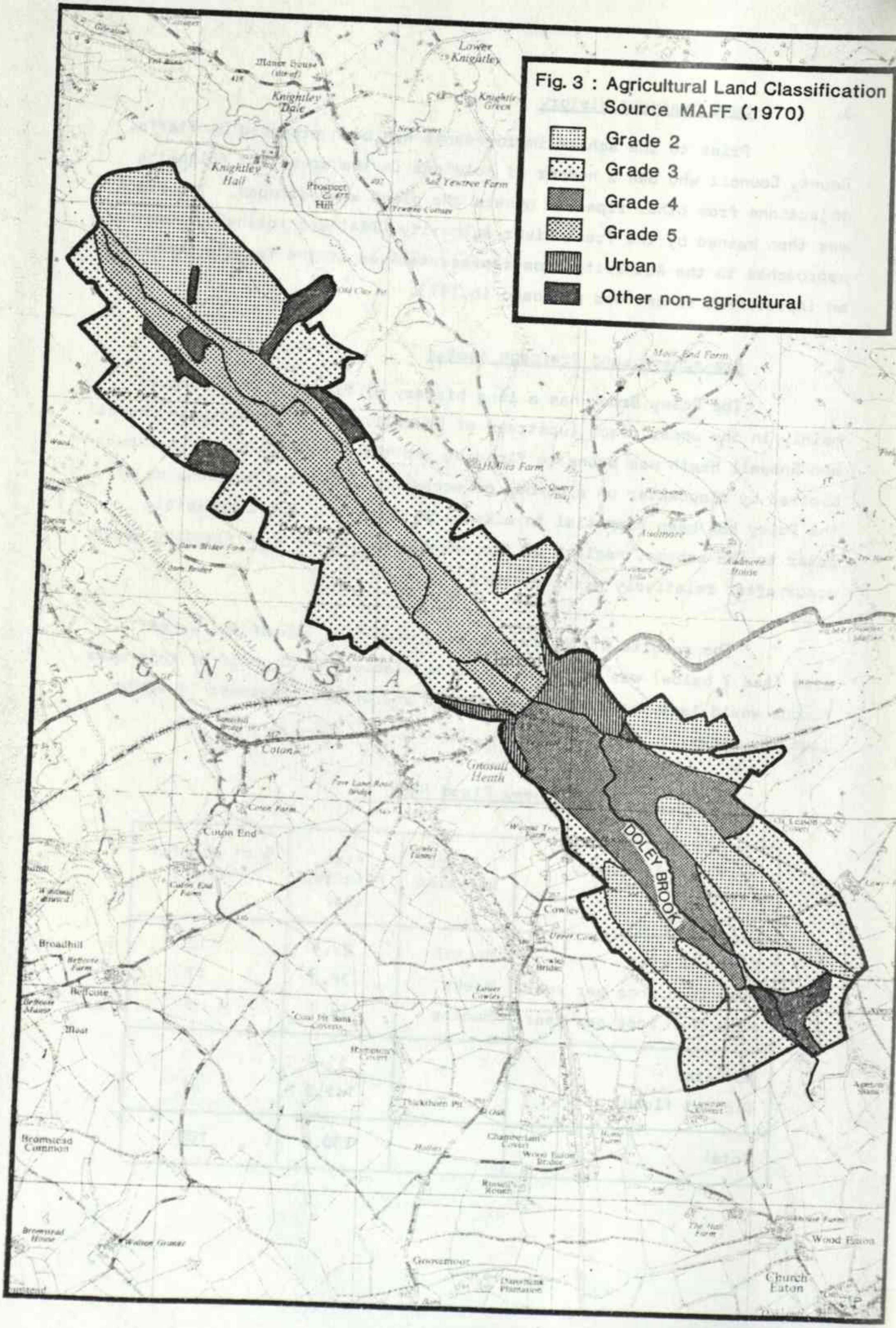


Fig. 3 : Agricultural Land Classification
Source MAFF (1970)

Fifty-six percent of the benefit area had underdrainage prior to the scheme although roughly half of this area was reported as being either 'commonly' or 'usually wet' before the scheme. The qualitative assessments of field drainage status are shown below:

Table 2 : Pre-Scheme Drainage Status

Drainage Status	Area (ha)	% of Benefit Area
Rarely or seldom wet	35.6	15
Occasionally wet	49.7	22
Commonly wet	68.2	30
Usually wet	42.6	18
No data	34.7	15
Total	230.8	100

The agricultural areas liable to flooding are mainly upstream of Gnosall where floods, that occurred at least annually, would remain on the land for weeks or in some cases months. It is to be noted that the area of flooding is restricted to the flat valley floor. None of the farmers interviewed below Gnosall reported any flooding before the scheme, although a letter from the NFU to the Trent River Authority in 1972 reported 16 ha that were partially under water.

The high water level in the brook prior to the improvement scheme meant that many areas would lie wet for much of the year. Upstream of Gnosall all the land of the valley floor suffered from poor drainage and there was insufficient outfall to permit underdrainage. Most of the valley sides have been underdrained in the past with tile systems dating back up to 100 years. However, reduced freeboard and lack of attention had caused blockages and reduced efficiency. Poor drainage did not appear to be a problem on the sloping valley sides.

Below Gnosall the areas that suffered from poor drainage were restricted to the land immediately adjacent to the brook. Much of the land appears to have been tile drained at some stage but again high water levels and neglect had reduced efficiency.

5. The Impact of Pre-scheme Drainage Status on Land Utilisation

Before the improvement scheme the fields adjacent to the brook were used for permanent pasture or woodland. A large area known as Doley Common (16.6 ha) was virtually useless from the agricultural point of view and the vegetation had become dominated by rushes. A further 12.8 ha downstream of the Common were also unfarmable. At the lower end of the scheme a few fields had been ploughed and resown with grass or used in an arable rotation. These fields rise fairly steeply from the Doley and were fairly free draining.

On riparian pasture, grazing seasons for cattle were limited to 6 months between April and November, compared with a possible 9-12 months on the valley sides.

6. Scheme Design

The objectives of the proposed scheme were:

(i) to improve the drainage of riverside land by lowering normal water levels, thereby enabling riparian farmers to carry out underdraining, and

(ii) to reduce the frequency of flooding of open land, especially in the Gnosall area. (Ref. 1).

These were to be achieved by regrading the four miles of the brook. Included in the proposals were the demolition and reconstruction of seven culverts and the road bridge at Gnosall. The trapezoidal channel cross-section was designed for an annual flodd discharge of 70 cusecs (1.98 cumecs) rising to a 25 year flood discharge of 200 cusecs (5.66 cumecs) in the Gnosall Area.

7. Benefit Area

The Engineers Report (Ref. 1) identified a benefit area of 470.2 ha as shown in Figure 4. However, following the farm survey (see 10 below), it was found that this was a significant over-estimate; not only did the proposed benefit area extend far above the Medway Line on the steep slopes of the upper reach, but it also included land in the lower reach that drained to another watercourse not affected by improvements to the Doley. The field observations were supported by aerial photograph interpretation (Ref. 6) and the boundary was adjusted to provide a revised agricultural benefit area of 231 ha (see Figure 4).

8. Anticipated Costs and Benefits

(a) Cost:

The total cost of the works was estimated at £73,400 (April 1973) to be financed by TRA with grant aid from MAFF. The cost estimate was made up as follows:

	£
Wages	42,500
Plant	20,000
Materials	8,000
Land purchase and compensation	2,800
Survey	100
	£73,400

(b) Benefits:

No assessment of likely benefits was made prior to the scheme.

9. The Scheme

Work began at the lower end of the scheme on 30th November 1973 and was completed on 5th September 1975. Although the works on the lower reach were carried out according to the design criteria a problem was encountered at Gnosall road bridge that prevented the improvements upstream from reaching design standards. A sewer pipe running under the brook below the road bridge could not be lowered and therefore served to keep water levels up in the upstream reach. The existing road bridge was not replaced.

The total cost of the works completed (before grant) was £32,526. This represented a saving of £40,874 on cost estimates for the original engineering specifications. Thirty percent of this saving was due to the road bridge and culvert that were not replaced.

Table 4 : Farm Size (Area)

Size Group (ha)	No. of Farms	% of Benefit Area
5- 10	1	3
20- 30	1	2
30- 40	1	7
40- 50	2	9
50-100	2	26
100-200	1	14
200-300	1	17
300-500	1	17
Total	10	95

Mean = 106 ha

Table 5 : Farm Size (Standard Man Days)

Size Group (SMD)	No. of Farms	% of Benefit Area
99	1	3
100- 174	0	0
175- 249	1	19
250- 499	2	13
500- 999	2	10
1000-1499	1	17
1500-1999	1	14
2000	1	17
Total	9	93

Mean = 2082 SMD

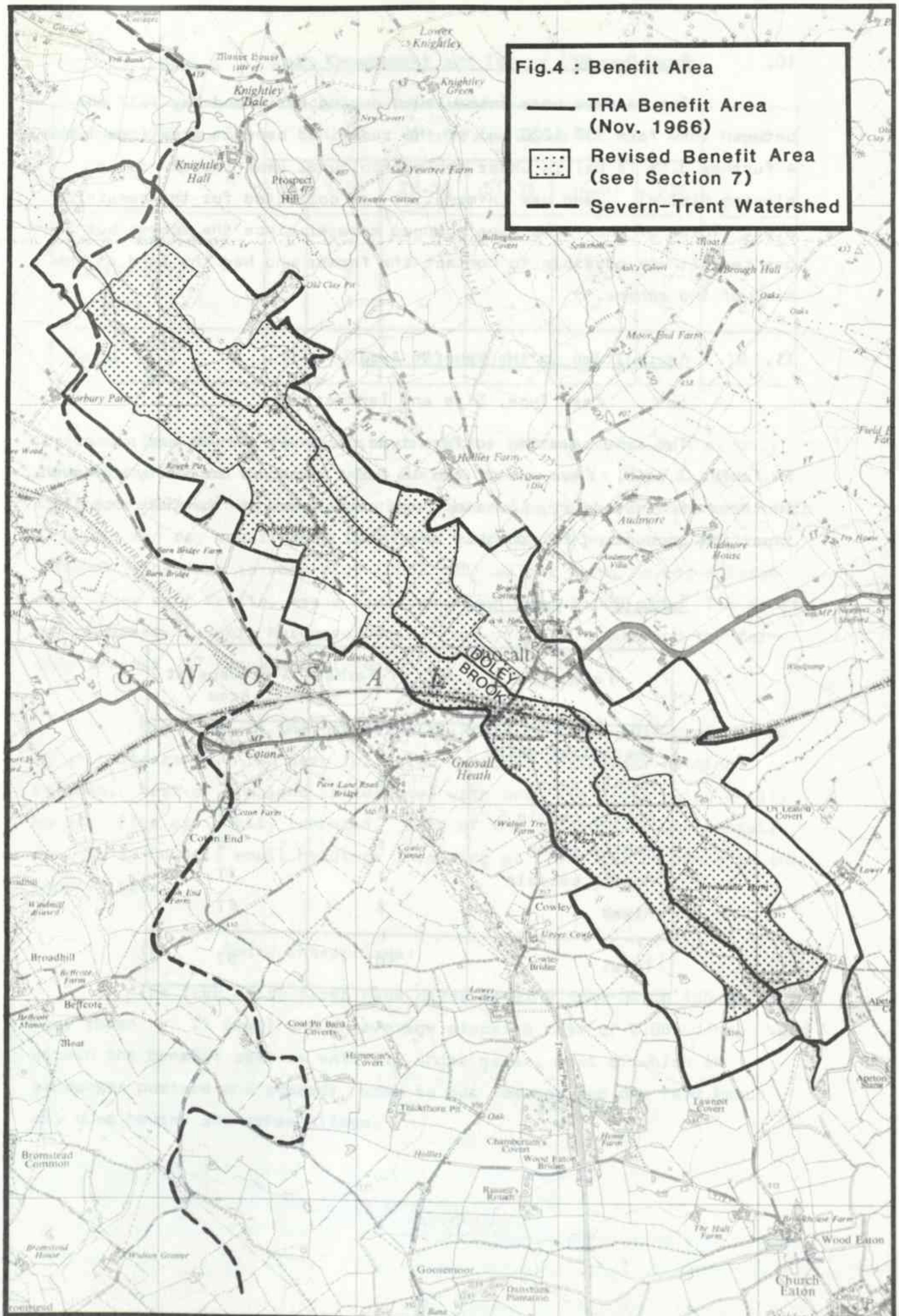


Fig.4 : Benefit Area
TRA Benefit Area (Nov. 1966)
Revised Benefit Area (see Section 7)
Severn-Trent Watershed
BOLEY BROOK
G N O S A L
Knightley Dale
Knightley Hall
Prospect Hill
Lower Knightley
Knightley Green
Audmore
Gnosall Heath
Coton
Coton End
Cowley
Broadhill
Beffcote
Moat
Bromstead Common
Wood Eaton
Church Eaton
Goosemoor

10. Farm Survey

Ten farmers were interviewed during April and May 1972 who between them farm 95% (220 ha) of the redefined benefit area (see 7 above). A further 3.5% (8 ha) is under non-agricultural uses (woodlands or playing fields). Land use information was collected for the remaining area. Three of the farms have changed manager since the scheme but in one case it was possible to contact the farmer who had the land at the time of the scheme.

11. Agriculture in the Benefit Area

(a) Farm Type, Size and Tenure:

The data relating to farm type, size and tenure are summarized in Tables 3 to 6. Five out of the 10 farms surveyed are dairy although in terms of area, dairy, livestock and cereals/mixed farms are equally important accounting for roughly one-third each.

Table 3 : Farm Type

Farm Type	No. of Farms	% of Benefit Area
Specialist dairy	3	12
Mainly dairy	2	20
Mostly cattle	2	26
Mostly sheep	1	3
Mostly cereals	1	17
Mixed	1	17
Total	10	97

Table 6 : Farm Management and Tenure (No. of Farms)

Management Status	% of Farm Owned						Total
	0	1-25	26-50	51-75	76-91	100	
Sole Proprietor	3	-	-	-	-	2	5
Partnership	1	1	1	1	-	-	3
Manager	1	1	-	-	-	-	2
Total	5	2	1	1	0	2	10

Five of the farms are under 50 ha in size although they only account for 21% of the area. The average farm size is 106 ha. Two of the farms (22% of the area) are classified as part-time in terms of their standard man day requirement (ie. less than 249 SMD) and most are under 1000 SMD. The mean is very high (2082 SMD) as one farm, having a large area under soft fruits, has a requirement of over 13,000 SMD. The fruits are, however, largely harvested on a 'Pick-your-Own' basis and the farm only employs 10 regular employees.

Eight out of the ten farmers interviewed are sole proprietors or in partnership. Two were full-time managers for larger farming estates. Most of the land is tenanted with only two farms being wholly owned. Five are wholly tenanted. Many of the holdings around Gnosall are County Council small holdings including at least two of those in the benefit area.

(b) Dairy Enterprises:

The five dairy farms have herds ranging from 32 to 125 dairy cows (mean = 71 cows) and an average stocking rate of 2.08 LU/ha. Land within the benefit area is entirely under grass, most of which is permanent pasture and grazed; some is cut for hay and one farm keeps all cows housed and makes silage.

(c) Livestock Enterprises:

Four farms keep some cattle for beef and two are classified as 'mostly cattle', a third is classified as 'mostly sheep'. Stocking rates averaged 0.7 and 0.9 Livestock Units per Hectare on cattle and sheep farms respectively.

(d) Arable Enterprises:

There is only one 'mostly cereals' farm with land in the benefit area, accounting for 17% of the land area. This has only been since a change of management that post-dates the scheme. Prior to the scheme it was a dairy farm, although some land within the benefit area was under a grass/arable rotation. Prior to the scheme spring and winter cereals were grown in rotations away from the watercourse although in the case of winter cereals timeliness was critical. Some potatoes were grown on lighter land where there was no flood risk. The stocking rate is 3.23 LU/ha.

Figures 5 and 6 summarize the trends in agriculture in the Parish of Gnosall over the period 1970-1980. Seventy-three percent of the benefit area lies within Gnosall Parish, the rest being divided roughly equally between the parishes of Norbury, Haughton and Church Eaton. The figures for Gnosall Parish provide an overview of trends in the area and should not be taken as representative of the benefit area itself which only accounts for 8% of the total agricultural area of the Parish. It can be seen that there is a net decline in the total agricultural area over this period with declines in the areas of grass and crops. Livestock numbers have fluctuated but there has been a steady increase in the number of dairy cows, suggesting an intensification of dairy enterprises. The total numbers of cattle and sheep have also risen slightly.

12. <u>The Effect of the Scheme on Flooding and Land Drainage</u>

Upstream of Gnosall there has been little extra freeboard provided by the scheme due to the non-replacement of the culvert at the road bridge, however, channel works have increased the bankfull capacity of the brook and reduced the frequency and duration of flooding over most of the area. Downstream of Gnosall, additional freeboard has been provided, although water levels have not been lowered by as much as were anticipated. Indeed, one field underdrained immediately following the scheme with direct outfalls needed remedial works within a few years as all the outfalls were permanently submerged.

Figure 5 : Trends in Land Use in Gnosall Parish 1970-80

Source: MAFF Census Returns

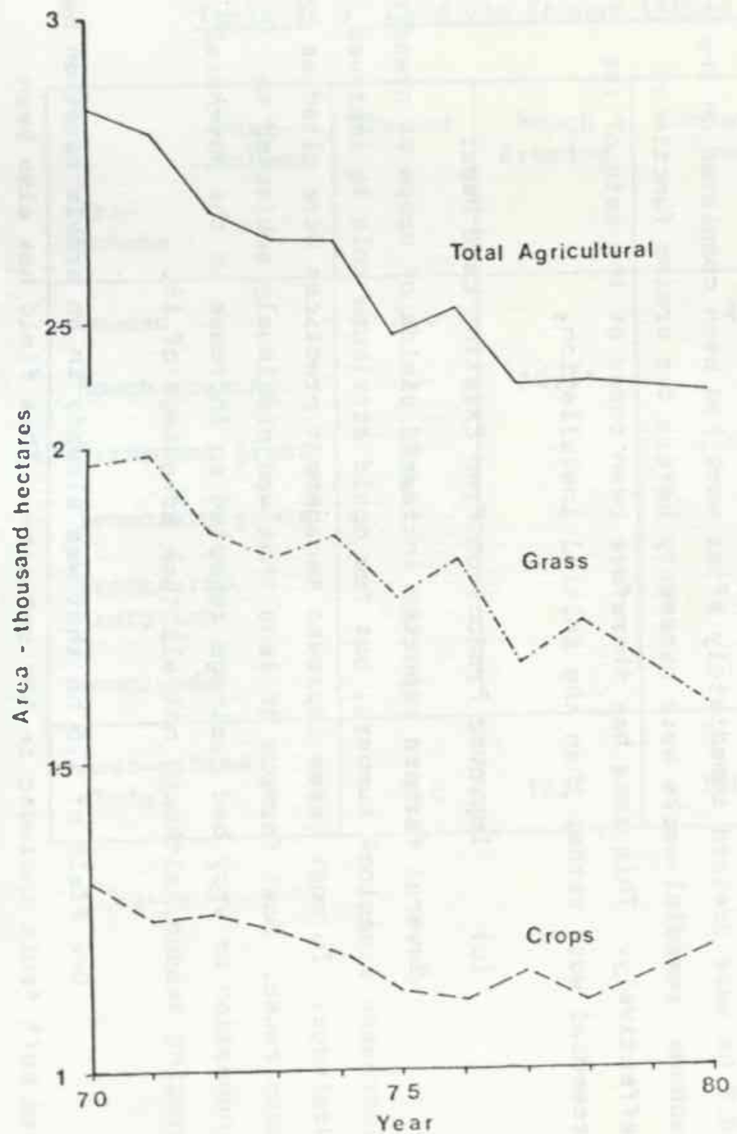
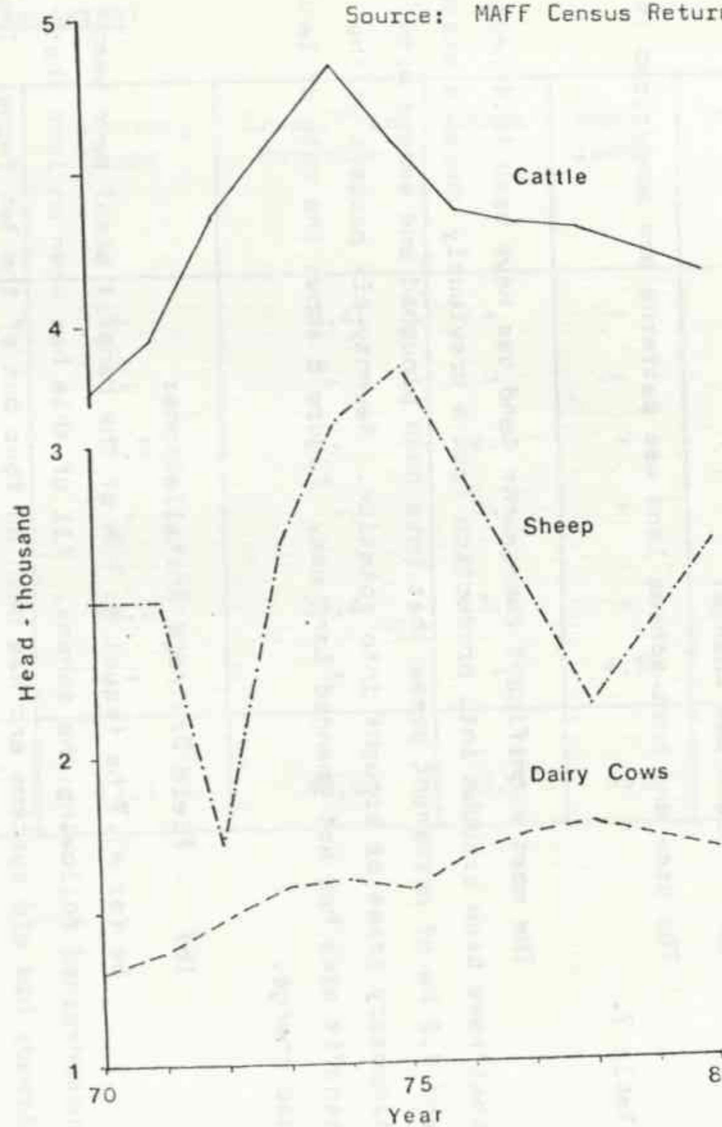


Figure 6 : Livestock Numbers in Gnosall Parish 1970-80

Source: MAFF Census Returns



The results of the farm survey indicated that of the area that was neither freely draining nor adequately underdrained, 24% had not been underdrained post-scheme due to outfall restrictions.

13. The Agricultural Benefits of the Scheme

(a) Land Use Change:

The pre- and post-scheme land use patterns are summarized in Table 7.

The most significant changes in land use have been 12.4 hectares that have been brought into production from a previously unusable state and 9.2 ha of permanent grass that have been ploughed and seeded with temporary grass or brought into rotation. Seventy-six percent of the benefit area has not changed land use. Figure 8 shows the rate of land use change.

(b) Field Drainage Installations:

So far 41.7 ha (equal to 18% of the benefit area) have been underdrained following the scheme. All of this has been on land that already had old systems and has been on four out of the ten farms. The rate of installation of field drainage is shown in Figure 9. Although 8.9 ha were drained immediately after work had been completed on the scheme, remedial works were necessary before the drains functioned effectively. This area has therefore been coded at the date of the remedial work rather than the initial installation.

(c) Improved Production From Existing Land Uses:

Several farmers reported increased yields of crops or grass or increased livestock numbers, but few could attribute this to improved drainage. In most cases improved management practices were cited as the main cause. Most farmers of land that was previously subjected to inundation or very bad drainage reported an increase in the potential grazing season, although not all took advantage of it.

One field of 1.6 ha that was already in an arable rotation has had soft fruit included in the rotation. This field has also been underdrained.

Table 7. : Land Use Change (Areas in Hectares)

Post-scheme / Pre-scheme	Unused	Rough Grazing	Permanent Grass	Temporary Grass	Grass/Crop Rotation	Crops	Wood-land	Pre-scheme Total
Unused	3.6	-	4.0	-	8.4	-	-	16.0
Rough grazing	-	16.1*	-	-	-	-	-	16.1
Permanent grass	-	-	106.8	3.2	-	6.0	-	116.0
Temporary grass	-	-	-	-	-	5.2	-	5.2
Grass/crop rotation	-	-	-	10.2	32.4	13.8	-	56.4
Woodland	-	-	-	-	-	-	4.5	4.5
Post-scheme Total	3.6	16.1	110.8	13.4	40.8	25.0	4.5	214.2

* Doley Common

Fig 8 : LANDUSE CHANGE

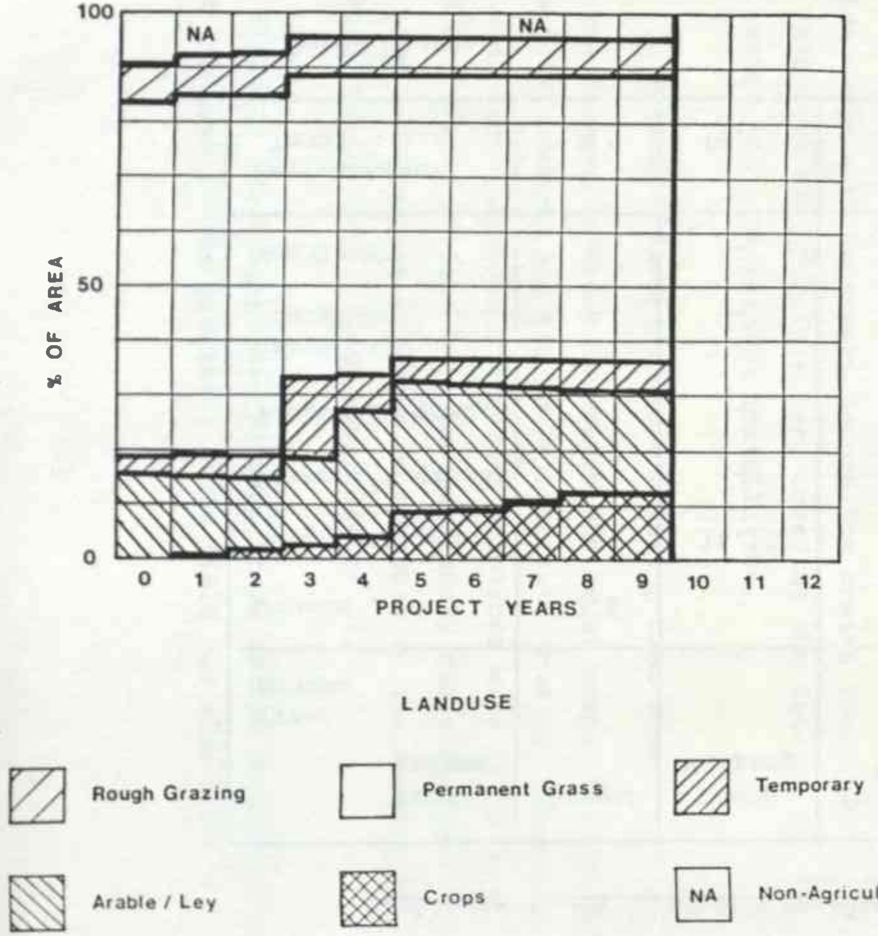
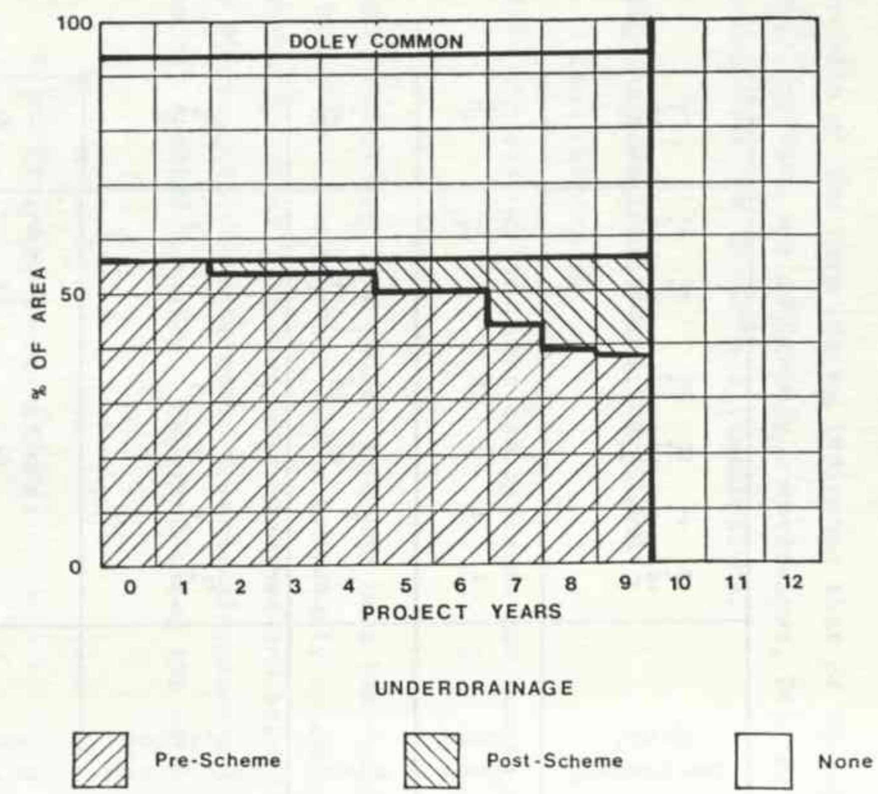


Fig 9 : INSTALLATION OF UNDERDRAINAGE



NB: Some of the dates of change were unknown and have therefore been phased over the study period.

(d) The Rate of Benefit Uptake:

A financial assessment of the Doley Brook scheme has been undertaken by identifying, on the basis of farmer interview, the change in farm enterprise gross margins attributable to drainage improvements, net of any additional fixed costs, and including the benefit of extended grazing if relevant. The procedures used for this purpose are described in Annexe V.

A summary of benefits (before field drainage costs) by farm in the benefit area is given in Table 9. Eight out of the ten potential beneficiaries, reported actual benefit, although 90% of total benefits accrued to five farmers.

The rate of uptake of financial net returns attributable to the scheme is shown in Figure 10. Over the 198.5 hectare (adjusted[1]) benefit area the average increase in net returns reached a maximum of £70 per hectare in 1981, but has reduced since then due to adjustments to rotations.

Figure 11 expresses actual take-up as a percentage of scheme potential which is taken to be a reasonably achieveable target for post-scheme land use, and based largely on land capability and local farming practice. To the north of Gnosall, land in the valley floor is most suited to grass, but the higher ground is suited to arable production including roots. To the south of Gnosall most of the area is potentially suited to arable/ley systems, with continuous arable on higher and/or drained areas.

On this basis Figure 11 shows that for 1983/4, 29% of potential gross margins had been taken up. This estimate of relative uptake requires careful interpretation as discussed in Annexe IX section 4.4.

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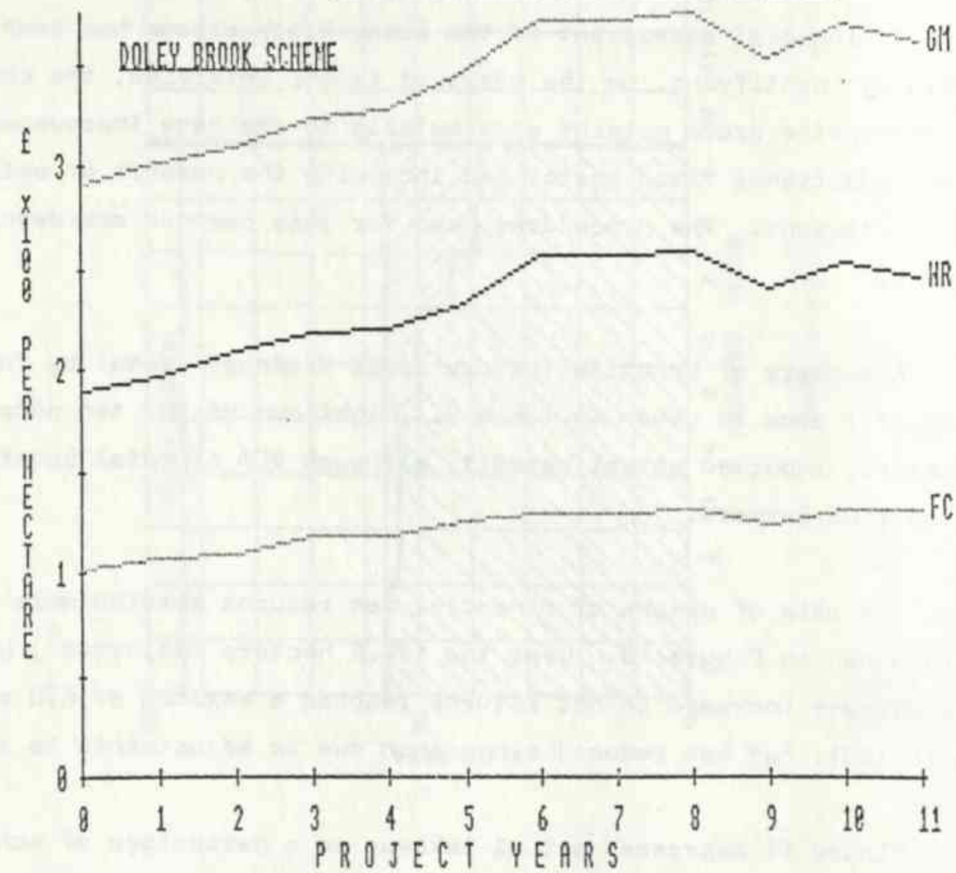
1 Excluding Doley Common and non-agricultural land.

FIGURE 10 : Degree and Rate of Financial Uptake



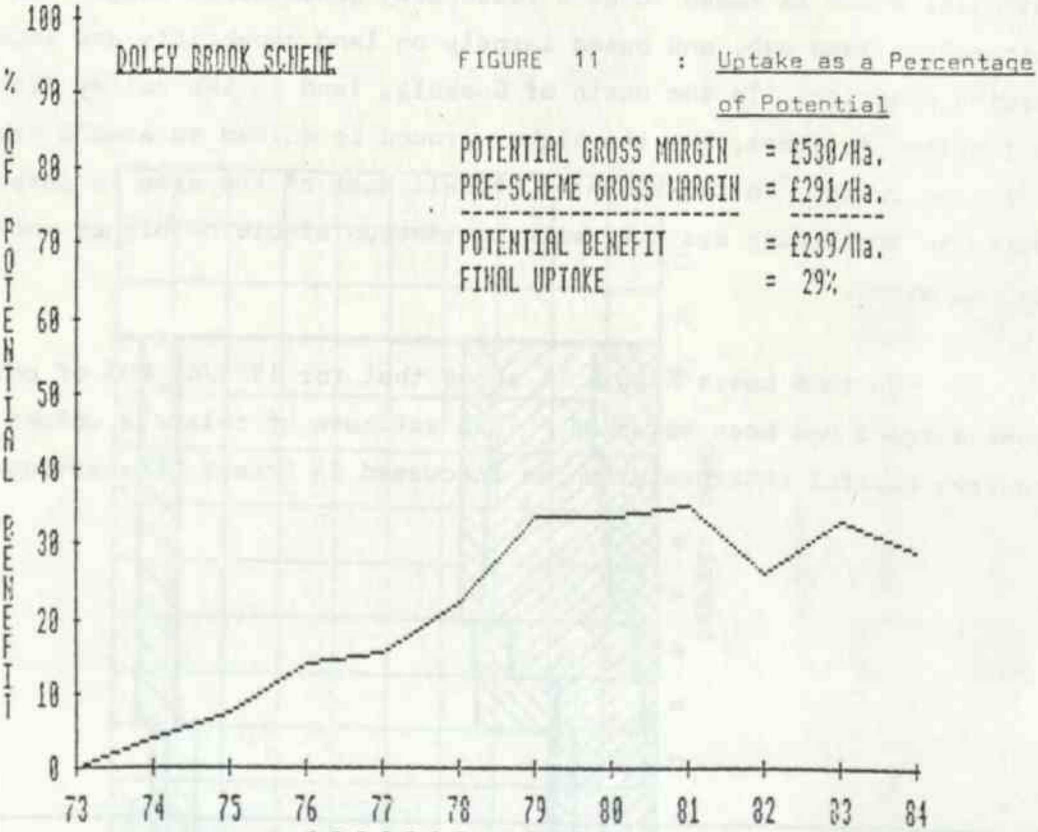


FIGURE 11 : Uptake as a Percentage of Potential

Table 9 : Distribution of Benefits by Farm

SCHEME 21 NET AGRICULTURAL BENEFIT
********* *************************

FARM CODE	YEAR FIRST	YEAR 3	YEAR 7	YEAR LAST	% OF BENEFITS	% OF AREA
2	0	18	1809	1809	16	9
3	0	0	0	0	0	8
4	0	0	0	0	0	3
5	992	1559	2172	2172	20	6
6	254	762	1525	2030	18	17
7	114	424	424	424	4	22
8	177	177	177	177	2	3
9	0	0	174	174	2	4
10	6	1837	3527	1870	17	20
11	0	1076	3606	2421	22	9
TOTAL				11081	100	198

14. Financial Analysis

A summary of the cash flow for the Doley Brook improvement scheme is contained in Table 10, expressed in 1982 prices.

(a) Net Agricultural Benefits:

The net agricultural benefits attributable to the scheme are the extra net returns shown in Figure 6, which relate to the whole benefit area. The net returns recorded for 1984 are assumed to apply over the remaining project life. No prediction is made of future uptake. Variation in yields from observed levels is considered in the sensitivity analysis.

(b) Capital and Recurrent Costs

The capital cost of the scheme was £72,985 or £368 per hectare of (adjusted benefit area). Incremental maintenance costs have been assumed at 1½% of gross capital costs.

Table 10 : Summary of Scheme Cash Flow and NPV

DOLEY BROOK IMPROVEMENT SCHEME

PROJECT YEAR	0	1	2	3	4	5	6	7	8	9	10	11 TO 30
CALENDAR YEAR	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984 TO 2003
AGRICULTURAL BENEFITS												
Net Agric Benefits	0	1544	4005	5857	6321	8752	13418	13418	13923	10316	12738	11081
Flood Damage Reduction	0	0	0	0	0	0	0	0	0	0	0	0
less Without Proj Ben	0	162	325	490	656	824	994	1165	1339	1514	1690	1869
less Field Drain Cost	0	0	7634	0	0	638	0	19938	2687	1100	0	0
NET AGRIC CASH FLOW	0	1382	-3954	5367	5665	7290	12424	-7685	9897	7702	11048	9212
SCHEME COSTS												
Capital	41213	31772	0	0	0	0	0	0	0	0	0	0
Recurrent	0	1095	1095	1095	1095	1095	1095	1095	1095	1095	1095	1095
TOTAL COSTS	41213	32867	1095	1095	1095	1095	1095	1095	1095	1095	1095	1095
SCHEME NET CASH FLOW	-41213	-31485	-5049	4272	4570	6195	11329	-8780	8802	6607	9953	8117

NET PRESENT VALUE AT %	0	2.5	5	7.5	10	12.5	15	17.5	20
	127545	56949	16352	-7707	-22320	-31354	-36987	-40484	-42606

(c) Field Drainage Costs:

The total cost of field drainage installations was £31,997, an average £650 per hectare drained, and equivalent to an average investment in field drainage of £161 per hectare in the benefit area. No incremental field drainage maintenance costs have been assumed.

(d) Without-Project Benefits:

It is assumed that without-project improvements in the financial performance of farming would equate to an annual increase of 1% compound of the pre-scheme farming net revenues. This charge has been levied only against those areas for which some post-scheme benefit uptake has been ascertained. In the case of the Doley, uptake occurred on 41.9% of the area. Without-project benefits are thus charged at 1% compound of 41.9% of the pre-scheme net returns, ie. £38,550 x 0.419 x 1% compound.

(e) Flood Damage Reduction:

No significant pre-scheme flood damage costs were reported for the pre-scheme situation. Stock had on occasion been lost in the Brook but this had not been attributed to flood risk.

(f) Project Worthwhileness:

Assuming benefits continue at their 1984 levels over a 30 year project life, the net present value of the Doley Brook scheme at the 5% discount rate is £16,352 with an internal rate of return of 6.6%. This satisfies the present Treasury criterion.

(g) Sensitivity Analysis:

Table 10 examines the sensitivity of the scheme to cost and benefit estimates. On the basis of performance todate, actual performance could be 10% less than estimated without prejudicing the project at the 5% discount rate. If the benefit stream is assumed to occur one year later than that actually related by farmers, internal rate of return would reduce to 5.6%.

TABLE 11

Doley Brook - Sensitivity Analysis

Run No.	Agricultural Benefits Factor	Without Project Benefits Compounding Factor	Flood Damage Reduction Factor (a)	Capital Works Cost Factor	NPV at 5% £	IRR %	Switching Value
1	1.0	1.0	1	1	16352	6.7	.88
2	1.0	0.5	1	1	26492	7.5	.80
3	1.0	1.5	1	1	5767	5.7	.96
4	1.0	0	1	1	36204	8.3	.72

* The factors show the weights applied to the original estimates eg a factor of 1.5 for the without-project benefits indicates that the new value is 1.5 x 1% compound (the original estimate) ie 1.5% compound.

* Switching value = Change in agricultural net benefits needed to make the project breakeven at 5% discount eg a 1.5 value shows that an increase of 1.5 x the original estimate is needed.

a. There were no significant flood damge costs pre- and post- scheme.

15. Discussion

The scheme has met with a reasonable response, especially from riparian farmers downstream of Gnosall where improved outfall has allowed the underdrainage of permanent grassland and better drainage has improved the condition of all the riverside land. Upstream of Gnosall, however, full benefits have not been realized, largely because of shortcomings of the scheme. The channel has been improved to allow flood water to pass quicker and therefore reduce flood damage but there has been little potential for field drainage improvement on the lower lying land due to the restricted outfall.

During the course of fieldwork, it became apparent that the benefit area defined by the Trent River Authority was too large and did not seem to bear any relationship to the Medway Line. Below Gnosall, about one-third of the defined benefit area drains into an independent watercourse and has never been affected by flooding from the Doley. At the top end, land on the valley sides above the brook has been included that was never constrained by poor drainage.

Most of the valley floor upstream of Gnosall is occupied by Doley Common. This is a wetland area of 16.1 hectares underlain by deep organic and alluvial soils that has considerable floral and faunal interest as a result of the permanently high water table. It has not always been a wetland, and it is claimed that it only reached its present state as a result of neglect to the drainage system over the last 20 years. If the area were drained again its agricultural potential would undoubtedly be high, although peat shrinkage <u>may</u> be a severe problem, such that investment in field drainage would need careful consideration.

Upstream of Gnosall there is a demand for further drainage improvement. If the water level in the Doley Brook could be lowered improvements could be carried out on a number of arterial ditches, especially in the Plardiwick area, which would undoubtedly improve the productivity potential of grassland in the area. Such works may, however, have severe effects upon the wildlife value of the Common unless a suitable engineering solution could be found to maintain the water level in that area.

The Doley Brook was included in the section 24 (5) survey along with the Church Eaton Brook as a watercourse in need of improvement. Works have since been carried out on the Church Eaton Brook up to Ruele Pool but no further work has been done on the Doley.

References

1. Engineers Report. Trent River Authority, 1973.
2. Soils in Staffordshire II, Soil Survey Records No. 31.
3. Mackney and Burnham (1964). Soils of the West Midlands. Soil Survey Bulletin No. 2.
4. Agricultural Land Classification. MAFF 1970, sheet 119.
5. STWA (1980). Section 24 (5) Survey. Water Act 1973.
6. Steidel, M. (1982). Measuring the impact of land drainage schemes - Appendix I, Doley Brook Scheme. MSc thesis, NCAE. (Unpublished).

APPENDIX I

SOILS OF THE DOLEY BROOK AREA

Ref: Soils in Staffordshire II, Soil Survey Record No. 31. Sheet SJ82 (Eccleshall)

Salop Series

Fine loamy over clayey soils developed in reddish clayey till, derived mainly from Triassic rock, and having a diagnostic gleyed horizon above 40 cm. They have gley morphology comparable with that of the Clifton series. The stagnogley features of these soils result from the fact that percolating drainage waters are held up by the very slightly porous and coarsely structured Btg horizon.

Suggested Underdrainage Treatments: Depth 75 - 90 cm
Spacing 20 m

Clifton Series

The slightly stony clayey soils of the Clifton series are classified with the typical (argillic) stagnogley soils and are developed in reddish fine loamy till. They have a marked increase in clay content down the profile and a diagnostic gleyed horizon above 40 cm.

The increased clay content at depth restricts percolation and drainage water gradually accumulates and saturates the upper horizons. Whilst these upper horizons remain wet for much of the autumn and winter, and waterlogged to the surface in spring, Clifton soils retain good supplies of moisture for arable crops and grass during periods of soil moisture deficit in the summer.

Suggested Underdrainage Treatment: Spacing 20 m

Newport Series

Sandy soils developed in glaciofluvial deposits and which have uniformly coloured horizons. They are classified with typical brown sands and are slightly stony to stony throughout. No underdrainage treatment is required.

Arrow Series

Soils developed in stony or very stony glaciofluvial deposits with distinct mottling above 80 cm and classified with the gleyic brown earths. Sand/Coarse loamy.

Undifferentiated Organic Soils

In the Gnosall depression they form the broad infill of a large former glacial overflow channel. The deposits consist of fibrous or semi-fibrous peat which is dark reddish brown or black in colour. The soils are poorly drained and liable to be periodically flooded in many places. Land use is dominantly rough grazing or poor permanent pasture. Surface bearing strength is low; poaching is a serious problem and the grazing season is short.

Undifferentiated Alluvial Soils

These soils generally have more than 18% clay and are mainly alluvial gley soils of the groundwater gley soil major group. Permanent pasture occupies most of the area because of poor drainage, partly because of the risk of flooding and partly because of the long thin nature of the fields.

Table I.1 : Soils Grouped According to Cultivation Needs

Group	Ease of Cultivation	Requirements	Soil
i	Easy	Autumn ploughing not essential. Traditional machinery adequate. Timeliness flexible.	Newport Arrow
ii	Moderate	Autumn ploughing desirable, traditional machinery adequate. Timeliness essential.	Clifton
iii	Moderately difficult	Autumn ploughing essential. Traditional machinery adequate. Timeliness essential.	Salop
iv	Difficult	-	
v	-	Not normally ploughed; summer ploughing and autumn cultivations are optimum for reseeding.	Undifferentiated alluvial and organic soils

APPENDIX II

LAND CAPABILITY UNITS OF THE DOLEY BROOK AREA

2s/1 (Newport)

Weak structure permits slaking and capping after repeated cultivation; minor erosion hazard on slopes; minor risk of droughtiness in dry years.

Crops: Cereals (wheat and barley), grass, potatoes, sugar beet, turnips, rape.

2s/2 (Arrow)

Weak structure permits slaking and capping after repeated cultivation; stoniness on terraces, erosion hazard on slopes and wetness due to rising groundwater minor limitations.

Crops: Cereals (wheat and barley), grass, potatoes, sugar beet.

3ws/1 (Clifton)

High groundwater table or very slightly porous subsoil causes moderate to severe wetness and makes careful timing of cultivations desirable; weak structure of surface soil and/or stoniness are minor limitations.

Crops: Grass, cereals (wheat and barley).

3ws/2 (Salop)

Slightly porous surface soil and very slightly porous subsoil causes severe surface wetness; very large retained water capacity of surface soil demands careful timing of cultivations.

Crops: Grass, cereals (mainly wheat).

5ws (Undifferentiated Organic and Alluvial Soils)

Very high groundwater table and/or very slightly porous subsoil cause very severe surface wetness; surface soil have very large retained water capacity and low bearing strength.

Crops: Grass (including rough grazing land).

APPENDIX D

Upper Trent Division

River Trent : Alrewas to Yoxall Bridge

SILSOE COLLEGE

STWA UPPER TRENT DIVISION - RIVER TRENT SCHEME (1976)

Report on the background to, and development of, the scheme and the nature and rate of agricultural benefits.

1. Physical Background

The present scheme relates to 6.5 km of the River Trent between Alrewas Mill (GR SK167155) and Yoxall Bridge (GR SK131178) in South East Staffordshire. The river has a catchment area of 1,230 km^2, including its tributaries, the Sow, Penk and Blithe, and is here in a mature stage. It meanders through a wide floodplain with a washland of up to 750 m from either bank.

Several watercourses enter the Trent along this reach; the Swarbourn, from the north, and the Curborough (also known as Pyford) and Bourne Brooks from the south, carry highland water across the floodplain. There are several minor watercourses that serve to drain the largely agricultural floodplain.

2. Soils and Land Classification

The soil of the area is generally mixed, but much is sandy and underlain by river gravels allowing free drainage. The Agricultural Land Classification is shown in Figure 1. The immediate floodplain was classified as grade 4, presumably due to land drainage limitations. Away from the washland, grade 3 land predominates with pockets of grade 2 land.

3. Land Drainage History

This length of river was improved by a regrading scheme in 1953-56 at a cost of £38,928. Extensive bank protection was carried out and the scheme was highly successful. Prior to the present scheme, however, the weir and sluice at Alrewas Mill obstructed normal river flow, especially when choked by weed and debris.

4. Pre-scheme Land Drainage Status

The high water levels above Alrewas Mill prevented any improvement to the Curborough and Bourne Brooks which frequently overtopped their banks, innundating adjacent land. Although a washland of 464 ha was shown on the Benefit Plan (Drawing No. UTLD 3/1/2) few of the farmers recognised flooding from the Trent as a major problem, with only small areas, immediately adjacent to the river being affected (see Farm Survey). More serious problems resulted from flooding from the Curborough and Bourne Brooks and their tributaries, the River Swarbourn and the Orgreave Drain. Each of these would overflow their banks at least once every year.

Of the washland area (see Figure 2) roughly half was free from flooding prior to the scheme. Nearly 30% would flood a number of times each year (for a matter of days only) and 20% would flood once each year. The results of the farm survey (see 10) show that 80% of the washland area was described as being only 'Rarely' or 'Occasionally Wet'. Fifteen percent was classified as 'Commonly Wet' and 5% was 'Usually Wet'.

5. The Impact of Pre-scheme Drainage Status on Land Drainage

It can be seen from the above that land drainage was not a severe constraint on agricultural productivity over most of the washland area. Localised problems were caused by the flooding and restricted outfall of arterial watercourses that restricted land use to permanent pasture in places. In some cases occasional losses from flooding have been accepted and intensive land uses, such as root vegetables, were practised prior to the scheme.

6. Scheme Design

The scheme provided for the rationalization of the channel between Yoxall Bridge and Alrewas to pass the annual flood within its banks and to provide 1.6 m freeboard at normal flow. This was to be achieved by the removal of the weir and sluice at Alrewas Mill and channel regrading upstream. The secondary channel which formed an island below Wychnor Hall was to be filled in and the Trent realigned accordingly. Watercourse outfalls were to be modified to take advantage of the lower normal river level. The designed scheme would have little effect on major flood levels.

7. Area of Benefit

It was predicted that the washland area of 464 ha would derive most benefit directly from the scheme (see Figure 2). However, the scheme would also benefit indirectly 688 ha of the area of secondary benefit shown on the benefit plan.

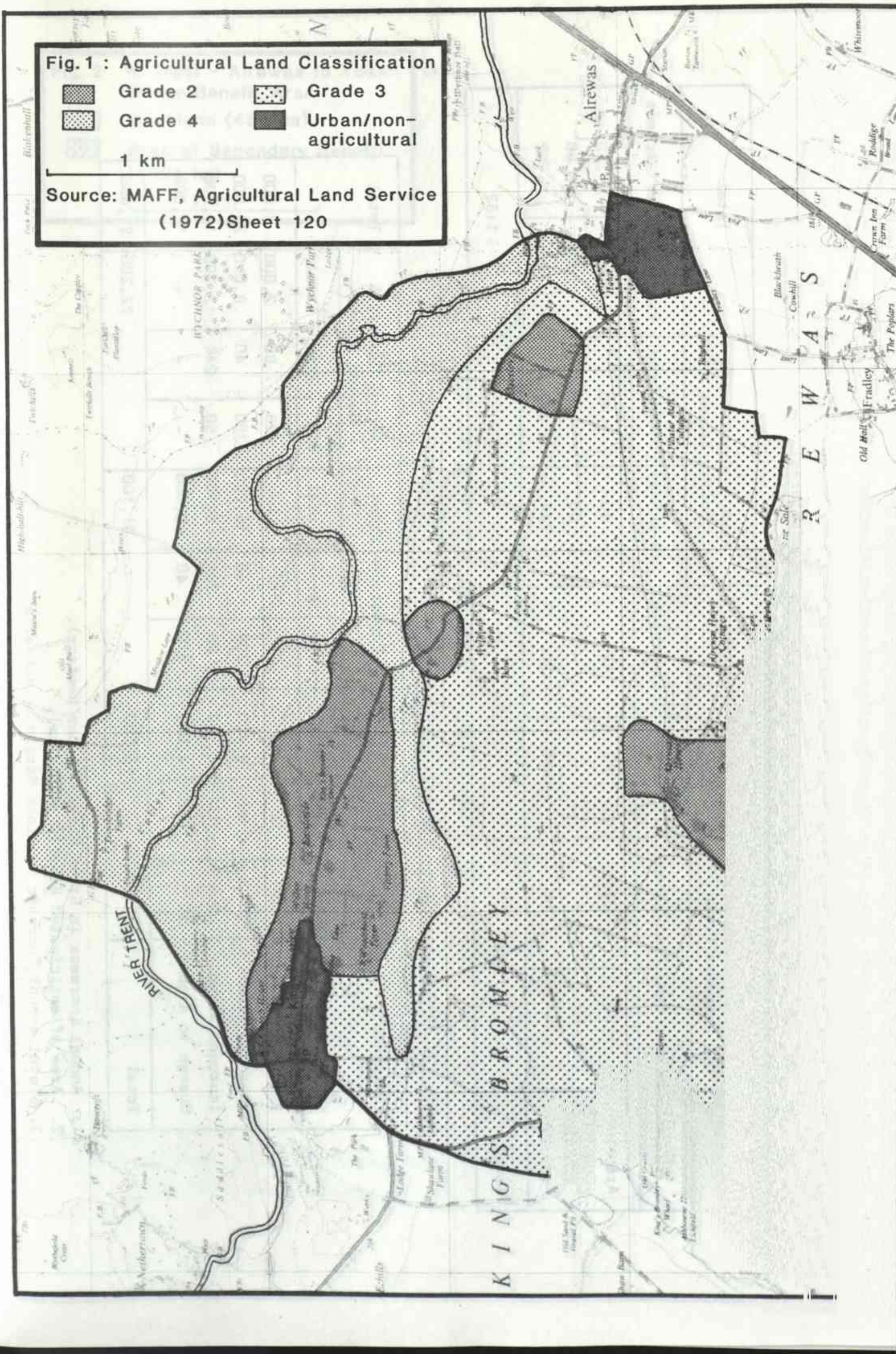


Fig. 1 : Agricultural Land Classification
Grade 2
Grade 3
Grade 4
Urban/non-agricultural
1 km
Source: MAFF, Agricultural Land Service (1972) Sheet 120
Alrewas
RIVER TRENT
KINGS BROMLEY
ALREWAS

Table 2 : Predicted Land Use Change by Sub-area (areas in hectares)

Land Use	R. Trent and Orgreave Drain		Curborough Brook		Ashby, Crawley and Bourne Brooks		Total	
	Pre-scheme	Post-scheme	Pre-scheme	Post-scheme	Pre-scheme	Post-scheme	Pre-scheme	Post-scheme
Arable	80	120	80	120	40	40	200	280
Cereals	-	-	-	-	80	80	80	80
Livestock	384	344	244	204	244	244	872	792
Total	464		324		364		1152	

Table 3 : Predicted Annual Benefit by Sub-area

Improvement	R. Trent & Orgreave Drain			Curborough Brook			Ashby, Crawley & Bourne Brooks			Total
	G.M.[1]	Area[2]	Total[3]	G.M.	Area	Total	G.M.	Area	Total	
Improved cereals	-	-	-	-	-	-	25	80	2,000	2,000
Improved Arable	30	80	2,400	200	80	16,000	200	40	8,000	26,000
Improved Grass	5.5	344	1,900	25	204	5,100	50	244	12,200	19,200
Change to Arable	50	40	2,000	250	40	10,000	-	-	-	12,000
Total			6,300			31,100			22,200	59,600

1. Annual increase in Gross Margin (£ per hectare).
2. Area of anticipated benefit (hectares).
3. Total annual increase in Gross Margin by sub-area.

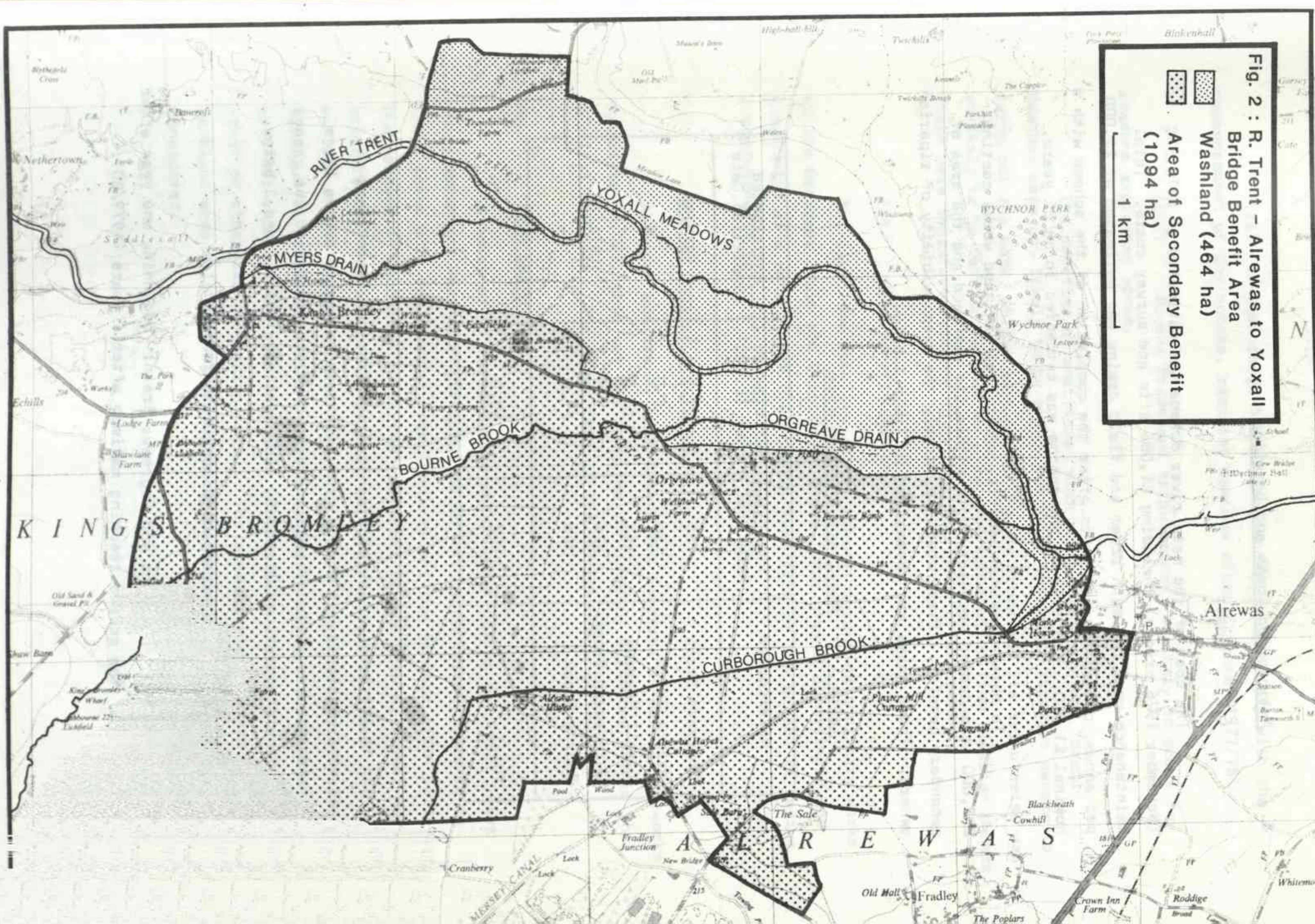


Fig. 2 : R. Trent – Alrewas to Yoxall Bridge Benefit Area

8. Anticipated Costs and Benefits

(a) Cost:

The cost of the main river scheme was estimated at £113,630 (November 1976 prices) including £1,056 site and survey costs. Total maintenance cost for main river and field drains was estimated at £2,000 per annum, commencing two years after the completion of the scheme with a nominal £1,000. The life of the scheme was estimated to be 25 years.

To obtain maximum benefit, additional drainage works costing £50,000 were deemed necessary both within the washland and the area of secondary benefit. These would be largely the responsibility of riparian owners. These works are summarized in Table 1 below.

Table 1 : Ancillary Drainage Work

Watercourse	Benefit Area (ha)	Anticipated cost (£,000)	Anticipated Completion Date
Orgreave Drain	169	7.5	1977/78
Myer's Drain	126	8.0	-
Yoxall Meadows	169	10.5	-
Curborough Brook	324	3.0	1976/77
Bourne Brook	364	21.0	-
Total	1152	50.0	

(b) Benefits:

Benefits were anticipated to arise from the improvement of grassland productivity, a change from livestock to arable over a large area, and improved yield of arable areas. The predicted land use change and net benefits are summarized, by sub-areas, in Tables 2 and 3 below.

Benefits were expected to accrue as follows:

(i) R. Trent and Orgreave Drain: beginning one year after commencement of the scheme reaching maximum after 4 years (1979/80).

(ii) Curborough Brook: beginning concurrently with the commencement of the scheme, reaching maximum after 2 years (1977/78).

(iii) Bourne Brook and tributaries: unlikely to occur for reasons explained above.

The benefits of additional work on Myer's Drain and Yoxall Meadows were not likely to be great enough to encourage riparian owners to carry out the work, whilst work on the Bourne Brook and its tributaries was unlikely to be carried out due to a lack of cooperation from riparian owners. These were therefore excluded from the final benefit assessment.

(c) Cost-Benefit Ratio:

The costs and benefits of the scheme, including ancillary works on the Orgreave Drain and Curborough Brook, were phased accordingly and discounted at a rate of 10% over the 25 year life of the scheme to derive a cost-benefit ratio of 1:1.99. See Table 4.

9. Actual Cost of the Scheme

Although additional expenditure was incurred on main river works totalling £5,020, this was met from the contingency allowance within the original estimate. The total cost of the scheme was £113,600.

10. Farm Survey

A total of 17 farmers were interviewed during May 1982. Five other occupiers were identified but could not be contacted, however in these cases only small areas were involved and the farmers often part-time. The manager of Woodshoot nurseries (adjacent to the Crawley Brook) was also interviewed. Between them, the farmers intervied farmed 80% of the washland and 55% of the secondary area (NB. only 63% of the secondary area was in a position to derive benefit ancillary drainage works and these precise areas were not shown on the benefit plan). About 50 ha of the secondary area is urban or otherwise non-agricultural. The present study refers to the washland area only although the impact on the secondary area has been considered.

Table 4 : Cost/Benefit Ratio

Year	Costs (£ x 10^3) Capital: Trent	Orgreave	Pyford	Total	PV (10%)	Maintenance	Total	PV (10%)	Benefit (£ x 10^3) Productivity: Trent & Orgreave	Pyford	Total	PV (10%)
76/7 1	29.6	4.0	3.0	36.6	36.6		36.6					
2	28	3.5		31.5	28.6		31.5		1.6	11.1	12.7	11.6
3	28			28	23.2		28		3.2	22.2	25.4	21.0
4	28			28	21.0		28		4.8	22.2	27.0	20.3
5						1	1	0.7	6.3	22.2	28.5	19.7
6						2	2	1.2	↓	↓	↓	
7						↓	↓					
8												
9												
10 ↓								10.7				169.6
25						2	2		6.3	22.2	28.5	
TOTAL	113.6	7.5	3.0	124.1								
PV					109.4			12.6				242.2

$$\text{Cost/Benefit Ratio} = \frac{242.2}{(109.4 + 12.6)} = 1.99 \text{ @ } 10\%$$

Source: Ref. 2

11. Agriculture in the Benefit Area

(a) Farm Size, Type and Tenure:

The farms are classified according to size, type, tenure and management status in Tables 5-8.

The predominant farm type in the area is dairy with 6 farms classified as either 'Specialist' or 'Mainly Dairy'. Between them they account for 59% of the area surveyed. Three 'Cropping' or 'Vegetable' farms account for 15% and 2 mixed farms 22%. Two 'Livestock - Mostly Cattle' farms account for only 4%.

The mean farm size is 81.5 ha although the range is high. Four of the farms (7% of area) are below 50 ha. Most of the area (53%) belongs to farms of over 100 ha. The mean Standard Man Days (SMD) requirement is 958 SMD, but again the range is high. Three of the farms (5% of area) are classified as 'part-time' in that they have an SMD requirement of less than 250. The largest farm has a requirement of 2452 SMD.

Roughly half of the farms are mostly owned and half mostly tenanted.

(b) Dairy Enterprises:

Seven of the farms surveyed have dairy herds with herd sizes ranging from 24 to 300 milk cows. The average milk yield is high (5847 litres/cow/year).

(c) Livestock Enterprises:

Eight of the farms surveyed keep cattle for beef although 5 of these only sell surplus yearlings from the dairy herd. One has a suckler herd, the other 2 finish stores. Some sheep are grazed with cattle in the benefit area.

(d) Arable Systems:

Roughly 7% of the area surveyed before the scheme and 8% after were under crops. The main crops grown are winter and spring cereals and root vegetables. Potatoes have been and still are grown on land adjacent to the River Trent.

Table 5 : Farm Size (by Area)

Farm Size (ha)	No. of Farms	% of Benefit Area
5- 10	1	1
10- 20	1	1
20- 40	2	6
40- 50	0	0
50-100	5	39
100-200	3	19
200-300	1	34
Total	13	100

Mean = 81.5 ha St. Dev. = 55.6 ha

Table 6 : Farm Size (by Standard Man Days)

Farm Size (SMD)	No. of Farms	% of Benefit Area
0- 100	1	1
100- 175	0	0
175- 250	2	4
250- 500	3	11
500-1000	3	31
1000-1500	1	7
1500-2000	0	0
2000-2500	3	46
Total	13	100

Mean = 958 SMD St. Dev. = 858 SMD

Table 7 : Farm Type

Farm Type	No. of Farms	% of Benefit Area
Specialist Dairy	3	14
Mainly Dairy	3	45
Mostly Cattle	2	4
General Cropping	2	12
Mainly Vegetables	1	3
Mixed	2	22
Total	13	100

Table 8 : Farm Management and Tenure

Management Status	% Tenanted	% of Farm Owned					Total
	100	1-25	25-50	50-75	75-99	100	
Sole Proprietor	2	1	-	-	2	1	6
Partnership	3	1	-	-	2	1	7
Total	5	2	-	-	4	2	13

12. The Effects of the Scheme on Flooding and Land Drainage

The improvement works have provided an improved outfall facility for all the arterial watercourses of the area. Of the area liable to flooding before the scheme, roughly 40 ha had the expected frequency of innundation reduced. This has been primarily on the washland north of the River Trent. In many areas, particularly those affected by the problems on the arterial watercourses the land drainage conditions have not changed significantly as a result of the scheme.

13. The Agricultural Benefits of the Scheme

(a) Land Use Change:

The pre- and post-scheme land use data are given in Table 9 below.

Table 9 : Land Use Change (Areas in Hectares)

Pre-Scheme \ Post-Scheme	Non-Agricultural	Permanent Grass	Temporary Grass	Crops	Pre-Scheme Total
Non-Agricultural	7.7				7.7
Permanent Grass		203.0		4.5	207.5
Temporary Grass			122.2		122.2
Crops				25.8	25.8
Post-Scheme Total	7.7	203.0	122.2	30.3	363.2

Prior to the scheme 57% of the area surveyed was under permanent grass, 34% under temporary grass and 7% under crops. Following the scheme there has been a slight increase in the area of crops to 8% of the total.

(b) Field Drainage Installation:

Roughly 10% of the washland area was drained before the scheme. There has been no field drainage installation following the scheme. Seventy-five percent of the area is considered to be naturally free-draining. On a further 6% there is insufficient outfall and on 11% the frequency of flooding is too great for field drainage installation. Seven percent has not been drained because of lack of finance at farm level.

(c) Improved Production from Existing Land Uses:

Due to the varying agricultural and hydrological conditions, it is best to review the effects of the scheme in four sub-areas.

(i) The Washland - North of the Trent: All land surveyed in this region was under permanent pasture. Field tenure is fragmented and most land is in small blocks away from the main farm unit. In terms of management and infrastructure it shows many of the features of traditional floodplain meadow land. Many areas were previously rented out as summer grazing but have, over the years, been taken on as full tenancies by regular users. Some land is still rented out on a seasonal basis. Remoteness from the farm buildings means the area is unsuitable for dairy cows and is therefore largely used as summer pasture for dary followers and beef cattle. On much of the land cattle could be grazed all year except when flooded.

Much of this strip of pasture land, bound by the Trent to the south and the Swarbourn to the north, was liable to inundation at least once each winter from either river. This would only last for a few days however, and did not interfere with summer grazing regimes to any large extent. The pasture, being wetter in spring and summer, was recognised by the farmers as good grassland.

Since the scheme flooding from the Trent appears to be reduced, and the floodwater now receeds sooner. Flooding from the Swarbourn has not been affected. The land is naturally free draining and although there is some evidence of old tile drain systems, few farmers see any need for underdrainage. There is some room for improvement of the ditch network of the area, but the fragmented ownership pattern makes such work difficult.

The farmers of the area find it difficult to quantify the benefits of the scheme as grazing seasons are often controlled by management factors, rather than field drainage status, and grass conservation is not widespread making yield estimates difficult. There has been no change of landuse since the scheme, the pattern today being the same as when the area was surveyed in 1962 (ref 3).

Most farmers suggested there had been no change in the profitability of the land and some even believed the land to be too dry in summer, with grass growth restricted and cattle drinking points on ditches often dry.

(ii) The Washland - South of the Trent: This is an area of mixed farming with grass for livestock (sheep, beef and dairy) and mixed arable land (cereals, potatoes and sugar beet). Tenure is not as fragmented as north of the river, and most farms are contiguous units.

Prior to the scheme, small areas adjacent to the Trent were liable to flooding, but the major land drainage problems occurred on the minor watercourses, particularly the Orgreave Drain and the lower ends of the Curborough and Bourne Brooks. The latter being carriers of upland runoff from urban and industrial areas caused contamination of the land when they flooded (Ref 2). Flooding of the Trent has been reduced by the scheme but the problems of the minor watercourses remain. Although a flapped outfall has been installed where the Orgreave Drain meets the Trent, and riparian owners have carried out some maintenance, both of the major landowners affected believe the situation to be no better than before. The Drain still floods at least once a year with floodwater remaining on the adjacent land for a few days. Only a narrow strip of land is affected, yet flooding controls the management of the whole field.

There has been no change of land use since the scheme, apart from arable rotations, although there appears to have been an i[...]sification of arable since the 1962 Land Use Survey (Ref. 3). Much of t[...]nd in grass, particularly in the upper half of the reach, is in small bl[...]away from the main farm unit. Some of the land at the extreme wester[...]of the washland is still liable to flooding from the Trent upstream [...] Foxall Bridge.

As the soil is largely underlain by gravels the land is naturally free draining and field underdrainage is not required. The lowering of water levels in the main river has lowered the watertable in the soil, however some farmers have observed an over-draining in summer, reporting lower stocking rates on grassland than before the scheme. It should be noted that potatoes are particularly sensitive to moisture conditions and any shortage during the period of tuber development can reduce both yield and quality. This over-draining has been a matter of great concern for at least one farmer. None of the farmers of this area have reported any increase in yields as a result of the scheme, but some riparian grassland has been ploughed and reseeded.

(iii) The Curborough Brook: The outfall of the Curborough Brook was modified to take advantage of the lower water levels in the River Trent as part of the main river scheme. Subsequently, the Brook was improved by the County Council (Ref. 4) in 1978. The scheme gave a great deal of benefit to one major occupier north of the Trent and Mersey Canal. The lower water level in the Brook meant that the adjacent land could drain naturally without underdrainage and in response, rather than convert to arable, the whole farm has been turned to intensive dairy production, with high fertilizer application rates and regular reseeding of pasture.

(iv) The Bourne Brook (including the Ashby Sitch and Crawley Brook): Several landowners got together to carry out extensive maintenance on the Bourne Brook in 1981. The work reduced the risk of flooding but was not entirely successful as a culvert, one 3 yards from the main river enhances water levels upstream. At normal flow the main Trent is at least half a metre below the invert level of the culvert. Land adjacent to the Bourne is intensively farmed, mostly in arable rotation and the flooding land produces noticably lower yields than elsewhere. The Bourne requires an extensive improvement scheme right down to the main river. Several of the riparian owners recognise this need, however the lack of cooperation from others has prevented the work from going ahead. This situation, which has caused a great deal of antagonism between farmers may have to be resolved by the Agricultural Land Tribunal.

(d) The Rate of Benefit Uptake:

A financial assessment of the Alrewas to Yoxall scheme has been undertaken by identifying, on the basis of farmer interview, the change in farm enterprise gross margins attributable to drainage improvements, net of any additional fixed costs, and including the benefit of extended grazing if relevant. The procedures used for this purpose are described in Annexe V.

A summary of benefits (before field drainage costs) by farm in the benefit area is given in Table 10. Only 2 out of the 13 farmer beneficiaries reported benefits attributable to the scheme. One farmer, accounting for 24% of the benefit area provided 83% of all perceived benefits. Average net benefits per hectare on the 352 hectares surveyed were £25 by the fourth year of the scheme's life and have been virtually constant at this level since that time.

The rate of uptake of financial net benefits attributable to the scheme is shown in Figure 3. Most of the uptake has comprised 'automatic' benefits due to extended grazing seasons, together with the intensification of pasture management. Actual uptake can be expressed as a percentage of scheme potential; the latter being a reasonably achieveable target for post-scheme land use and local farming practice. For the most part the scheme has not significantly increased the agricultural potential of the area. In these circumstances, a statement of the relative uptake of potential benefits is not helpful.

14. Financial Analysis

A summary of financial cash flow for the Alrewas to Yoxall Bridge scheme is given in Table 11 expressed in 1982 prices.

(a) Capital and Recurrent Costs:

The capital costs of the scheme, at £246,956, average £532 per hectare if set against the 464 hectares of direct benefit. Capital costs would be £214 per hectare if the benefit area extended to include an estimated extra 688 hectares of secondary benefit. However, benefits to the latter have not materialised due to lack of follow-up work on arterial drains. Recurrent costs for scheme maintenance have been assumed at 1½% of gross capital cost per year.

Table 10 : Distribution of Benefits by Farm

SCHEME 22 NET AGRICULTURAL BENEFIT

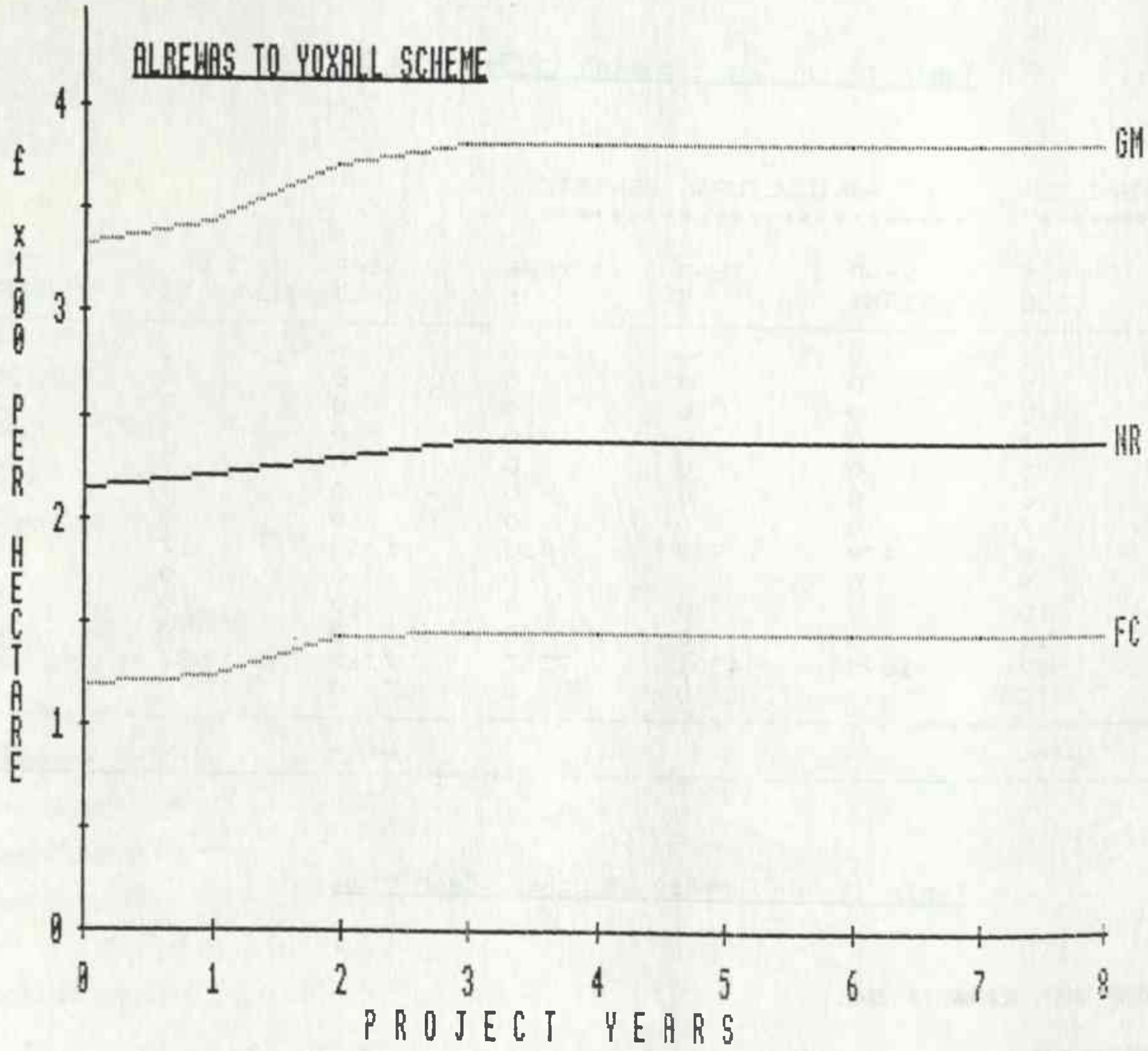
FARM CODE	YEAR FIRST	YEAR 3	YEAR 6	YEAR LAST	% OF BENEFITS	% OF AREA
1	0	0	0	0	0	1
2	0	0	0	0	0	0
3	0	0	0	0	0	3
4	0	0	0	0	0	3
5	0	0	0	0	0	6
6	0	0	0	0	0	15
7	0	0	0	0	0	7
8	479	959	1438	1438	17	6
9	0	0	0	0	0	7
10	0	0	0	0	0	5
11	0	0	0	0	0	7
12	1895	4301	7262	7262	83	34
13	0	0	0	0	0	5
TOTAL				8701	100	363

Table 11 : Summary of Scheme Cash Flow

RIVER TRENT ALREWAS TO YOXALL

PROJECT YEAR	0	1	2	3	4	5	6	7	8 TO 30
CALENDAR YEAR	1976	1977	1978	1979	1980	1981	1982	1983	1984 TO 2006
AGRICULTURAL BENEFITS									
Net Agric Benefits	0	2375	5260	8701	8701	8701	8701	8701	8701
Flood Damage Reduction	0	1152	1152	1152	1152	1152	1152	1152	1152
less Without Proj Ben	0	284	570	860	1152	1447	1746	2047	2351
less Field Drain Cost	0	0	0	0	0	0	0	0	0
NET AGRIC CASH FLOW	0	3243	5842	8993	8701	8406	8107	7806	7502
SCHEME COSTS									
Capital	246956	0	0	0	0	0	0	0	0
Recurrent	0	2470	2470	2470	2470	2470	2470	2470	2470
TOTAL COSTS	246956	2470	2470	2470	2470	2470	2470	2470	2470
SCHEME NET CASH FLOW	-246956	773	3372	6523	6231	5936	5637	5336	5032
NET PRESENT VALUE AT %	0	2.5	5	7.5	10	12.5	15	17.5	20
	-128732	-158457	-174794	-183641	-188141	-190031	-190307	-189560	-188152

FIGURE 3 : Degree and Rate of Financial Uptake



(b) Field Drainage Costs:

There have been no field drainage investments by farmers since the scheme. There is evidence that some farmers have improved the standard of maintenance on riparian ditches but no cost estimates are available.

(c) Flood Damage Reduction:

Six farmers reported pre-scheme flood damage costs for collecting litter and debris, and repairing fencing which took about 2 days work each time to undertaken, together with estimated fencing materials, at £600 total. One farmer reported a loss of 8 ha of vegetables due to flooding on the Bourne Brook, but argued that the flood risk had not been reduced. Another lost 2 ha of potatoes on the Curborough Brook which does not now flood, but the farmer did not relate this benefit to improvement on the Trent. Total flood damage reduction is assumed to be £1,152 per year.

(d) Without-Project Benefits:

A basic assumption is made that agricultural net revenues would increase at the rate of 1% compound from their pre-scheme base level in the absence of any improvement project (see Annexe V). Without-project benefits are charged for those areas where there has been some observed benefit uptake; 37.5% of the total area in this case. Without-project benefits are therefore taken as 1% compound per year of the pre-scheme net return (£75,670) multiplied by 37.5%, ie. £28,376 × 1% compound. Some farmers argued that yield losses had sometimes resulted from over-drainage, but as these remain unsubstantiated they have not been included in the analysis.

(e) Project Worthwhileness:

Assuming benefits continue at their 1984 levels over a 30 year life, the scheme shows a net present value of -£174,794 in 1982 prices at the 5% discount rate, and a negative internal rate of return. Benefits would need to increase by a factor of about 3.5 times their present level over the remaining years of project life for the scheme to break even at the 5% discount rate.

Using the derived uptake curve to predict benefits over remaining project life, expected uptake would peak in year 13 at 1.72 times its observed year 7 level, resulting in a net present value of -£124,000, and an internal rate of return of 0.1%.

(f) Sensitivity Analysis:

Table 12 examines the sensitivity of the scheme to selected benefit and cost assumptions. At present levels of benefits, the scheme is likely to recover some 25% of capital costs at the 5% discount rate.

15. Non-Agricultural Aspects

The River Trent is popular with fishermen and fishing rights are reserved for private angling clubs along most of the reach. The scheme was designed with due regard to the requirements of anglers and attempts were made to minimise disturbance, whilst longitudinal bed profiles were such that riffles and pools could be retained. Throughout the execution of the works close liaison with fishing clubs was maintained. Cooperation between farmers, anglers and the water authority allowed access to be improved and excavated spoil to be used for car park construction.

Water levels in the Swarbourn were maintained to preserve the excellent trout fishery. The Nature Conservancy Council confirmed that the scheme would not affect the wildlife interest of the river.

16. Discussion

Alrewas Mill ceased to use water power in 1930 and in 1933 the Trent River Catchment Board purchased the weir, sluices and water rights. The sluice gates were subsequently removed. However the structure remained for over 40 years as an unnecessary debris trap, enhancing local water levels and thus preventing the improvement of tributary watercourses.

It is not clear from which directions, if any, pressure was exerted on the Water Authority to remove the weir and sluice at Alrewas Mill, but it is apparent from the benefit assessment that the primary motive was not the alleviation of flooding from the Trent itself, but providing a suitable outfall for the subsequent improvement of non-main water courses. Indeed, the anticipated benefits of the improvement of the Curborough Brook were nearly 5 times that resulting from main river works plus work on the Orgreave Drain.

TABLE 12

River Trent : Alrewas to Yoxall - Sensitivity Analysis

Run No.	Agricultural Benefits Factor	Without Project Benefits Compounding Factor	Flood Damage Reduction Factor	Capital Works Cost Factor	NPV at 5% £	IRR %	Switching Value
1	1.0	1	1	1	-174794	-ve	2.5
2	1.0	0	1	1	-135816	-ve	2.2
3	1.0	1	0	1	-191660	-ve	2.7
4	1.0	1	1	0.25	0	5.0	0

* The factors show the weights applied to the original estimates eg a factor of 1.5 for the without-project benefits indicates that the new value is 1.5 x 1% compound per year (the original value) ie 1.5% compound.

* Switching value : change in agricultural net benefits needed to make the project breakeven at 5% discount rate eg a 1.5 switch value shows an increase of 1.5 x the original estimated is required.

In this case the main factor controlling the rate of the realization of potential benefits has not been the installation of field underdrainage by the farmers but the rate at which ancillary arterial drainage works have been carried out. Largely because there appears to have been no improvement in the condition of the Orgreave Drain the anticipated increase in the area of arable farming from 17% to 26% of the washland area has not as yet taken place. The rapid uptake of arterial improvements on the Curborough Brook have, on the other hand, had significant benefits although land use change has not necessarily been in the direction predicted.

It is clear that there is still a need for arterial drainage improvement, however, responsibility for such work lies largely in the hands of riparian owners. Experience on the Bourne Brook has shown the difficulty of organizing a number of farmers to carry out ditch clearance and maintenance, especially where the degree of benefit is not proportional to the investment required.

It is interesting to note the allegations of farmers of the washland who have witnessed an over-draining of their land. Whether the yield reductions reported are directly related to drainage is difficult to establish. However, on fragmented summer pastures such as Yoxall Meadows ditches are important for cattle drinking points. The drying up of these in summer can be a serious problem when individual fields are remote from the farm and piped water supply is impractical.

References

1. MAFF (1972) Agricultural Land Classification Map (provisional). Sheet 120, 1:63,360

2. STWA (Upper Trent Division (1976) River Trent, Alrewas to Yoxall Bridge Improvement Scheme. Engineering Report

3. Second Land Utilization Survey - 1962. King's College, London (unpublished).

4. STWA (1980) Land Drainage Survey, Section 24(5) Water Act 1973. Upper Trent Division & Staffordshire: pp. 102 and 107.

APPENDIX E

Upper Trent Division

River Blithe : Blythe Bridge to Cresswell

SILSOE COLLEGE

STWA UPPER TRENT DIVISION - RIVER BLITHE SCHEME, CRESSWELL TO BLYTHE BRIDGE (1972)

Report on the background to and development of the scheme and the nature and rate of uptake of agricultural benefits.

1. Physical Background

The River Blithe rises in the high ridge area of Werrington to the east of Stoke on Trent. It falls rapidly before flowing into a flat valley in the Caverswall district. From Blythe Bridge downstream the river valley is defined by the railway embankment on the eastern side and natural contours on the western side.

The catchment area to Blythe Bridge is some 1620 ha, the watercourse being about 6.5 km long to this point. At the inception of the scheme urban runoff was known to be likely to increase due to the construction of the A.50 bypass, which now crosses the R. Blithe 1.5 km south east of Blythe Bridge, with subsequent housing developments, and also the development of Meir Airport for housing. There was, therefore, a requirement from Local Authorities for an improvement of the watercourse as well as an opportunity to improve the agricultural potential of the riverside lands.

The stretch of river from Blythe Bridge to Cresswell suffers from the deposition of sandy material from upstream which forms shoals and disturbs the river's regime. Downstream of Cresswell the channel was in better condition.

2. Soils and Land Capability

There has been no detailed soil survey of the area. The land in the immediate floodplain was classified by MAFF as Grade 4 and the adjoining land as Grade 3 (Figure 1) (1). Near the river a clayey layer overlies a shallow band of peat, which surfaces some 100 m or more from the river, and extends outside the flood limit of modern times. The peat lies on a gravelly layer which gives it a free-draining characteristic provided that the peat layer has sufficient outfall at the river. The clayey upper layer however, not only impedes infiltration but also slows down lateral movement of water through the soil towards the river. Uphill of the strip where the peat surfaces there is a free draining alluvial soil; this upper area is outside the real benefit area of the scheme (see 7).

3. Land Drainage History

The length of river under consideration was 'mained' in 1968 and prior to that date very little maintenance work had been carried out by the riparian owners. Subsequently a pioneer scheme was carried out between Hamstall Ridware and Blythe Bridge (LDW 25086) between 1969 and 1971 at a cost of £15,000. This involved the removal of fallen trees and trees obstructing flow and general trimming of the batters.

On the eastern side of the river the railway line limits the extent of flooding. The railway line itself was the cause of flooding on about 6 ha of land to the east (see Figure 2), until the construction of a culvert by British Rail in 1968, in collaboration with the owners. This culvert, however, led extra water into the railway ditch on the west side, which discharged into the Old Mill Race. This aggravated flooding in adjacent fields until some years later the owner of these fields piped the railway ditch under the Old Mill Race and directly into the river.

4. Pre-Scheme Land Drainage Status

Before the scheme the riverside lands used to flood several times every year. Even moderate rainfalls could cause flooding with the river level rising very rapidly, and heavy rainfall caused considerable problems at Blythe Bridge and Stallington. The water level at Blythe Bridge railway level crossing came to within 0.6 m of the soffit following one heavy autumn storm and on Stallington Road it rose to within 2 cm of the bridge deck.

The extent of flooding in the benefit area was variable. Where it was governed only by relief it extended only 100-150 m from the river due to the relatively steep slope up from the river, but the diversion of water out of the valley bottom had aggravated the flood problem. In particular the flow of water through the Old Mill Race at Cresswell led to more or less continuous spillage and seepage over the land between it and the river. This area therefore stayed waterlogged through winter and spring and even into summer. Further upstream on the western bank similar but slightly less serious flooding occurred through river levels backing water up brooks which

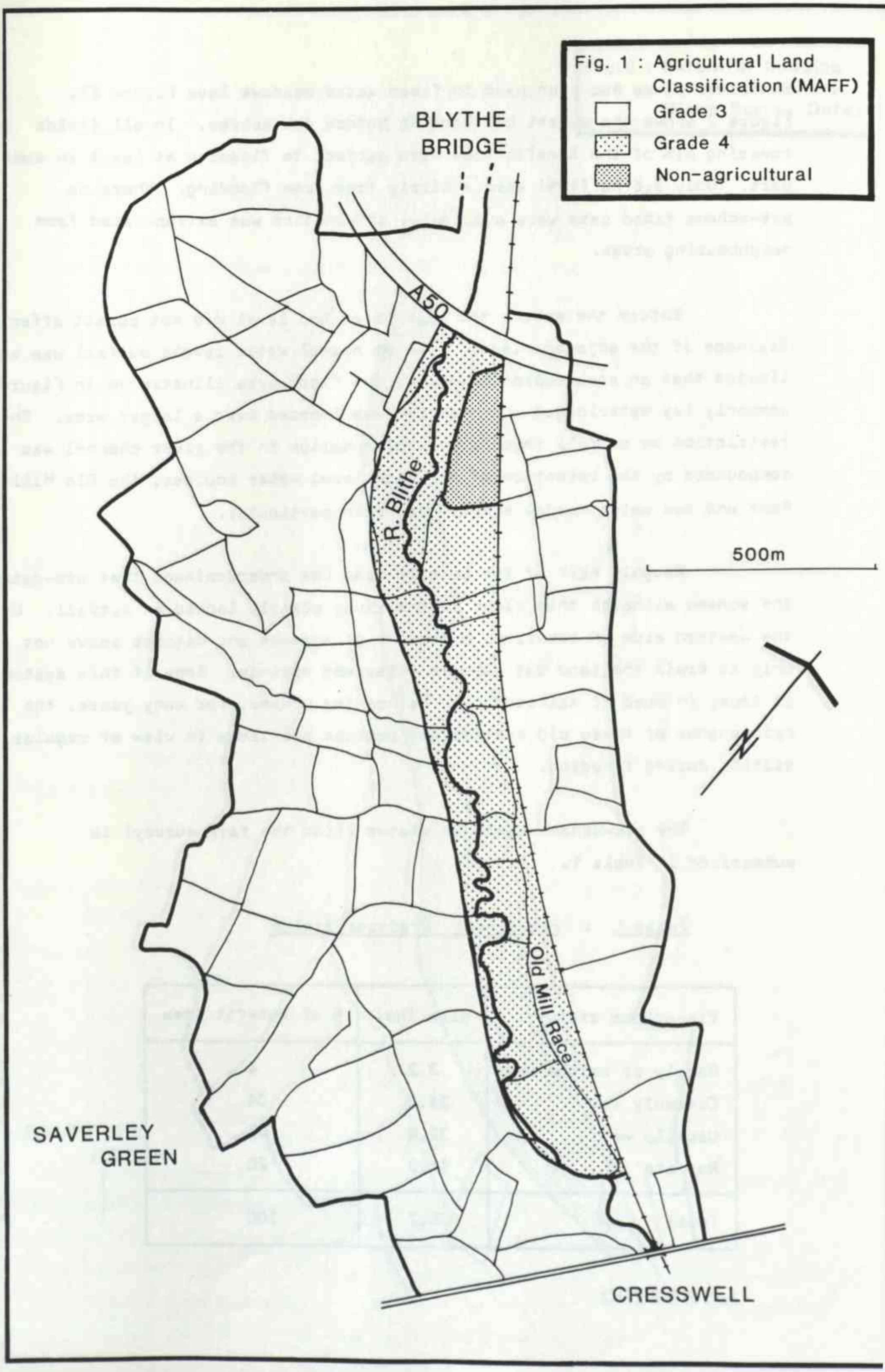


Fig. 1 : Agricultural Land Classification (MAFF)

in former times had been used to flood water meadows (see Figure 2). Figure 2 shows the extent of flooding before the scheme. In all fields covering 87% of the Benefit Area were subject to flooding at least in some part. Only 9.6 ha (13%) were entirely free from flooding. Where no pre-scheme flood data were available, information was extrapolated from neighbouring areas.

Before the scheme the high river bed level did not permit effective drainage of the adjacent land. Even at normal water levels outfall was so limited that an area approximating to the flood area illustrated in Figure 2 commonly lay waterlogged and drainage was impeded over a larger area. The restriction on outfall imposed by sedimentation in the river channel was compounded by the retention of the high level water courses, the Old Mill Race and two water meadow supply brooks in particular.

Roughly half of the benefit area has underdrainage that pre-dates the scheme although that close to the river plainly lacked an outfall. On the western side of the river a complex of streams and ditches serve not only to drain the land but also to intercept springs. Some of this system is today in need of maintenance. Before the scheme, for many years, the maintenance of these old systems was perhaps pointless in view of regular silting during flooding.

The pre-scheme drainage status (from the farm survey) is summarized in Table 1.

Table 1 : Pre-scheme Drainage Status

Pre-scheme status	Area (ha)	% of Benefit Area
Rarely or seldom wet	3.2	4
Commonly wet	26.2	34
Usually wet	32.4	42
No data	14.9	20
Total	76.7	100

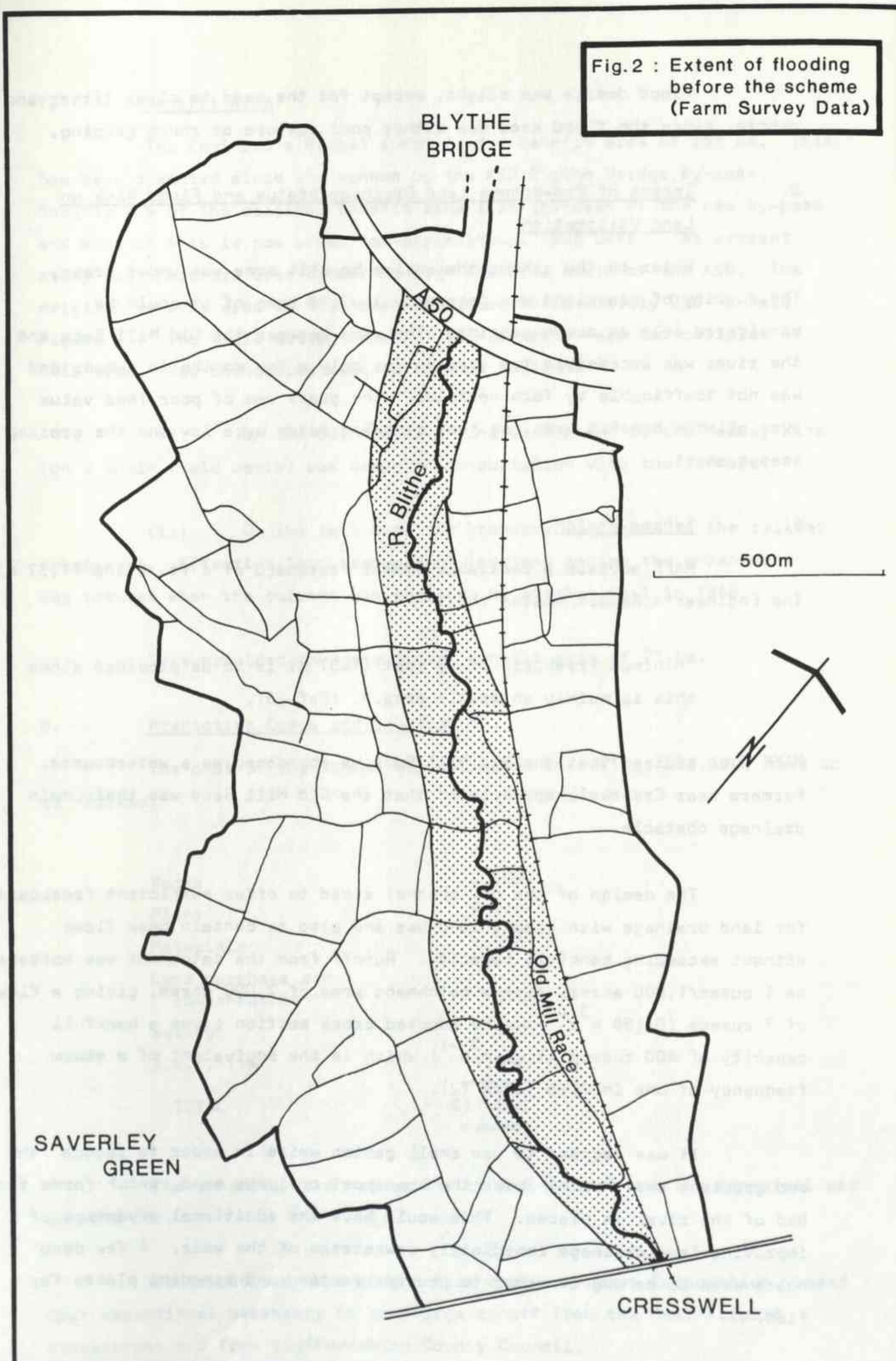


Fig.2 : Extent of flooding before the scheme (Farm Survey Data)

Flood damage was slight, except for the need to clear litter and debris, since the flood area was either poor pasture or rough grazing.

5. Impact of Pre-scheme Land Drainage Status and Flood Risk on Land Utilization

Prior to the scheme the entire benefit area was under grass. The quality of grassland was generally low and some of it could be considered only as rough grazing. The area between the Old Mill Race and the river was accessible for grazing for only a few months in summer and was not trafficable by farm vehicles. The grass was of poor feed value over all the benefit area, so that stocking rates were low and the grazing season short.

6. Scheme Design

MAFF advised a desirable summer freeboard of 4 ft. 6 ins (1.37 m). The Engineer's Report states that:

> "Minimum freeboard of 4½ feet (1.37 m) is to be provided since this is mainly an arable area." (Ref. 3).

MAFF also advised that the Old Mill Race be abandoned as a watercourse. Farmers near Cresswell appreciated that the Old Mill Race was their main drainage obstacle.

The design of the new channel aimed to offer sufficient freeboard for land drainage with arable land use and also to contain peak flows without exceeding bankfull capacity. Runoff from the catchment was assessed as 1 cusec/1,000 acres, from a catchment area of 7,000 acres, giving a flow of 7 cusecs (0.198 m^3s^{-1}). The adopted cross section gives a bankfull capacity of 400 cusecs (11.2 m^3s^{-1}) which is the equivalent of a storm frequency of one in five years (2).

It was decided to use small gabion weirs in order to reduce the bed gradient and thus minimise the transport of loose sand, which forms the bed of the river in places. This would have the additional advantage of improving land drainage immediately downstream of the weir. A few deep holes were to be dug in order to provide resting and breeding places for fish.

7. Benefit Area

The Engineer's Report identified a benefit area of 259 ha. This has been disected since the scheme by the A50 Blythe Bridge by-pass. Roughly 20% of the original benefit area lies upstream of the new by-pass and most of this is now under non-agricultural land uses. The present study has therefore been concerned with the area south of the A50. The original benefit area in this reach measured approximately 200 ha (see Figure 3). The field survey (see 10) identified a need for revision of this area. New boundaries were defined as follows:

(i) On the right bank a line equivalent to the Medway Line (on a whole field basis) was drawn in consultation with the farmers.

(ii) On the left bank the boundary was taken as the railway embankment. Effective land drainage of the land behind the embankment was ensured when the culvert was replaced by British Rail in 1968.

This provided an agricultural benefit area of 77 ha.

8. Predicting Costs and Benefits

The cost of the scheme was estimated in 1971 as £17,200, made up as follows:

	£
Wages	8,402
Plant	5,140
Materials	1,920
Land purchase and compensation	510
Survey	190
S.E.T. 11%	1,038
TOTAL	£17,200

The benefits were not estimated and no cost/benefit appraisal was carried out.

Contributions were sought from Stoke-on-Trent Corporation, based upon expenditure necessary to discharge runoff from the Meir Airport development and from Staffordshire County Council.

9. The Scheme

The scheme was carried out as designed, and was completed in 1972. The A50 by-pass at Blythe Bridge was due for construction at the same time as the Cresswell to Blythe Bridge regrading scheme was proposed, and it was originally intended that Staffordshire County Council would carry out the river realignment for the by-pass along with the road construction. In the event, the by-pass was delayed and STWA carried out the works on this section themselves. There were some delays due to wet weather and restricted access, and to the late delivery of stone. High flows during the execution of the scheme discovered a need for greater bank protection. Variation orders were therefore written for channel re-excavation, stone pitching, the formation of a flood relief channel and construction of additional low stone weirs; the cost of these totalled £5,780, for which a grant was obtained.

Actual costs were as follows:

	£
Expenditure to 25.7.72	15,706
Estimate of over-expenditure from four Variation Orders (grant paid)	5,780
TOTAL	£21,486

The following contributions were obtained:

	£
Contribution from Stoke-on-Trent Corporation	1,540
Contribution from Staffordshire County Council	450
Additional contribution from Staffordshire County Council in respect of channel realignment for A.50 bypass	1,516
MAFF grant at 37%	7,950
TOTAL	£11,456

Cost to the Authority = £10,030

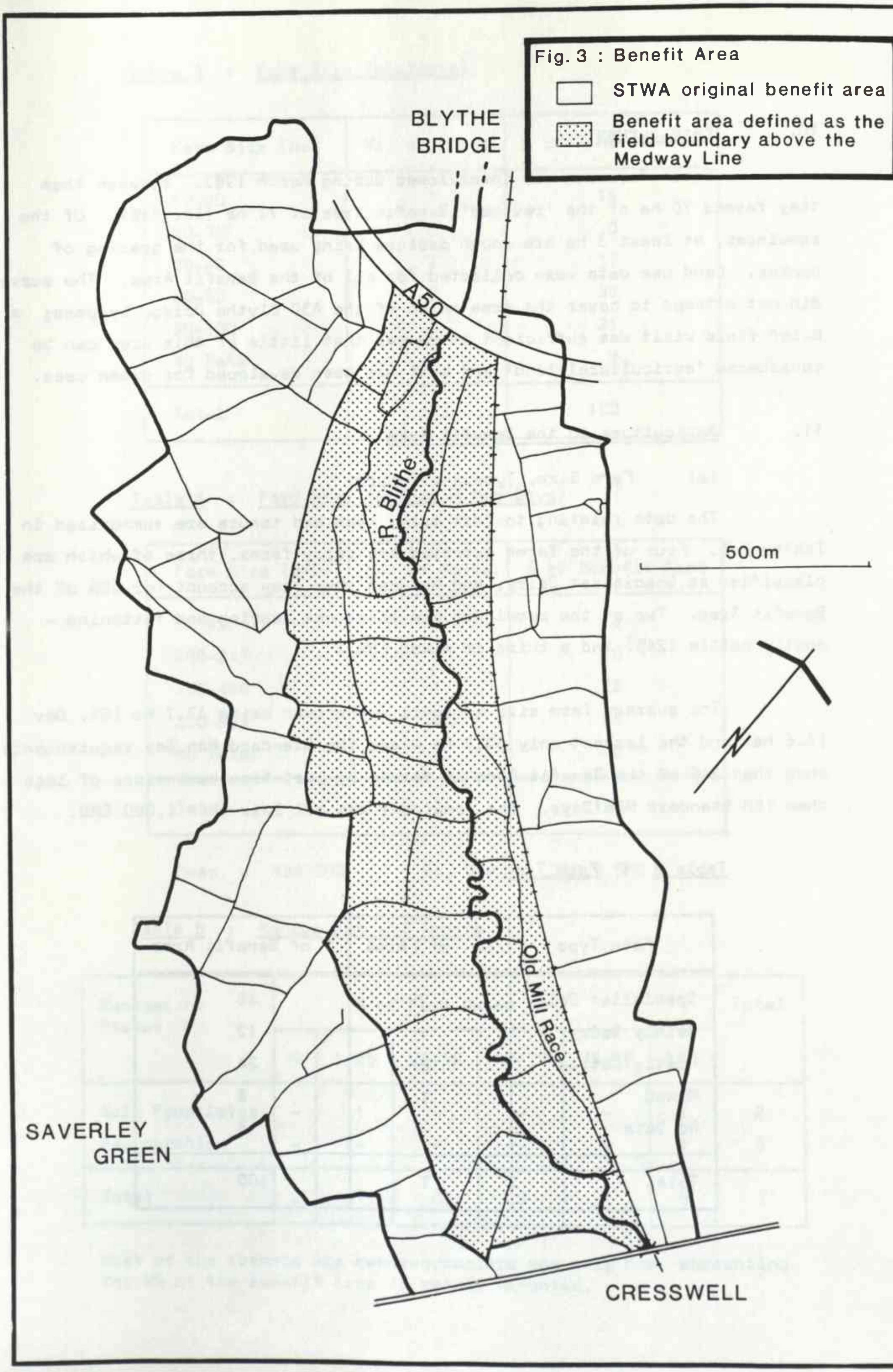


Fig. 3 : Benefit Area
STWA original benefit area
Benefit area defined as the field boundary above the Medway Line
BLYTHE BRIDGE
A50
R. Blithe
500m
Old Mill Race
SAVERLEY GREEN
CRESSWELL

10. Farm Survey

Seven farmers were interviewed during March 1983. Between them they farmed 70 ha of the 'revised' Benefit Area of 77 ha (ie. 91%). Of the remainder, at least 3 ha are rough pasture being used for the grazing of ponies. Land use data were collected for all of the Benefit Area. The survey did not attempt to cover the area north of the A50 Blythe Bridge by-pass; a brief field visit was sufficient to reveal that little of this area can be considered 'agricultural land' and most has been developed for urban uses.

11. Agriculture in the Benefit Area

(a) Farm Size, Type and Tenure:

The data relating to farm size, type and tenure are summarized in Tables 2-5. Four of the farms surveyed are dairy farms, three of which are classified as Specialist Dairy, and between them they account for 60% of the Benefit Area. Two of the remainder are livestock rearing and fattening - mostly cattle (24%) and a third is mixed (8%).

The average farm size is small - the mean being 43.7 ha (St. Dev 16.6 ha) and the largest only 63.9 ha - and the Standard Man Day requirements show that 24% of the Benefit Area is farmed by part-time businesses of less than 100 Standard Man Days. The remainder are all less than 1,000 SMD.

Table 2 : Farm Type

Farm Type	No. of Farms	% of Benefit Area
Specialist Dairy	3	48
Mainly Dairy	1	12
Mostly Cattle	2	24
Mixed	1	8
No Data	-	8
Total	7	100

Table 3 : Farm Size (hectares)

Farm Size (ha)	No. of Farms	% of Benefit Area
10-20	1	16
20-30	0	0
30-40	2	17
40-50	2	38
50-100	2	21
No Data	-	8
Total	7	100

Table 4 : Farm Size (Standard Man Days)

Farm Size (SMD)	No. of Farms	% of Benefit Area
99	2	24
100-249	0	0
250-499	1	22
500-999	4	46
No Data	-	8
Total	7	100

Mean = 488 SMD St. Dev = 328.9 SMD

Table 5 : Management and Tenure

Management Status	% of Farm Owned						Total
	0	1-25	25-50	50-75	75-99	100	
Sole Proprietor	-	1	-	-	-	1	2
Partnership	-	-	-	-	1	4	5
Total	0	1	0	0	1	5	7

Most of the farmers are owner-occupiers and only one, accounting for 8% of the Benefit Area is mainly tenanted.

(b) Dairy Enterprises:

Dairying is the main activity within the Benefit Area and four of the farms are classified as Specialist or Mainly Dairy. These account for 60% of the Benefit Area and most area to the west of the river. All the dairy farms are on higher ground with land going down to the river used for grass conservation and/or grazing for followers or sheep. In each case 65-85% of the farms lie outside the Benefit Area.

Herd sizes range from 43-96 cows plus replacements and up to 10 cattle reared for beef. The average farm stocking rate is 1.91 Livestock Units per hectare of grass.[1] Milk yield averages 5312 l/cow/year.

(c) Beef Enterprises:

Three farms, accounting for 32% of the Benefit Area have significant beef enterprises. Two are classified as Livestock Rearing and Fattening: Mostly Cattle and a third as Mixed. Most of the land involved is between the river and the railway line and accounts for 10-20% of the farms' area. All are store finishing enterprises with up to 100 head of cattle. Farm stocking rates average 0.97 Livestock Units per hectare of grass[1] and all of the land within the Benefit Area is grazed.

Three of the Dairy farms have small beef enterprises, raising up to 10 dairy born calves for beef, although not necessarily finishing them.

(d) Arable Enterprises:

There are no arable enterprises within the Benefit Area.

(e) Other Enterprises:

Occupiers accounting for 8% of the Benefit Area were not interviewed. However, field observation revealed that most of this was being used for grazing horses and therefore not in agricultural use.

12. <u>The Effect of the Scheme on Flooding and Land Drainage</u>

In the eleven years since the scheme, the river has not flooded and adequate freeboard has been provided for field drainage. At the time of the

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1. Weighted by area in benefit.

field survey (March), water level was at least 1.5 m below land level, except immediately downstream of the A50 road bridge.

13. The Agricultural Benefits of the Scheme

(a) Land Use Change:

The land use data are summarized in Table 6 below.

Table 6 : Land Use Change 1972-83 (hectares)

Pre-scheme \ Post-scheme	Permanent Grass	Temporary Grass	Pre-Scheme Total
Rough grazing	5.7	-	5.7
Permanent grass	58.9	12.1	71.0
Post-Scheme Total	64.6	12.1	76.7

Only two blocks of land have changed use since the scheme, 5.7 ha (7% of surveyed area) of rough grazing have been improved to permanent grass level with grazing increased from four months to a possible year round grazing; 12.1 ha (16% of surveyed area) have been ploughed and resown as temporary grass cut three times a year for silage. This took place two years after the scheme and was associated with underdrainage (see below).

(b) Field Drainage Installation:

Table 7 : Field Drainage Installation

Date of Drainage	Area (ha)	Land Use		
		Pre-scheme	Post-scheme	Date of change
1974	12.1	P. grass	T. grass	1974
1976	2.0	P. grass	P. grass	-

So far, 14.1 ha (18% of surveyed area) have been underdrained. Most of this took place two years after the scheme in 1974. Much of the area has old drainage systems from before the scheme, some installed by the 'War Ag' and the river improvements have allowed these to function effectively. 21.5 ha were identified as being in need of drainage. The main reason for not draining were either the limited availability of finance or that the arterial ditches are in need of maintenance or improvement to provide an adequate outfall. Many of the ditches are blocked at their outfall to the Blithe from years of silt deposition during floods. The present underdrainage status is shown in Table 8 below. Figure 4 shows the rate of drainage installation.

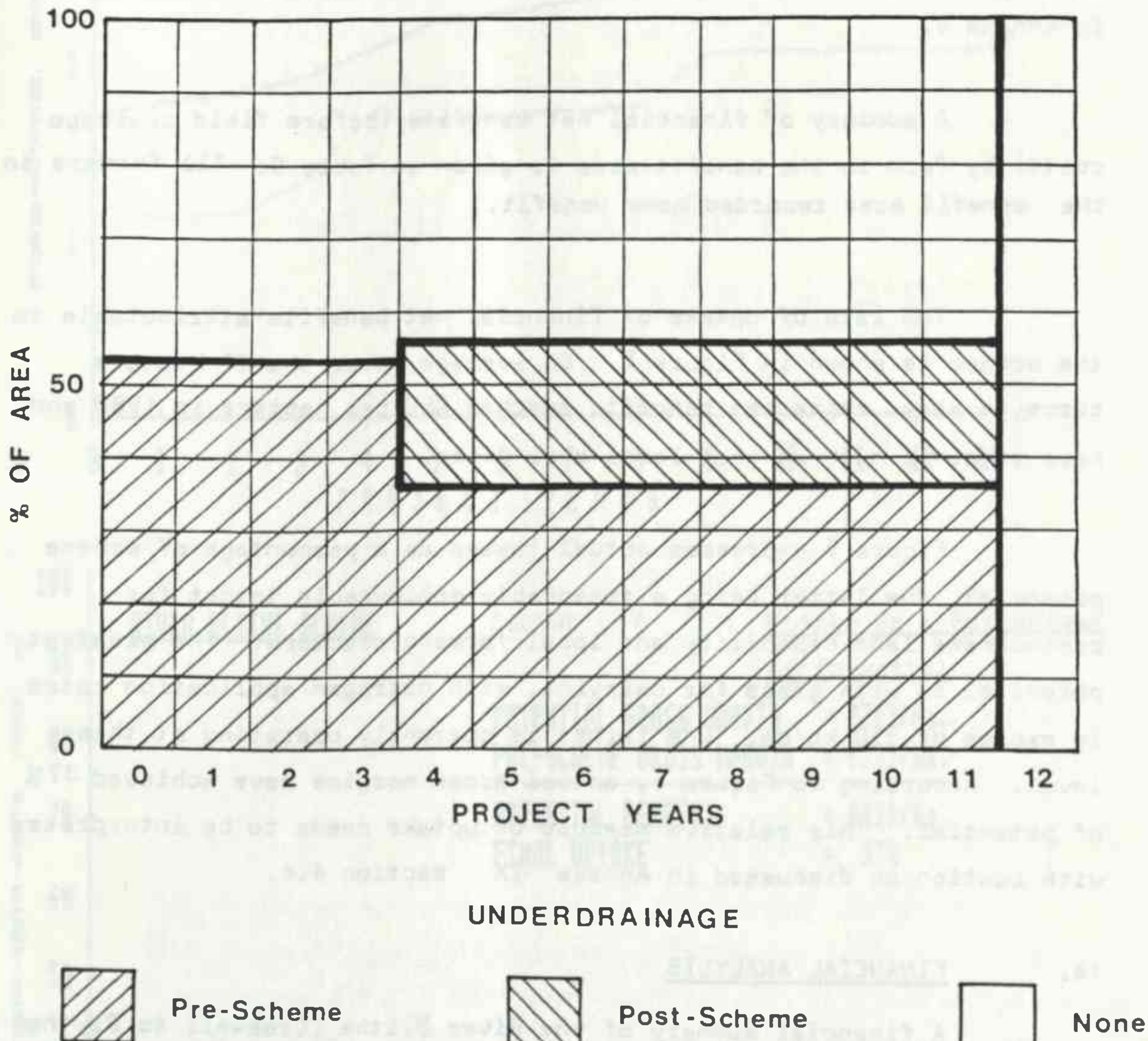
Table 8 : Underdrainage Status 1983

Status	Area (ha)	% of Surveyed Area
Old drains sufficient / Naturally free draining	18.2	24
Drained since the scheme	14.1	18
Does not need draining for present use (pasture)	16.9	22
Needs redraining but insufficient finance	12.6	16
Ditches need cleaning first	8.9	12
No data	6.0	8
Total	76.7	100

(c) Improved Production from Existing Land Use:

Most of the permanent pasture has improved since the scheme. In some cases this has been because farmers can now get on to fertilize earlier in spring and in others the sward has been resown - in one case after two years of barley. Two of the farmers however could see that there was still a great deal of improvement potential that they had not taken up; one saw improvements elsewhere on the farm as being more pressing and the other felt that he had reached a manageable size of herd and had no desire to increase it further.

Fig 4 : INSTALLATION OF UNDERDRAINAGE



(d) Rate of Benefit Uptake:

A financial assessment of the River Blithe scheme has been undertaken by identifying, on the basis of farmer interview, the change in farm enterprise gross margins attributable to drainage improvements, net of any additional fixed costs, and including the benefit of extended grazing if relevant. The procedures used for this purpose are described in Annexe V.

A summary of financial net benefits (before field drainage costs) by farm in the benefit area is given in Table 9. All farmers in the benefit area recorded some benefit.

The rate of uptake of financial net benefits attributable to the scheme is shown in Figure 5. On average, over the 71 hectare surveyed area, extra net benefits reached £90 per hectare in 1980 and have remained much at that level ever since.

Figure 6 expresses actual takeup as a percentage of scheme potential, the latter being a reasonably achieveable target for post-scheme land capability and local farming practice. The greatest potential is with grass for dairying, with nitrogen application rates in excess of 350 kg/ha. One farmer is currently operating at this level. According to Figure 6, actual gross margins have achieved 37% of potential. This relative measure of uptake needs to be interpreted with caution as discussed in Annexe IX section 4.4.

14. FINANCIAL ANALYSIS

A financial summary of the River Blithe (Creswell to Blythe Bridge) scheme is given in Table 10, expressed in 1982 prices.

(a) Net Agricultural Benefits:

The net agricultural benefits attributable to the scheme are the net returns given in Figure 5, applied to the benefit area as a whole. Benefits are assumed to continue at their 1984 levels for the remainder of scheme lift. No attempt is made to predict future uptake. The implications of a variation in uptake are considered in the sensitivity analysis.

FIGURE 6 : Degree and Rate of Financial Uptake

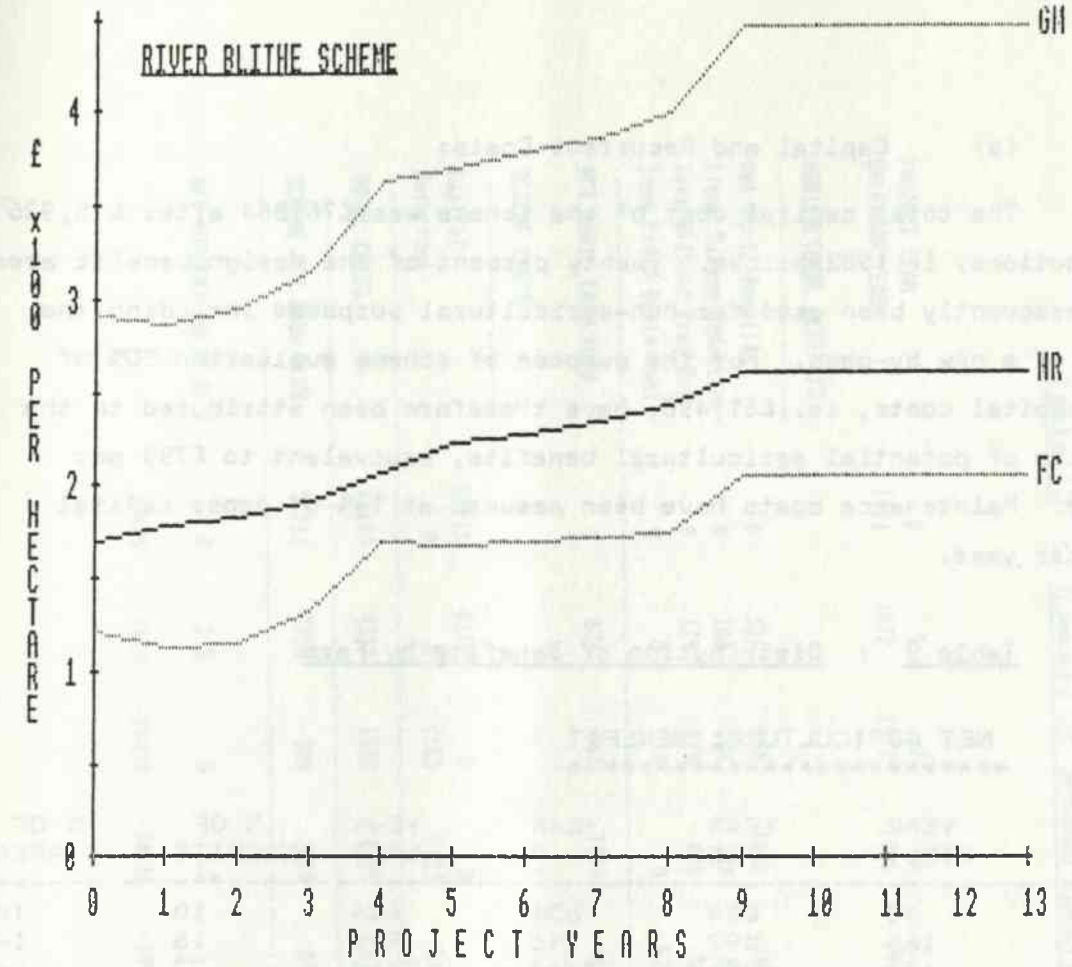
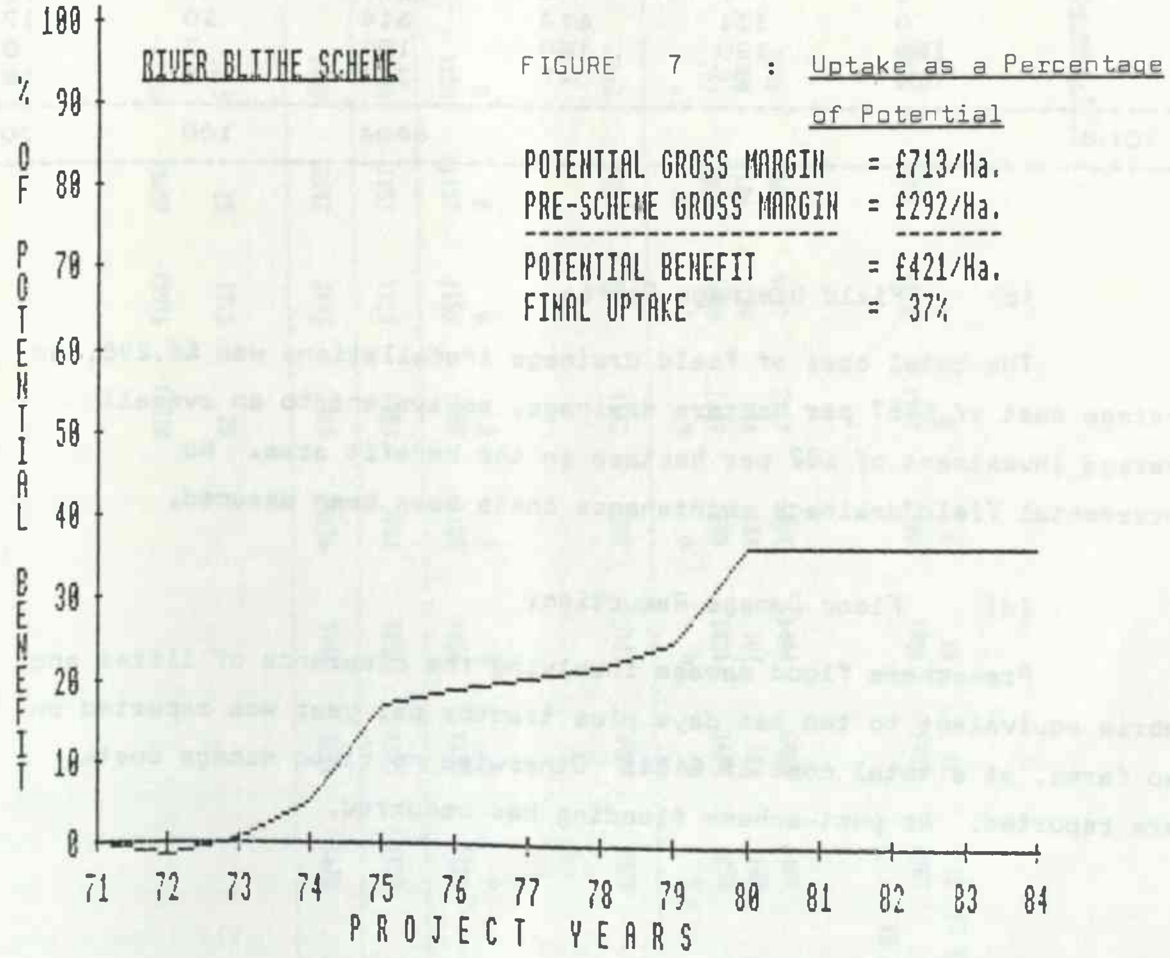


FIGURE 7 : Uptake as a Percentage of Potential



(b) Capital and Recurrent Costs:

The total capital cost of the scheme was £76,864 after £15,936 contributions, in 1982 prices. Twenty percent of the design benefit area has subsequently been used for non-agricultural purposes including the siting of a new by-pass. For the purpose of scheme evaluation 80% of total capital costs, ie. £61,490, have therefore been attributed to the provision of potential agricultural benefits, equivalent to £799 per hectare. Maintenance costs have been assumed at 1½% of gross capital costs per year.

Table 9 : Distribution of Benefits by Farm

SCHEME 23 NET AGRICULTURAL BENEFIT

FARM CODE	YEAR FIRST	YEAR 5	YEAR 9	YEAR LAST	% OF BENEFITS	% OF AREA
1	73	634	634	634	10	10
2	160	597	995	995	16	10
3	135	1091	2364	2364	37	24
4	0	0	0	1267	20	13
5	0	131	614	614	10	17
6	180	180	180	180	3	8
7	29	29	347	347	5	18
TOTAL				6404	100	70

(c) Field Drainage Costs:

The total cost of field drainage installations was £6,298, an average cost of £467 per hectare drainage, equivalent to an overall average investment of £82 per hectare in the benefit area. No incremental field drainage maintenance costs have been assumed.

(d) Flood Damage Reduction:

Pre-scheme flood damage involving the clearance of litter and debris equivalent to two man days plus tractor per year was reported on two farms, at a total cost of £184. Otherwise no flood damage costs were reported. No post-scheme flooding has occurred.

Table 10 : Summary of Scheme Cash Flow and NPV

PROJECT YEAR	0	1	2	3	4	5	6	7	8	9	10	11	12	13 TO 30
CALENDAR YEAR	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984 TO 2001
AGRICULTURAL BENEFITS														
Net Agric Benefits	0	581	959	1606	2665	3686	4064	4442	5137	6404	6404	6404	6404	6404
Flood Damage Reduction	0	184	184	184	184	184	184	184	184	184	184	184	184	184
less Without Proj Ben	0	139	279	420	563	707	853	1000	1149	1299	1451	1604	1759	1915
less Field Drain Cost	0	0	0	0	6298	0	0	0	0	0	0	0	0	0
NET AGRIC CASH FLOW	0	626	864	1370	-4012	3163	3395	3626	4172	5289	5137	4984	4829	4673
SCHEME COSTS														
Capital	57113	4377	0	0	0	0	0	0	0	0	0	0	0	0
Recurrent	0	0	1153	1153	1153	1153	1153	1153	1153	1153	1153	1153	1153	1153
TOTAL COSTS	57113	4377	1153	1153	1153	1153	1153	1153	1153	1153	1153	1153	1153	1153
SCHEME NET CASH FLOW	-57113	-3750	-289	217	-5165	2010	2242	2473	3019	4136	3984	3831	3676	3520
NET PRESENT VALUE AT %	0	2.5	5	7.5	10	12.5	15	17.5	20					
	22625	-7430	-24430	-34236	-39940	-43230	-45057	-45976	-46318					

(e) Without-Project Benefits:

It is assumed that without-project benefits would arise at the rate of 1% compound per year of the pre-scheme.agricultural net returns. Without-project returns are charged on those areas on which uptake has been observed. This applies to 100% of the (adjusted) 77 ha benefit area. Without-project benefits are therefore taken to be 1% compound per year of the pre-scheme net return (£13,869) multiplied by 100%, ie. 13869 x 1% compound.

(f) Project Worthwhileness:

Assuming benefits continue at their present level over a 30 year project life, the net present value of the scheme at the 5% discount rate is -£24,500, implying an internal rate of return of 1.75%. Net benefits would need to increase by a factor of 1.75 to allow the scheme to break even at 5% discount rate.

(g) Sensitivity Analysis:

Table 11 examines the sensitivity of the scheme to benefit and cost parameters. Agricultural net benefits would need to increase by more than twice over the remaining part of project life to break even at 5% discount rate. At present levels of performance about 60% of the capital cost of the scheme will be recovered.

15. Discussion

The scheme appears to have met, if not exceeded, the design criteria set out in the Engineer's Report, ie. that flood frequency should be reduced to 1 in 5 years and a minimum freeboard provided of 1.37 m. However, there have been some engineering problems. Most of the gabion weirs have now collapsed (in some cases assisted by local children) and the resultant increase in net gradient has led to severe bank erosion problems. Some farmers are regularly having to replace fences as land is lost on bends.

The uptake of potential benefits has been poor. Only one farmer has made any substantial improvements and significantly he was one of the main promoters of the scheme. The others have appreciated the largely automatic benefits of reduced flooding and improved field drainage (where soil conditions have been favourable) but have made no substantial investment to capitalize on the postential. Some farmers, particularly newcomers have suggested that they may underdrain and improve the grassland, but not in the immediate future.

TABLE 11

River Blithe : Sensitivity Analysis

Run No.	Agricultural Benefits Factor	Without Project Benefits Compounding Factor	Flood Damage Reduction Factor	Capital Works Cost Factor	NPV at 5% £	IRR %	Switching Value %*
1	1.0	1.0	1	1.0	-24450	1.75	1.75
2	1.0	1.0	1	1.25+	-39021	0.5	2.1
3	1.0	0	1	1.0	-5379	4.4	1.2
4	1.0	1.0	0	1.0	-27124	1.4	1.8
5	1.0	0.5	1	1.0	-14665	3.2	1.4
6	1.0	1.5	1	1.0	-34697	-ve	2.0
7	1.0	1.0	1	0.63	0	5.0	0

The factors show the weights applied to the original estimates, eg. a factor of 1.5 for the without-project benefits indicates that the new value is 1.5 x 1% compound per year (the original value), ie. 1.5% compound.

* Switching value : change in agricultural net benefits needed to make the project breakeven at 5% discount rate, eg. a 1.5 switch value shows an increase of 1.5 x the original estimated is required.

\+ Charging for total capital costs including costs relating to area deriving non-agricultural benefits, ie. new by-pass.

References

(1) Ministry of Agriculture, Fisheries and Food (1972)
Agricultural Land Classification (sheet 120)

(2) Trent River Authority (1969)
River Blithe Pioneering Scheme - Hamstall Ridware to Blythe Bridge. Scheme Files (unpublished).

(3) Trent River Authority (1969-72)
River Blithe Regrading Scheme. Blythe Bridge to Cresswell (LDW 26637). Scheme Files (unpublished)

APPENDIX F

Upper Severn Division

River Morda : Morton Bridge to Vyrnwy Confluence

SILSOE COLLEGE

STWA UPPER SEVERN DIVISION - RIVER MORDA SCHEME (1972)

Report on the background to, and development of, the scheme and the nature and rate of uptake of agricultural benefits.

1. Physical Background

The River Morda is a tributary of the River Vyrnwy. The braided confluence of the two rivers lies on the Shropshire/Powys boundary near Llanymynech, Shropshire. The River Morda drains a total area of 81.4 km^2 (31.8 $miles^2$), originating to the west of Oswestry where land levels range between 120 m and 500 m above O.D. At the confluence with the Vyrnwy, land levels average 67 m above O.D.

The improvement scheme relates to 9.8 km of the River Morda between Morton Bridge (GR 314232) and Vyrnwy confluence (GR 303200), and incorporates the outfall reach of the Morda where it meanders in a broad floodplain before bifurcating and joining the Vyrnwy (Figure 1).

A number of man-made structures have at various times influenced hydrological conditions in the lower Morda; notably the installation of mill weirs at Llwyntidmon and Pentre Heylin; the now disused West Shropshire railway line; and the network of argaes (flood embankments) on the River Vyrnwy floodplain.

The relevant reach of the River Morda flows through the Melverley Internal Drainage Board District, and a number of IDB watercourses drain into the Morda.

2. Soils and Land Classification

Detailed soils data are not available. On the basis of field investigation soils are generally light sandy loams, with clay sub areas with some peat and gravel layers to north.

The National Soils Map (Ref. 4) shows the floodplain of the Vyrnwy to be characterised by deep, stoneless and permeable silty soils of the Teme Association derived from river alluvium. Most of the Morda valley, away from the immediate floodplain is classified as the East Keswick Association. This is a typical brown earth developed in coarse loamy drift. It is a deep, but imperfectly drained soil with a sandy loam texture and a slowly permeable subsoil.

Most of the immediate floodplain is classified as Conway Association. This is a typical alluvial gley soil with a silty clay loam texture. It is generally liable to flooding and its natural drainage is poor.

The land in the Morda area is mainly classified Class III, with Class IV in Vyrnwy flood areas as shown in Figure 1. (Ref. 3)

3. Land Drainage History

The weir crest at Llwyntidmon Mill was lowered by 0.51 m by the Severn River Board in 1946, however high retention at the weir remained a major cause of poor drainage prior to the scheme.

4. Pre-Scheme Land Drainage Status

The relevant reach of the River Morda can be divided into 2 parts for the purpose of discussing pre- (and post-) drainage status:

(i) The northern reach between Morton Bridge (GR 314232 and Pont Fadoc (GR 293212) (immediately downstream of Llwyntidmon Mill):

According to the Engineer's Report (Ref. 1) numerous complaints were received by the Authority concerning 'bad drainage conditions' in the area upstream of Llwyntidmon Mill. Requests for improvement were received from individual farmers, the Melverley IDB and the NFU.

A District Engineer's Report (Scheme Files 1970) stated that whilst no records of flood frequency were available, observations suggested that flooding occurred one to 2 times per year due to waters from the Morda (and not influenced by the Vyrnwy). The area subject to flooding is delineated in Map 2. According to official local authority sources, parts of this area were 'virtually derelict bogs'.

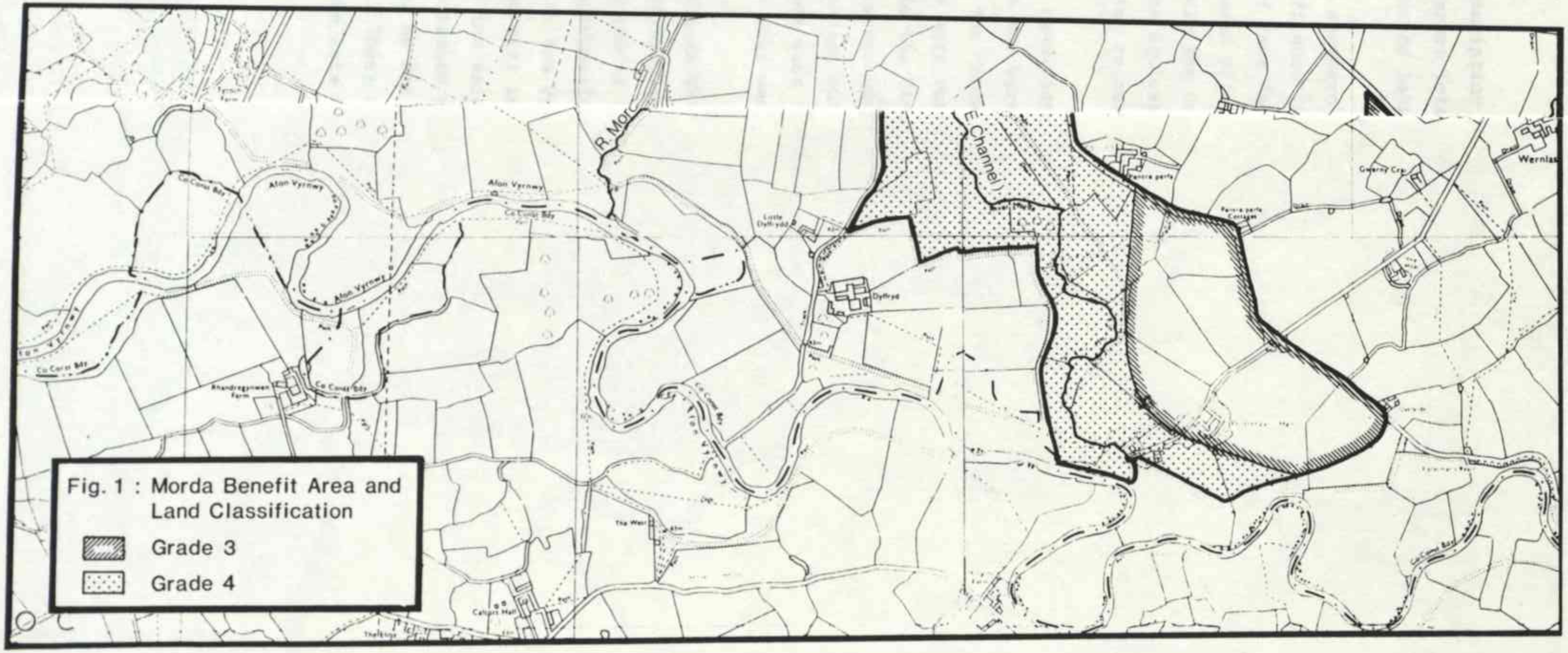
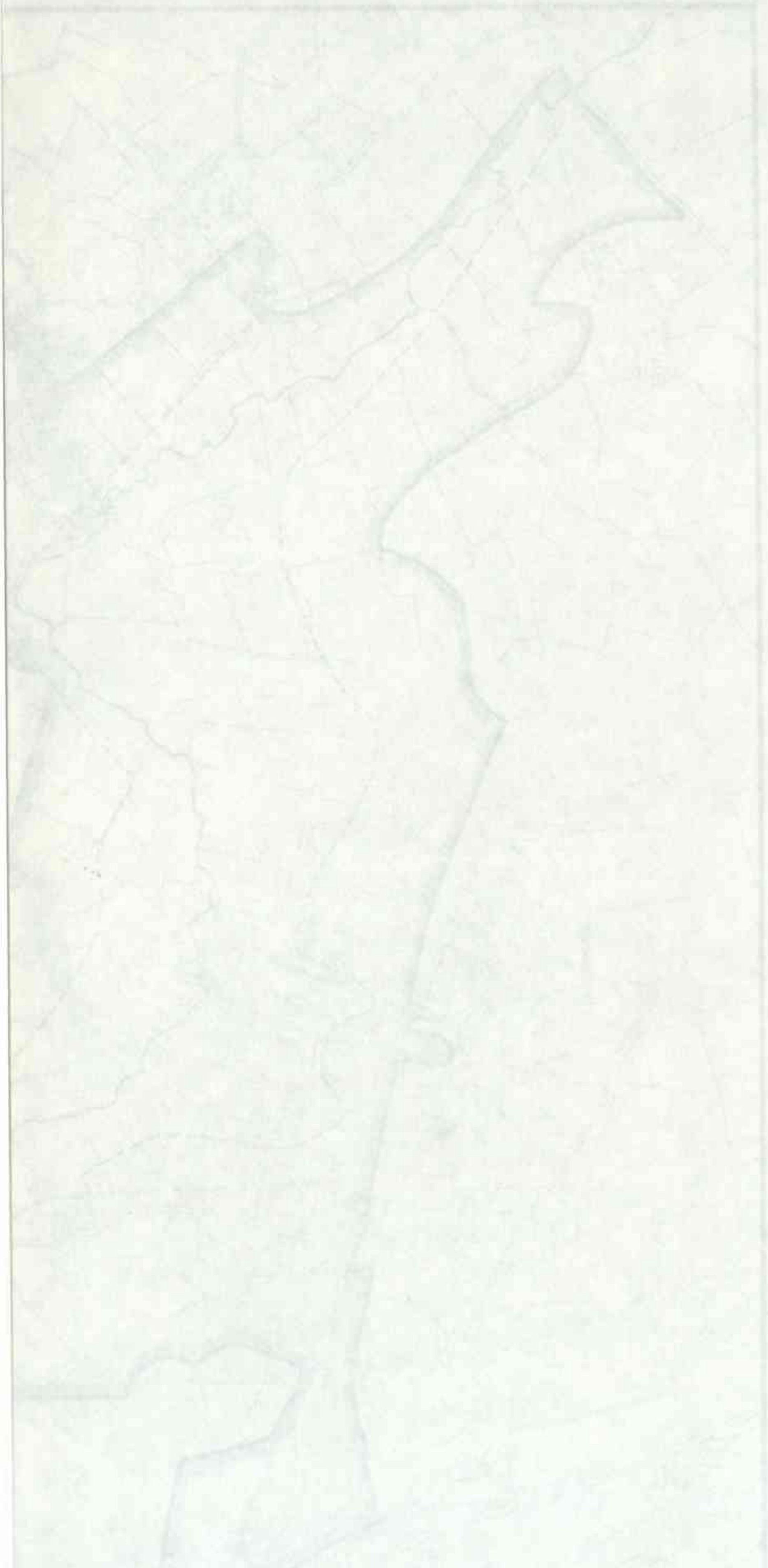


Fig. 1 : Morda Benefit Area and Land Classification



The above description of pre-scheme drainage status was confirmed during the course of farmer interview. Frequent flooding and limited outfall severely restricted land use and productivity.

(ii) The southern reach between Pont Fadoc and the Vyrnwy Confluence (GR 303200):

Downstream of Pont Fadoc the river bifurcates. Before the scheme, the Western Channel flowed directly into the River Vyrnwy, the Eastern Channel to the Vyrnwy via the unused Pentre Heylin Mill where it was impounded. Normally the sluices were kept open, although in summer they were sometimes closed for recreation and irrigation purposes.

Hydrological conditions in this section of the Morda are influenced by levels in the Vyrnwy. The District Engineer reported (Ref. 2) that he 'had not known the Morda to cause flooding with the Vyrnwy low' and that Morda waters alone were rarely responsible for flooding in this part of the reach. According to the District Engineer, overflow from the Vyrnwy (whereby water flows reverse upstream along the Western Channel, backing-up the Morda water, and running out via the Eastern Channel) caused flooding twice per year on average over the 1966-69 period, and 3 times per year on average if the wet 1965 year was included.

Drainage status in this downstream section is also influenced by the system of argaes constructed in the last century for flood control on the Vyrnwy. These embankments (1-1.5 m high) effectively restrict the floodplain of the Morda channels. The Engineer's Report (1970) pointed out that where high levels in the Vyrnwy caused overtopping in the Morda East Channel, water travelled over land and escaped through orifices in the railway embankment into the Weir Brook (Melverley IDB). During severe flooding, authority maintained embankments on the eastern bank of the Morda East Channel overtopped, as did private embankments on the eastern bank of the Morda West Channel. These embankments had been the subject of grant aided improvements in the late 1960's.

(iii) Results of the farm survey:

The farm survey (see 10 below) found that fields covering 47% of the Benefit Area (see 7 below) were free from flooding prior to the scheme. 5% would flood once per year or less often, for a matter of days. 48% would flood a number of times each year of which over a third would remain under water for weeks, or even months, at a time. The farmers' qualitative assessment of field drainage status is summarized in Table 1 below. Although 32% of the area had field drains that pre-date the scheme, much was old and ineffective. Nearly 50% of the Benefit Area was classified as 'Rarely' or 'Occasionally' wet; 33% as 'commonly' wet and 18% as 'Usually' wet (excluding the area for which no data were available).

Table 1 : Pre-Scheme Drainage Status

Drainage Status	% of Area
Rarely or seldom wet	14
Occasionally wet	31
Commonly wet	30
Usually wet	17
No data	8
Total	100

5. The Impact of Pre-Scheme Land Drainage Status on Land Utilization

Before the scheme, poor drainage conditions in the northern reach of the river restricted land use to unimproved permanent pasture with low levels of nitrogen. Spring flooding prevented early turnout of stock, and occasional summer floods resulted in loss of hay crops. Limited outfall prevented field drainage installation. Fields adjacent to the river were described by IDB officials as 'virtually derelict bogs'. The removal of drainage constraint has enabled land use change in the northern reach.

In the southern reach, flooding and seasonally high water tables restricted land use to permanent grass. Since the scheme, hydrological conditions have not greatly changed such that land utilization has altered little (see 12 below).

6. Scheme Design

The scheme proposed channel excavation and realignment works between the Vyrnwy and Morton Bridge, with improvements to both outfall channels. It was proposed to use spoil to raise existing banks to contain the designed discharge. Alternatively, spoil would be levelled on fields as appropriate. Some transport of spoil was deemed necessary.

With the permission of the owner, the weir at Llwyntidmon Mill was to be removed, and the channel diverted around the Mill premises. Outfalls into the new channel would also be installed. The West Channel was to be realigned near Llwyntidmon Lane. Salop County Council undertook to replace an existing 1.7 m road bridge with a new 7.3 m span, to reconstruct an access bridge near Paper Mill Cottage, and to underpin Pont Fadoc on the Llanymynech-Pant road. The Authority undertook to replace 3, and underpin one, accommodation bridges.

No measured flow data were available for design, and a run-off of 18.8 mm (¾") in 24 hours (0.22 cumecs/km^2) was taken to determine bank full flow. This estimate of 18.0 cumecs (635 cusecs) was used as a mean annual flood with a return period of 2.33 years (Ref. 1).

7. Benefit Area

The Engineer's Report (Ref. 1) identified an area of benefit of 498 ha (1230 m) as shown in Map 2. The District Engineer's Report suggested the following distribution of benefits from the proposed flood alleviation and drainage improvement.

	(a) Areas liable to flooding	(b) Areas of drainage benefit (including (a))
Above Pont Fadoc	142 ha	350 ha
Below Pont Fadoc	41 ha	148 ha
	183 ha	498 ha

Following the farm survey, the benefit area was adjusted slightly to (i) exclude an area of higher ground near Waen Wen that was not constrained by the condition of the Morda before the scheme, and (ii) to exclude an area each of (and protected by) the argaes along the Morda East Channel which drains to the Weir Brook (Melverley IDB).

8. **Anticipated Costs and Benefits**

(a) Cost:

The cost of the main river scheme was estimated at £42,500 (February 1970 prices) including bridge replacement works executed by Salop County Council (5,000), but excluding site survey, design and supervision costs (Ref. 1). Estimates for maintenance were not specified. The predicted duration of scheme implementation was 3 years.

(b) Benefits:

Whilst an agricultural benefit area of almost 500 ha was identified, no indication was given in pre-investment documentation of the predicted type and extent of benefits, and a cost-benefit analysis was not presented as a justification for the scheme.

9. **The Scheme**

Work on the scheme commenced in, and was completed in, 1973. The final cost of the scheme was £50,500 (Ref. 2).

In direct consequence of the river improvement, the Melverley IDB, re-excavated approximately 10 miles of secondary water courses, at a total cost of £3,800 in 1974. These water courses have subsequently been maintained at a cost of £600 per mile (1982 prices) per 3 year period. The capital cost of ancillary drainage works can be attributed to the scheme, but not the maintenance costs, as these would have been incurred by the IDB in the absence of the scheme.

10. **Farm Survey**

A survey of farmers operating within the Morda benefit area was conducted in July 1982 using the standardised questionnaire format. Discussions were held with 28 land users covering a total 500 hectares. Of these 22 farmers were judged to be potential beneficiaries of the Morda improvement and these farmed a total of 431 hectares, thereby accounting for almost all of the revised benefit area.

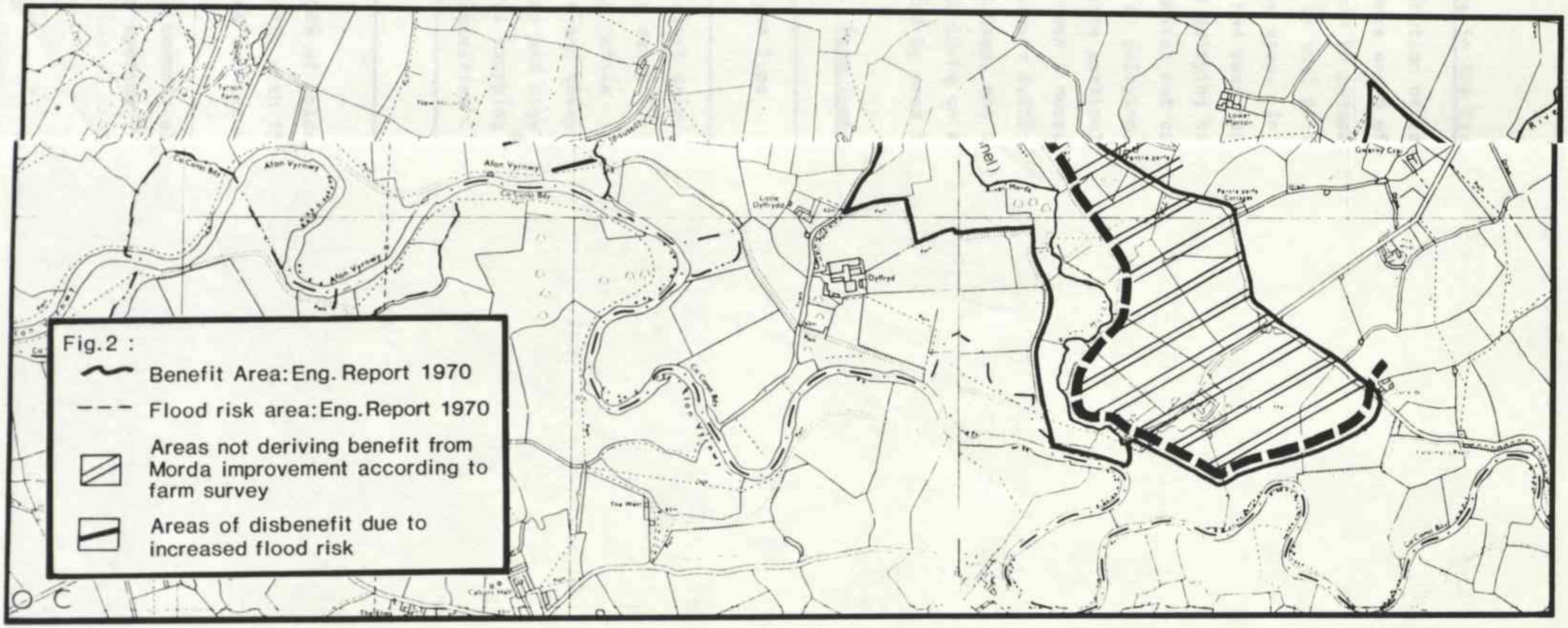


Fig.2 :
Benefit Area: Eng. Report 1970
Flood risk area: Eng. Report 1970
Areas not deriving benefit from Morda improvement according to farm survey
Areas of disbenefit due to increased flood risk
Dyffryd

11. Agriculture in the Benefit Area

The distribution of farming types within the Morda benefit area by % of holding numbers and % of farmed area is given in Table 2. In common with the region in general, the predominant type of farming system in the benefit area is that of dairying, accounting for 59% of all holdings and 67% of the farmed area. In 1970 before the Morda scheme, 75% of farms and 84% of the area had been concerned with dairy but during the mid-1970's 4 farms changed from dairying to livestock fattening for management reasons (mainly retiring farmers) not connected with the river improvement scheme. For those remaining in dairying, the trend has been one of increased herd size and stocking rates particularly amongst the smaller farms, for whom intensification has been a necessary condition for commercial viability. Average yields are around 4,950 litres/cow. Most farmers breed their own replacements, make silage, and carry some dairy beef. Stocking rates average 2.39 and 1.68 LU/ha on specialist and mainly dairy farms respectively (weighted by area in benefit).

Table 2 : Farm Type in Morda Benefit Area

Farm Type	No. of Farms	% of Area Surveyed
Specialist dairy	10	58
Mainly dairy	3	9
Mostly cattle	3	27
Cattle and sheep	2	3
Poultry and pigs	1	1
General cropping	1	1
Not classified	2	1
Total	22	100

A further 14% of holdings are classed as livestock, mainly cattle, concerned mainly with 18 to 24 month grass/cereal fattening systems. There is one suckler herd.

Sheep are a common, although minor, enterprise, kept by 70% of Morda farmers. Sheep systems include both resident and non-resident (flying) ewe flocks for fat lamb production, overwintering upland breeding flocks, and overwintering and grass finishing 'hoggets'.

Present stocking rates on livestock fattening farms (sheep and cattle) average 1.31 livestock units per hectare which is consistent with the regional average.

The non-livestock farms in the Morda benefit area have only a small proportion of their total area in the benefit area.

Farm size expressed in hectares and standard man days are contained in Tables 3 and 4 respectively, and suggest a range which is not untypical of the region in general.

Table 3 : Farm Size (Hectares)

Farm Size (ha)	No. of Farms	% of Area
5- 10	1	1
10- 20	1	1
20- 30	4	14
30- 40	1	6
40- 50	2	14
50-100	9	36
100-200	4	28
Total	22	100

Mean = 69.8 ha St. Dev. = 51 ha

Table 4 : Farm Size (Standard Man Day Requirement)

Farm Size (SMD)	No. of Farms	% of Area
< 99	1	1
100- 174	1	1
175- 249	2	16
250- 499	5	16
500- 999	7	30
1000-1499	3	20
1500-1999	1	6
No Data	2	10
Total	22	100

Mean = 615 SMD St. Dev. = 407 SMD

The proportion of total farm area lying within the Morda benefit area varies considerably between farms (Table 5). Eight farms (33% of the sample) had areas accounting for less than 20% of total farm size and these were often parcels of land fragmented from the main part of the holding. Four farms (17% of sample) lay almost entirely within the benefit area.

Table 5 : Percentage of Farm Area Within Morda Benefit Area

Less than (%)	No. of Farms	% of Total
0- 20	8	33
21- 40	5	21
41- 60	3	13
61- 80	4	17
81-100	4	17
Total	24	100

Farms with land in the benefit area were predominantly owner occupied as shown in Table 6. The letting of summer keep is a common practice. Three farmers with large proportions of their land in the benefit area let sizeable areas off to summer graziers on a variety of short term arrangements. Adjacent farmers (with land in the benefit area) were amongst those renting this summer keep.

Table 6 : Farm Tenure

% of Farm Owned	No. of Farms	% of Farms
100	8	36
75-99	6	27
50-74	1	5
25-49	2	9
1-24	2	9
All tenanted	3	14
Total	22	100

The majority (54%) of holdings in the benefit area were held in family partnerships (Table 7).

Table 7 : Management Status of Farmer

Status of Farmer	No. of Farms	% of Total
Sole proprietor	9	41
Partnership	12	54
Company	1	5
Total	22	100

12. Effects of the Scheme on Flooding and Land Drainage

During the course of interviews, farmers reported that 82% of the lands previously subject to annual flooding from the Morda (Figure 2) had not been inundated since the scheme. The improved outfall facility of the Morda, combined with IDB works had improved drainage status on lands adjoining the Morda. Land located to the west of the Maesbrook-Crickheath road, however, although included in the benefit area, has not received drainage benefits because of restrictive culverts under the said roadway.

Farmer opinions on the hydrological effect of the scheme were divided. Along the lower part of the Eastern Channel (point 'x' Map 2 to

Pentre Heylin Mill) farmers reported little change as much of the area is protected by argaes or drains away from the Morda. In other parts of the benefit area (Pont Fadoc to point of bifurcation, and the upper part of the Western Channel) farmers reported a net deterioration in drainage status. They argued that Vyrnwy floodwaters ran back up the Morda Western Channel and then down the Eastern Channel, at the same time backing up the Morda waters at the point of bifurcation. Whilst the improvement works had reduced the duration of flooding, the frequency had increased such that waters rose and fell quickly and unpredictably. The overtopping of the East Channel referred to in 3 (ii) still occurs. One farmer was particularly critical of the deleterious effect of the scheme, both on the farmer's land within the benefit area, and on part of the holding west of the Morda West Channel which was now much more susceptible to flooding than ever before.

In summary, the improvements in drainage status have been largely confined to the northern reach of the River Morda, Morton Bridge to Pont Fadoc.

13. Agricultural Benefits of the Scheme

(a) Land Use Change:

The change in land use in the benefit area is summarised in Table 8 and 9 and the present distribution of field cropping patterns is illustrated in Figure 4.

Before the Morda improvement scheme, with the exception of 4.5 hectares of continuous arable and 32.7 hectares in rotation, the entire area was down to grass, almost exclusively permanent pasture.

By 1982, 87.2 ha of permanent grassland had been ploughed. This is equal to 23% of the pre-scheme total (including summer let). Of this 61% went into a rotation of (typically) four years cereals and a three year ley, and 32% of temporary leys, often with a one-year barley break. 7% has gone to continuous cereals.

It is pertinent to note the 73.5 ha increase in the area of summer let grazing, especially the 25.1 ha that have changed from a grass/crop rotation. This has been due to management changes and not in any way due to the scheme.

Table 8 : Land Use Change 1972-82

Pre-Scheme \ Post-Scheme	Permanent Grass	Temporary Grass	Grass/Crop Rotation	Crops	Summer Let	Pre-Scheme Total
Permanent grass	213.4	28.0	53.1	6.1	48.4	349.0
Temporary grass	-	21.0	-	-	-	21.0
Grass/crop rotation	3.6	-	4.0	-	25.1	32.7
Crops	-	-	-	4.5	-	4.5
Summer let	-	-	-	-	23.4	23.4
Post-scheme total	217.0	49.0	57.1	10.6	96.9	430.6

Table 9 : Net Land Use Change 1972-82

Land Use	Pre-Scheme (ha)	Post-Scheme (ha)	Net Change (ha)
Permanent grass	349.0	217.0	-132.0
Summer let	23.4	96.9	+73.5
Temporary grass	21.0	49.0	+28.0
Grass/crop rotation	32.7	57.1	+24.4
Crops	4.5	10.6	+6.1

A comparison of field drainage installation (Figure 3) and land use change (Figure 4) suggests a high positive correlation between the two. Most field drainage has been associated with a change from permanent pasture to mixed arable ley rotations (see Table 10).

(b) Installation of Field Drains:

Since the Morda improvements, a total of 96 hectares of land have had field drains installed, which are attributable to the Morda improvements as shown in Table 10. This estimate is based on the sizes of fields in which drains have been installed, and is likely to overestimate the actual area drained. The latter has been assessed from drawings held in MAFF drainage files and is equal to 79.51 Ha.

Virtually all the field drains have been installed on the right bank of the north reach of the Morda (Morton Bridge to Pont Fadoc). No field drainage has occurred in the southern section of the scheme (Pont Fadoc to Vyrnwy Confluence) (Figure 3).

Thirty-eight per cent by area of all field drainage installations occur on one holding. A further 12 hectares of drainage is currently being considered by Morda farmers. Apart from this, farmers do not regard further field drainage as necessary in the context of their present farming systems.

(c) Improved Production from Existing Land Uses:

The main benefits recognised by livestock farmers have been an extended grazing season, and increases in stocking rates. In many cases improved productivity has been accompanied by, and has encouraged, other management changes, notably an increase in nitrogen fertilizer use and silage conservation. In some cases, increased stocking rates have meant an increase in herd size, in some cases the release of land on other parts of the farm (often outside the benefit area), in others substantial savings in purchased feed and/or rented keep costs.

The increase in arable production since the Morda improvement has been mainly in the form of arable-temporary grass ley systems on dairy farms. The release of land to arable production has been achieved by the increased productivity and effective stocking rates on the ley components of the rotations. In such cases, farms have required additional investments in fixed costs for both livestock and arable enterprises.

Table 10 : Field Drainage Installation

Date of Drainage	Field Size (ha)	Land Use		
		Pre-Scheme	Post-Scheme	Date of Change
1973	6.5	Permanent grass	Arable/ley rotation	1975
1974	0.4	" "	" " "	1977
	7.3	" "	" " "	1974
	4.9	" "	Temporary grass	1976
	3.2	" "	Arable/ley rotation	1974
1975	2.0	" "	Permanent grass	-
	2.4	" "	Arable/ley rotation	1974
	4.9	" "	" " "	1974
1977	2.8	" "	Permanent grass	-
	3.2	" "	" "	-
	0.8	" "	" "	-
1978	3.6	" "	Arable/ley rotation	1982
	6.5	" "	" " "	1978
	8.5	" "	" " "	1977
	4.0	" "	Permanent grass	-
	7.7	" "	" "	-
	2.0	Arable/ley rotation	Arable/ley rotation	-
	2.0	Permanent grass	Permanent grass	-
1979	2.0	Arable/ley rotation	Arable/ley rotation	-
1980	4.5	Permanent grass	" " "	1980
	1.2	" "	Permanent grass	-
	8.1	" "	Temporary grass	1974
	4.9	" "	" "	1974
1982	1.2	" "	Permanent grass	-
	1.2	" "	" "	-
Total	95.8 (22% of benefit area)			

The rate of installation of field drains is shown in Figure 5.

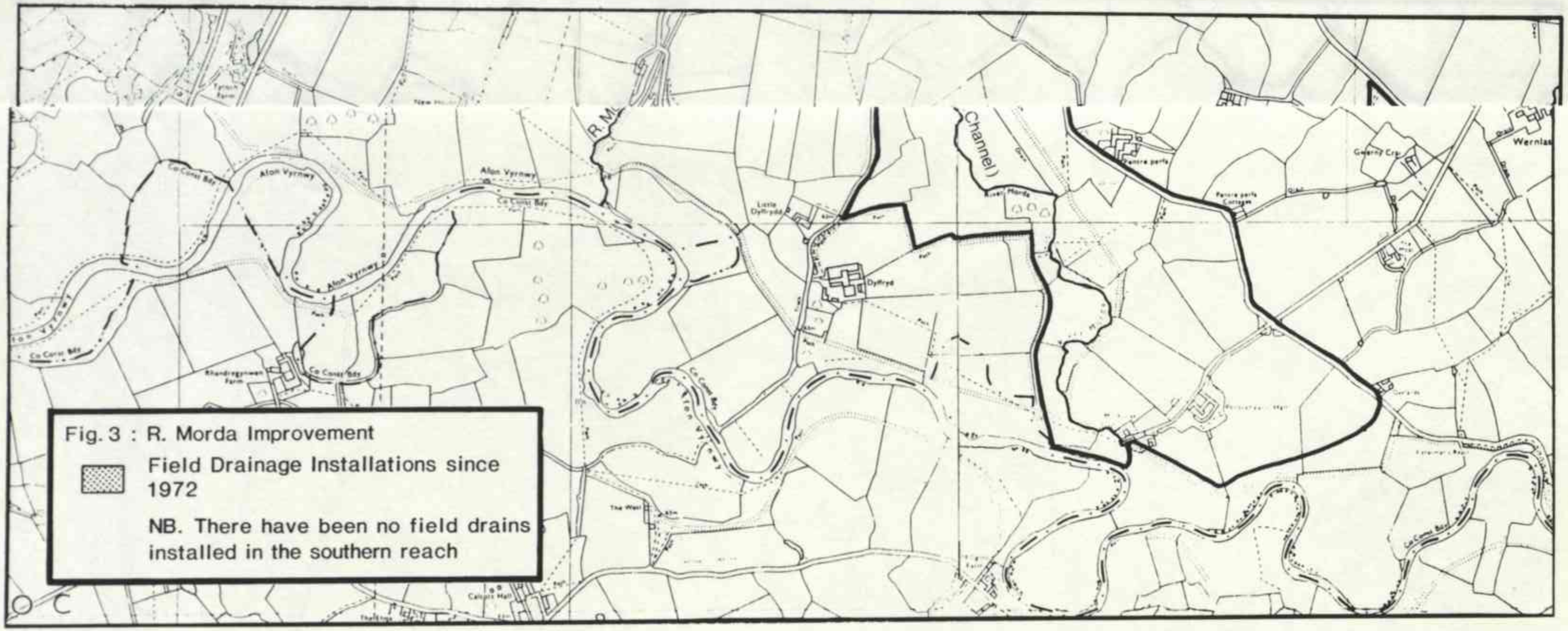


Fig. 3 : R. Morda Improvement

Field Drainage Installations since 1972

NB. There have been no field drains installed in the southern reach

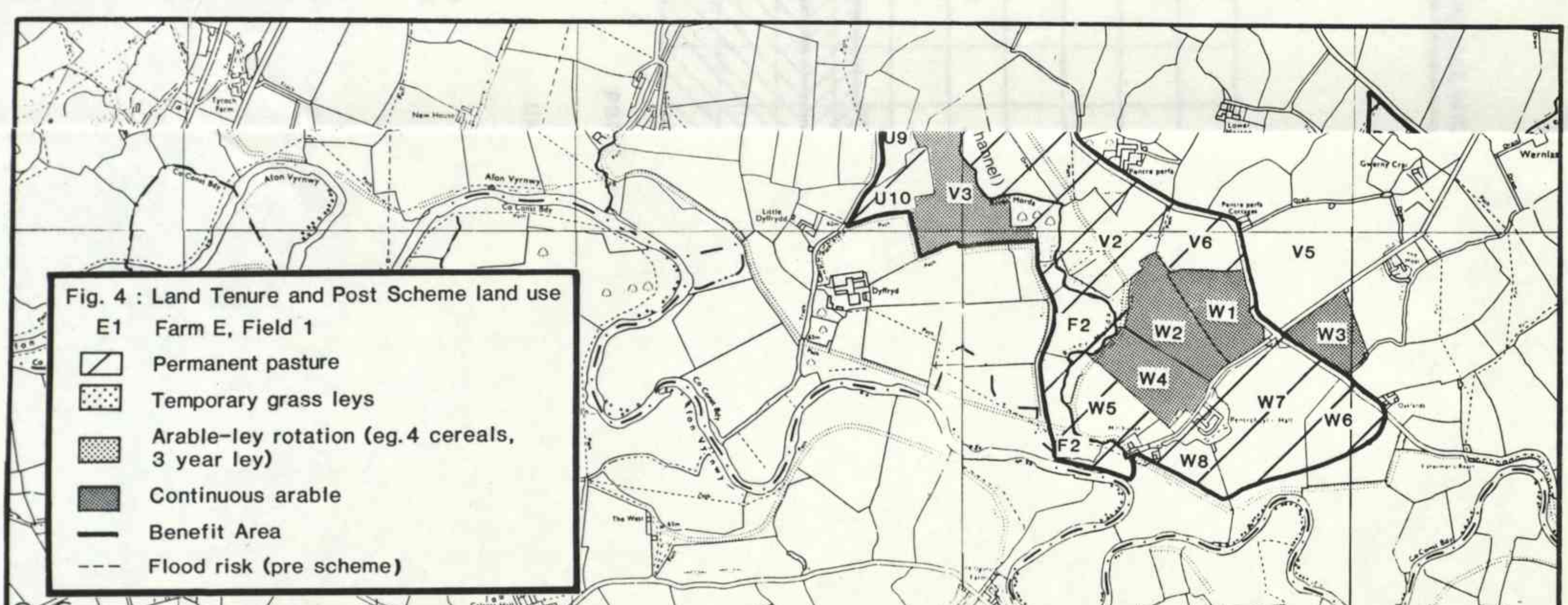
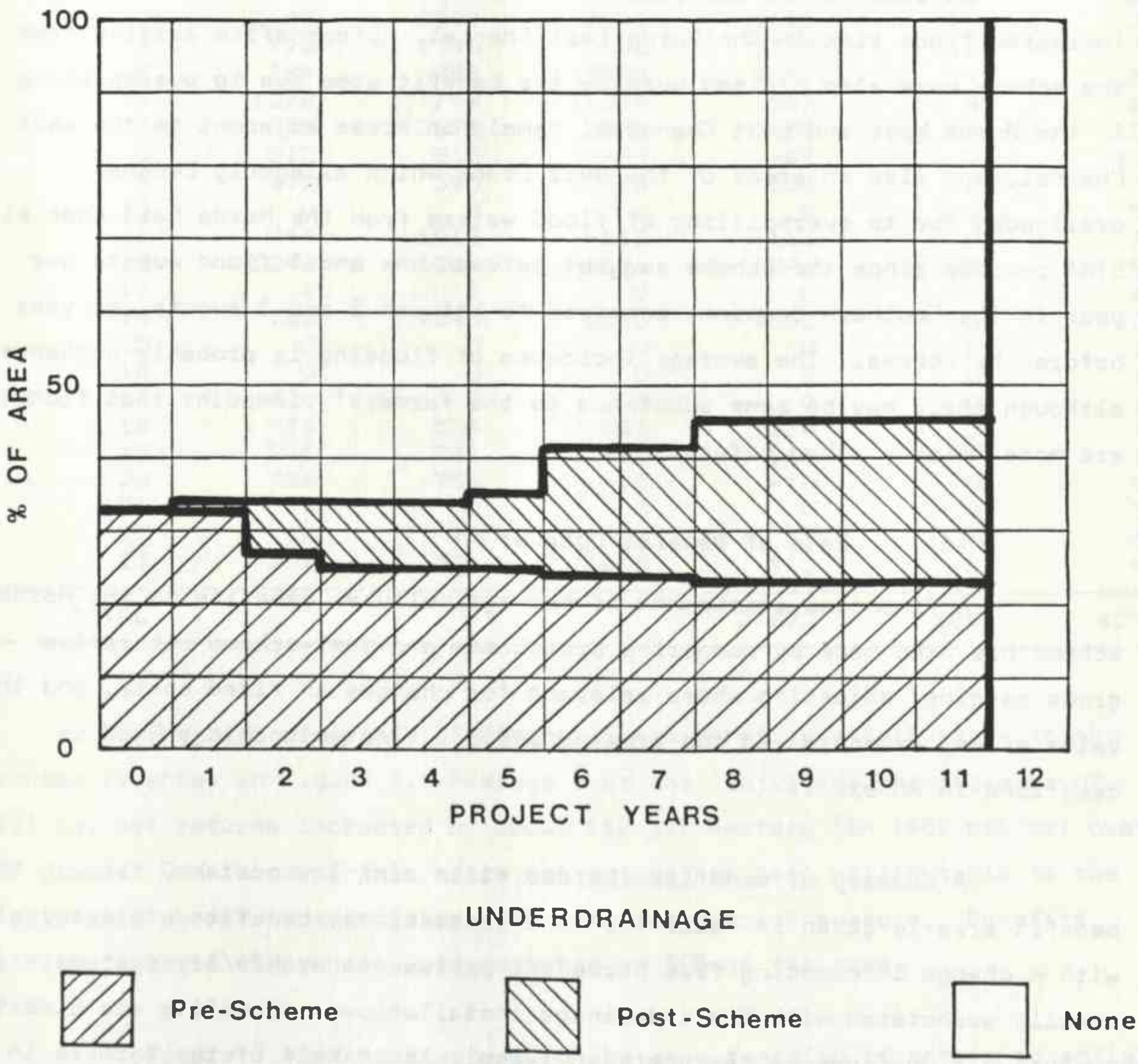


Fig. 4 : Land Tenure and Post Scheme land use

Fig 5 INSTALLATION OF UNDERDRAINAGE



Farmers have found it more easy to perceive the benefits of improved drainage where this has required some conscious decision on their part, eg. field drainage, reseeded pasture, cereal production. The need for investment in farm fixed costs (notably labour, buildings and machinery) has varied considerably according to farm circumstances.

At least 2 farmers claimed disbenefits from the scheme due to increased flood risk in the Morda East Channel. Disbenefits arising from the scheme were also claimed outside the benefit area due to overspilling in the Morda West and East Channels, namely in areas adjacent to the West Channel, and also in areas of the Weir Brook which allegedly became overloaded due to overspilling of flood waters from the Morda East Channel. STWA records since the scheme suggest between one and 5 flood events per year in the Southern Section, compared to between 2 and 3 events per year before the scheme. The average incidence of flooding is probably unchanged, although there may be some substance to the farmers' viewpoint that floods are more 'flashy' than before.

(d) Rate of Benefit Uptake:

A financial assessment of net agricultural benefits to the Morda scheme has been made by comparing pre-scheme and post-scheme enterprise gross margins, adjusting where relevant for changes in fixed costs, and the value of any extension to the grazing season. The methodology used is described in Annexe V.

A summary of benefits (before field drainage costs) by farm in the benefit area is given in Table 11. The greatest net benefits are associated with a change in cropping from permanent pasture to arable/ley systems, usually associated with field drainage installations. Benefits are almost exclusively confined to the northern reach. About half of the farmers in the benefit area recorded benefits, with 80% accruing to 5 farmers. Three farmers switched from dairy farming to grazing fatstock after the scheme, with the effect that net returns declined compared to the pre-scheme situation. (Whilst this negative response is included for analysing uptake, it needs to be excluded for the purpose of scheme appraisal.)

Table 11 : Distribution of Benefits by Farm

SCHEME 31 NET AGRICULTURAL BENEFIT

FARM CODE	YEAR FIRST	YEAR 4	YEAR 9	YEAR LAST	% OF BENEFITS	% OF AREA
1	0	0	0	0	0	1
2	493	1039	2045	2045	8	5
3	2107	3009	8381	9441	35	12
4	778	1348	3166	3327	12	5
5	799	799	3853	3853	14	6
6	1278	799	1339	1567	6	6
7	548	2875	2875	2875	11	3
8	812	812	-89	-89	0	10
9	395	395	538	538	2	3
10	0	0	0	0	0	5
11	744	1018	-113	-113	0	7
12	1246	1246	1246	1246	5	9
13	0	0	0	0	0	1
14	165	1246	1352	1352	5	2
15	0	0	0	0	0	2
16	0	0	0	0	0	1
17	0	0	0	0	0	1
18	534	534	534	534	2	1
19	241	241	168	168	1	1
20	756	756	-10	-10	0	5
21	0	0	0	0	0	2
22	16	16	16	16	0	5
23	531	531	413	413	2	9
TOTAL				27172	100	429

The rate of uptake of financial net benefits attributable to the scheme is shown in Figure 6. Average over the (adjusted) benefit area of 431 ha, net returns increased by about £62 per hectare (in 1982 prices) over 12 years. One-third of this extra net return has been attributable to the 'automatic' benefits associated with extended grazing seasons. Benefits attributable to the scheme were reported on 50% of the area.

Figure 7 expresses actual uptake as a function of scheme potential which is taken to be a reasonably achieveable target for post-scheme land use, and based largely on land capability and local farming practice. In the case of the Morda the potential for the area north of Pont Fadoc, based on what is currently being achieved by one farmer, is a 2/3 year ley (300 kg N) for dairy (84%) and 18 month beef (16%), followed by 2 wheats (7.5 t/ha), and 2 barley (6.0 t/ha).

FIGURE 6 : Degree and Rate of Financial Uptake

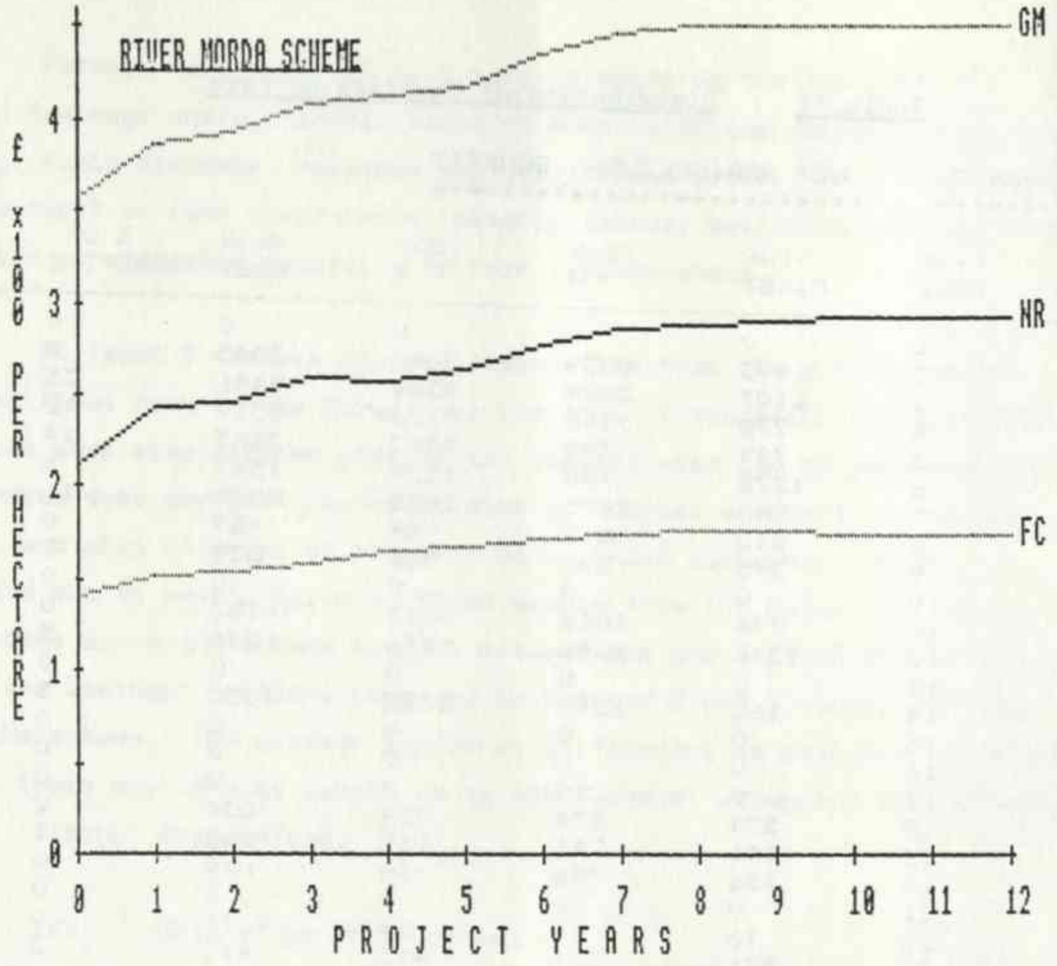
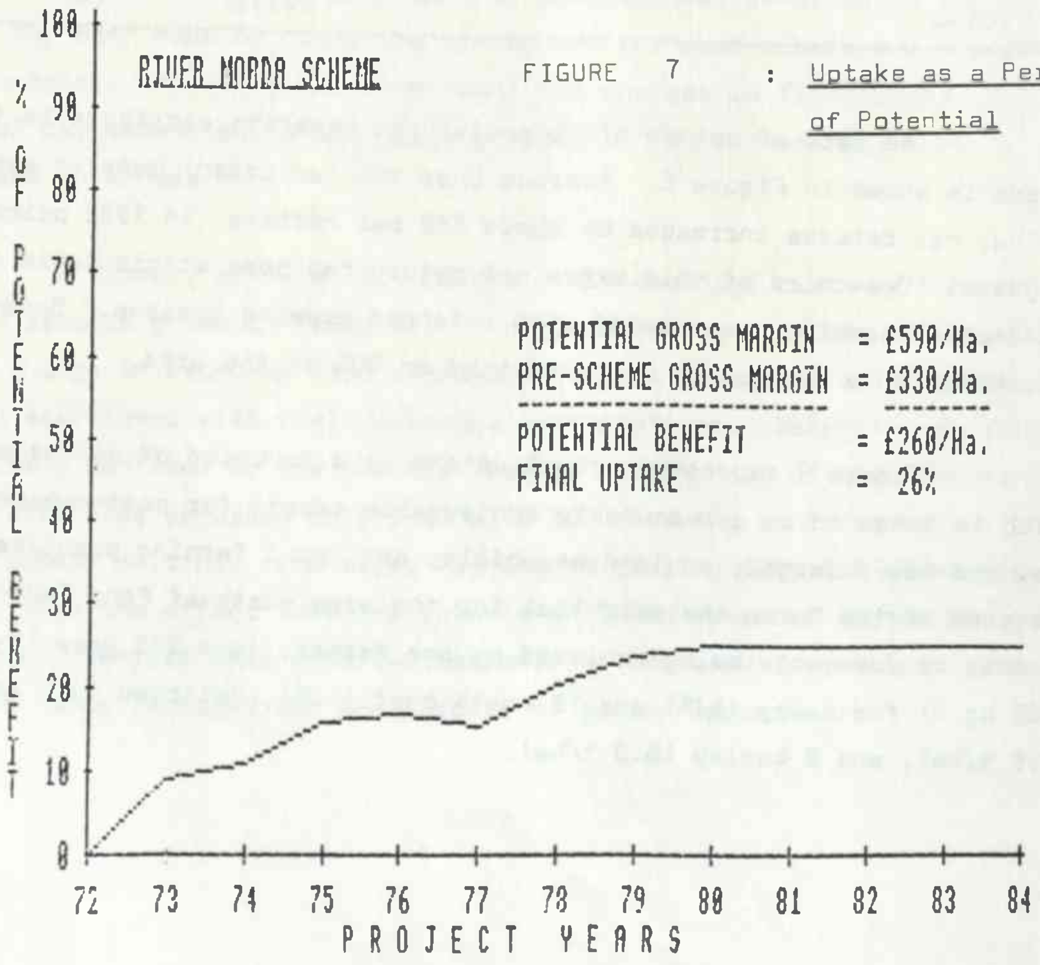


FIGURE 7 : Uptake as a Percentage of Potential



In the southern reach, where drainage conditions have changed little, and land capability is best suited to grass the potential is that given by the existing most intensive use: 75 kg N/ha for a mixture of dairy and fatstock. According to Figure 7 actual gross margins reached a maximum 26% of potential by 1983/4. This relative measure of uptake needs to be interpreted cautiously as discussed in Annexe IX, Section 4.4.

14. Financial Analysis

A summary of the River Morda improvement scheme cash flow expressed in 1982 prices is given in Table 12.

(a) Net Agricultural Benefits:

The increase in net agricultural benefits attributable to the scheme are the net returns identified in Figure 6, adjusted for the small negative returns due to the farmers leaving dairying. The total area was covered in survey, so no grossing up factor is needed. Benefits are assumed to continue at their 1984 level for the remainder of project life with no attempt to predict future changes. A summary of benefits is given in Appendix I.

(b) Capital and Recurrent Costs:

The capital costs of the scheme averaged £410 per hectare of potential benefit, including additional works by Melverley IDB. Incremental costs for STWA maintenance have been assumed but not for IDB works.

(c) Field Drainage Costs:

The total cost of field drainage installations was £41,150, an average of £460 per hectare, and equivalent to an overall investment of £96 per hectare in the benefit area. No incremental farm level maintenance costs have been assumed.

(d) Flood Damage Reduction:

Flooding has not recurred in the northern reach since the scheme, thus alleviating the loss of the hay crop on the conserved part of the flooding area (65 ha) in the event of a summer flood (estimated one in 15 years). An average annual sum of £2,056 is used. Whilst some farmers in the southern reach argue flood incidence is possibly greater, there is no evidence that this has resulted in a change in flooding costs.

Table 12 : Summary of Scheme Cash Flow and NPV

RIVER MORDA IMPROVEMENT MORTON BRIDGE TO VYRNWY CONFLUENCE

PROJECT YEAR	0	1	2	3	4	5	6	7	8	9	10	11	12
CALENDAR YEAR	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984 -2002
AGRICULTURAL BENEFITS													
Net Agric Benefits	0	10080	11182	15300	15005	16873	21645	24383	25373	25963	26434	26824	26824
Flood Damage Reduction	0	1050	1050	1050	1050	1050	1050	1050	1050	1050	1050	1050	1050
less Without Proj Ben	0	367	738	1112	1490	1872	2258	2648	3041	3439	3840	4246	4655
less Field Drain Cost	0	1000	8726	0	2729	5049	6005	2100	13537	0	2000	0	0
NET AGRIC CASH FLOW	0	9763	2768	15238	11836	11002	14432	20685	9845	23574	21644	23628	23219
SCHEME COSTS													
Capital	89830	85670	9670	0	0	0	0	0	0	0	0	0	0
Recurrent			2630	2630	2630	2630	2630	2630	2630	2630	2630	2630	2630
TOTAL COSTS	89830	85670	12300	2630	2630	2630	2630	2630	2630	2630	2630	2630	2630
SCHEME NET CASH FLOW	-89830	-75907	-9532	12608	9206	8372	11802	18055	7215	20944	19014	20998	20589
NET PRESENT VALUE AT %	0	2.5	5	7.5	10	12.5	15	17.5	20				
	344134	164340	60677	-993	-38660	-62134	-76941	-86297	-92132				

(e) Without-Project Benefits:

A basic assumption of 1% compound per annum is used to account for likely improvements in farming performance achieveable without the project (see Annexe V). Without-project benefits are charged for those areas for which there has been some observed post-scheme benefit uptake: 46.4% of the total benefit area in the case of the Morda. Without-project benefits are therefore taken as 1% compound per year of the pre-scheme net return (£79,107) multiplied by 46.4%, ie. £36,705 x 1% compound.

(f) Project Worthwhileness:

Assuming benefits continue at their 1984 level over a 30 year project life, the net present value of the scheme at 5% discount rate is £60,677 in 1982 prices. The scheme's internal rate of return is 7.4%.

(g) Sensitivity Analysis:

Table 13 examines the sensitivity of the scheme to selected benefit and cost parameters. The estimated value of agricultural benefits would need to fall by 18% to reduce net present value to zero at the 5% discount rate.

15. Summary Discussion

The scheme divides into 2 sections, north and south, distinguishable in terms of hydrological conditions and agricultural benefits.

The scheme was initiated in response to pressures from farmers in the northern section (mainly Crickheath) and the river works have provided substantial benefits to farmers by way of reduced flood liability and waterlogging. Improvements in IDB watercourses was a necessary sequel, and these were implemented immediately after the main river works. River works have performed satisfactorily and maintenance has been regular, although some criticisms were made of IDB maintenance schedules. The benefit area perceived by farmers is less than originally specified.

Farmers in the northern section of the scheme were well disposed to the scheme, recognising substantial benefits (financial and non-financial eg. easier, less worrying livestock management conditions). In many cases, farmers maintained that a combination of relatively free draining riverine soils and the requirements of a grassland farming system did not

TABLE 13

River Morda - Sensitivity Analysis

Run No.	Net Agricultural Benefit Factor: basis as per benefit assessment	Without Project Returns Factor basis	Flood Damage Reduction Factor basis	NPV at 5%	IRR %	Switching* Value
1	1.0	1	1	60677	7.4	0.82
2	1.0	1.5	1	35021	6.5	0.89
3	1.0	0.5	1	85163	8.3	0.75
4	1.0	0	1	108531	9.2	0.68
5	1.0	1	0	45304	6.8	0.86

* The factors show the weights applied to the original estimates eg a factor of 1.5 for the without-project benefits indicates that the new value is 1.5 x 1% compound per year (the original value) ie 1.5% compound.

* Switching value : change in agricultural net benefits needed to make the project breakeven at 5% discount rate eg a 1.5 switch value shows an increase of 1.5 x the original estimated is required.

necessitate field drainage. The 96 ha (22% of the benefit area) of field drainage installed since the scheme lies entirely in the northern section. The majority of this has been put in to enable a mixed-arable ley rotation, in the main by farmers who have the greater part of their holdings outside the benefit area. One farmer alone, is responsible for 38% of all field drainage. He purchased his Morda farm in 1971, at the onset of the Morda scheme, and improved drainage has enabled him to bring the management of his Morda holding more into line with that of his 2 other 'upland' farms. Farmers with most of their holding in the benefit area are committed livestock farmers.

Further field drainage and land use change in the Morda are likely to be limited to about 12 ha in the foreseeable future. At present 3 major potential beneficiaries have retained or moved into extensive livestock systems, which has limited the exploitation of potential benefits. A change in tenure on these farms would probably be accompanied by intensification, but this is unlikely to greatly affect the discounted return of the Morda project.

In the southern stretch, few benefits are attributable to the Morda improvement, and many farmers claimed that flood risk had increased. Some farmers maintained that benefits accruing to the northern section had been achieved at their cost. In this context the engineering design of the southern section, particularly the bifurcation works, came under much criticism. Farmers were quick to point out that hydrological conditions in the southern section of the Morda were largely determined by the Vyrnwy, and not the Morda. They foresaw the increased flood risk of deepending the Morda West Channel, and subsequent happenings had vindicated their anticipation. The areas liable to flooding are mainly used for summer keep.

The area to the west of the Maesbrook-Crickheath Road and north of the disused railway potentially stands to benefit from the Morda works and has been included within the benefit area. However the restricted road culvert and IDB watercourses have ensured that no extra freeboard has been provided and prevented benefits from being taken up. Since the survey, the culvert has collapsed and is currently (1984) being replaced. One farmer upstream of the culvert now intends to underdrain.

The Morda improvement scheme has been worthwhile at the 8% discount rate, giving an internal rate of return of 7.4% over a 30 year project life.

References

1. Severn River Authority (1970) River Morda - Vyrnwy confluence to Morton Bridge Proposed River Improvement Scheme. Momorandum by the Engineer.

2. Severn River Authority (1970-75) River Morda Scheme files.

3. Ministry of Agriculture, Fisheries and Food ( ) Agricultural Land Classification map.

APPENDIX I

SELECTED FARM AND FIELD DATA : MORDA IMPROVEMENT

	FIELD NO.	SIZE ha	LAND USE (with dates) Before	LAND USE (with dates) After	FIELD. DRAINS cost and date	PREVIOUS LIABILITY TO FLOODING	BENEFIT PERCEIVED DUE TO SCHEME Yes/No	BENEFIT PERCEIVED DUE TO SCHEME Type
(A) LOWER MORTON SPECIALIST DAIRY 31 ha (78 ac) 170 SMD 1.0 Lu/ac. 13% in Benefit	A 1	2.860	pp	pp		-	No	-
	A 2	1.300	pp	pp	-	-	No	-
(B) THE LEY SPECIALIST DAIRY 24 ha (60 ac) 450 SMD 1.00 Lu/ac 81% in Benefit	B 1	3.582	rough pp	5 years rot. 2 ww, 3 yr L now imp. pp	Drained before scheme	✓	Yes	Extended grazing season, ↑ stocking rate and numbers, more silage. Sheep over-wintering
	2	4.441	pp	Improved pp		50% of Area ✓	Yes	
	3	2.604	pp	Improved pp		✓	Yes	
	4	3.048	pp	Improved pp		✓	Yes	
	5	3.704	pp	Improved pp			No	
	6	3.550	pp	Improved pp			No	
(C) CHICKHEATH HALL SPECIALIST DAIRY 109 ha (273 ac) 1368 SMD 1.2 Lu/ac 46% in Benefit	C 1	6.374	pp	2 w, 2 b, 2 or 3 yr L (1978)	£3505 1978	✓	Yes	Extended grazing ↑ stocking rates ↑ stocking nos. More recently same stock nos. supported on reduce grass area. High N rates, 3 Lu/ha on leys. 24 t silage/ha.
	2	7.221	pp	" (1974)	£4000 1974	✓	Yes	
	3	3.575	pp	" (1982)			Yes	
	4	4.468	pp	" (1980)	£2364 1980		Yes	
	6	4.768	pp	5 yr Leys (1976)	£1456 1976		Yes	
	7a	1.216	pp	Improved	£1273 1976			
	7b.c.d	1.257	pp	Summer keep			Yes	
	8	4.032	pp	pp			Yes	
	9	2.800	pp	pp			No 'dry field'	
	10	8.673	pp	2 w, 2 b, 2/3 L (1977)	£5049 1977		Yes	
	11	5.267	pp	"			Yes	
(D) EAST FARM SPECIALIST DAIRY 33 ha (83 ac) 464 SMD 0.96 Lu/ac 67% in Benefit	D 2	1.529	pp	pp	-	✓	Yes	Extended grazing and doubling of stocking rates. reduced rented keep, more N.
	3	2.339	pp	pp	-	✓	Yes	
	4	1.905	pp	pp	-	✓	Yes	
	5	2.623	pp	pp	-	✓	Yes	
	6	5.242	pp	pp	-	✓	Yes	
	7	7.000 incl. adjacent field	pp	Temporary leys	-	✓	Yes	
	8	1.644	pp	Temporary leys	-	✓	Yes	
(E) MANOR FARM SPECIALIST DAIRY 96 ha (240 ac) 987 SMD 0.91 Lu/ac 29% in Benefit	E 1	10.874	pp	pp			Yes	Extended grazing ↑ stocking rates, and nos., more N
	2	7.640	pp	pp	£1000 1980		Yes	
	3	3.98	pp	pp			Yes	
	4	5.430	pp	pp	£2900, 1980	✓	Yes	

	FIELD NO.	SIZE ha	LAND USE (with dates)		FIELD, DRAINS cost and date	PREVIOUS LIABILITY TO FLOODING	BENEFIT PERCEIVED DUE TO SCHEME	
			Before	After			Yes/No	Type
(F) LYFFYD MAINLY DAIRY 108 ha (270 ac) 1900 SMD 0.63 Lu/ac 29% in Benefit	F 1	7.988	pp	2 yrs b then t. leys	£4700, 1980	✓	Yes	Extended grazing season, ↑ silage making, ↑ stocking rates and nos.
	2	6.223	pp	pp		✓	Yes	
	3	4.284	pp	pp		✓	No	
	4	4.934	pp	2 yrs b then t. leys	£2600, 1980	✓	Yes	
	4a	1.727	pp	"			Yes	
	5	2.399	pp	Barley			No	
	6	1.153	pp	pp			No	
	7	1.871	pp	pp			No	
(G) CLAWD COCH SPECIALIST DAIRY 86 ha (210 ac) 826 SMD 0.80 Lu/ac 16% in Benefit	G 1	3.292	pp	Mixed arable	✓		Yes	Cereal production, extended grazing, doubled stocking on leys.
	2	2.060	pp	pp	✓	✓	Yes	
	3	2.559	pp	Mixed arable	✓	✓	Yes	
	4	4.922	pp	Mixed arable	✓		Yes	
(H) TREPRENNAL L/STOCK CATTLE 74 ha (184 ac) 356 SMD 0.83 Lu/ac 67% in Benefit (Half of farm let to summer graziers)	H 1	2.729	pp	Improved reseeded pp	£2500, 1978	✓	Yes	Extended grazing, ↑ stocking rates, ex-dairy, now double sucklers.
	2	3.080	pp	"		✓	Yes	
	2a	3.044	pp	"		✓	Yes	
	3	3.677	pp	"		✓	Yes	
	4	1.848	pp	"	part 1978 ✓		Yes	
	5	1.561	pp	"		✓	Yes	
	6	5.283	pp	pp			No	Arable rotation possible before scheme, but now down to grass (and mainly let off for management reasons). Restricted road culvert.
	7	3.552	pp	pp			No	
	8	3.949	pp	pp			No	
	9	10.258	pp	pp			No	
	10	2.534	pp	pp			No	
	12	3.819	pp	pp			No	
	14	2.603	pp	pp			No	
	15	1.982	pp	pp			No	
(I) REDWITH SPECIALIST DAIRY 18 ha (44½ ac) 271 SMD 0.98 Lu/ac	I 1	0.330	pp	pp			Yes	Extended grazing season, ↑ stocking rates, ↑ silage, increase arable in rotation, reduced rented keep.
	2	1.897	1 b, 3 L	2 b, 3 ley	✓ £2100 1979		Yes	
	3	1.975	1 b, 3 L	2 b, 3 ley	✓ £2100 1979		Yes	
	4	1.007	pp	pp		✓	Yes	
	5	1.623	pp	pp		✓	Yes	
	6	0.681	pp	pp			Yes	
	7	0.810	pp	pp		✓	Yes	
	8	1.829	pp	pp			No	
	9	1.273	pp	pp			No	
	10	3.033	pp	pp		✓	No	
	11	1.159	pp	pp			No	
(J) WAEN WEN SPECIALIST DAIRY 31 ha (76½ ac) 597 SMD 0.91 Lu/ac	part 1	1.500	temp grass	temp grass			No	Drains to an IDB watercourse outfall determined by culvert under Crickheath to Maesbrook road, which has now been lowered since Morda improvement, but could be.
	2	4.460	"	"			No	
	3	1.143	"	"			No	
	4	1.500	"	"			No	
	5	3.703	"	"			No	
	6	2.000	pp	pp			No	
	7	4.127					No	
	8	2.911					No	
	9	1.953					No	

	FIELD NO.	SIZE ha	LAND USE (with dates)		FIELD, DRAINS cost and date	PREVIOUS LIABILITY TO FLOODING	BENEFIT PERCEIVED DUE TO SCHEME	
			Before	After			Yes/No	Type
(K) ? LIVESTOCK SHEEP 18 ha (44 ac) 100 SMD 0.84 Lu/ac 28% in Benefit	K 1	5.084	pp	pp			No	Drainage impeded by road culvert not lowered since scheme.
(L) FOUR ASHES LIVESTOCK CATTLE 86 ha (215 ac) 202 SMD 0.50 Lu/ac 35% in Benefit (Now lets 79% off to summer graziers)	L 1a	2.000	pp	pp		✓	Yes	Extended grazing and ↑ stocking by 30% on 1, 4 & 8, 10% on others.
	1	3.320	pp	pp		✓	Yes	
	2	3.025	pp	pp			Yes	
	3	5.380	pp	pp		✓	Yes	Ex-dairy, now over-wintering & grass finished stores
	4	4.269	pp	pp			Yes	
	5	1.250	pp	pp			Yes	
	6	3.187	pp	pp			Yes	
	8	2.903	pp	pp			Yes	
	13	2.230	pp	pp			Yes	
	14	2.542	pp	pp		✓	Yes	
(M) THE FIELDS SPECIALIST DAIRY 42 ha (105 ac) 500 SMD 0.76 Lu/ac 92% of farm in Benefit Area	part 1	0.500	pp	pp			No	Little change in productivity.
	2	3.689	pp	pp			No	
	3	2.433	pp	pp			No	
	4	2.815	pp	pp			No	
	5	1.670	pp	pp			No	
	6	6.896	pp	pp		✓	Yes	} Extended grazing and milk yields
	6a	2.807	pp	pp		✓	Yes	
	7	6.795	pp	pp		✓	Yes	
	8	4.676	pp	pp		✓	Yes	
	9	2.498	pp	pp			No	
	10	1.726	pp	pp			No	
	11	2.066	pp	pp			No	
(N) PENTRYTH FARM MAINLY DAIRY 68 ha (170 ac) 590 SMD 0.99 Lu/ac	N 1	1.073	pp	pp		✓	Yes	50% ↑ in stocking plus cereals
	2	1.305	pp	pp	£2000 1982	✓	Yes	
	3	6.571	pp	5 b, 3 L	£4726 1974	✓	Yes	
(O) GREENFIELD FARM PIG & POULTRY 28 ha (70 ac) 480 SMD 0.8 Lu/ac 19% in Benefit	O 1	1.681	pp	pp	Drained in 1970 before scheme	✓	No	Ex dairy, now pigs.
	2	3.706	pp	pp		✓	No	
(P) HIGHER FARM, OSBASTON GENERAL CROPPING 0.8 Lu/ac 84 ha (209 ac), 527 SMD 5% in Benefit	P 1	4.381	B	1 b, 2 w, 3 ab	£1000, 1973		Yes	Root crops possible.
(Q) OSBASTON FARM SPECIALIST DAIRY 52 ha (130 ac) 710 SMD 0.96 Lu/ac 4% in Benefit	Q 1a	0.400	pp	pp		✓	No	'Small patch rather neglected'
	1	0.600	pp	3 b, 5 L			Yes	
	2	1.242	pp	pp			No	

	FIELD NO.	SIZE ha	LAND USE (with dates)		FIELD, DRAINS cost and date	PREVIOUS LIABILITY TO FLOODING	BENEFIT PERCEIVED DUE TO SCHEME	
			Before	After			Yes/No	Type
(R) OSBASTON HS.	R 1	0.769	pp	pp			No	Retired
SPECIALIST DAIRY	2	0.680	pp	pp			No	smallholder
6.5 ha (16 ac)	3	1.604	pp	pp			No	
79 SMD	4	0.890	pp	pp			No	
0.79 Lu/ac 73% in Benefit	5	0.797	pp	pp			No	
(S) LLWINTIDMON MILL LIVESTOCK	S 1	0.673	pp	pp		✓	Yes	Extended grazing,
22 ha	2	3.564	pp	pp		✓	Yes	↑ stocking rates,
572 SMD	3	0.896	pp	pp		✓	Yes	↓ bought feeds
0.8 Lu/ac	4	1.690	pp	pp		✓	Yes	was in dairy, now
100% in Benefit	5	0.292	pp	pp		✓	Yes	retired. sublett-
	6	2.141	pp	pp		✓	Yes	ing to beef/sheep
	7	0.884	pp	pp		✓	Yes	
	8	0.640	pp	pp		✓	Yes	
	9	1.127	pp	pp			Yes	
	10	3.532	pp	pp		✓	Yes	
	11	5.858	pp	pp			Yes	
(T) WOLFSHEAD FARM	T 1	5.142	pp	pp		✓	No	No change -
LIVESTOCK	2	2.559	pp	pp		✓	No	increased
110 ha (275 ac)								flooding
940 SMD								liability
.09 Lu/ac								
[illegible] in Benefit								
(U) LLWYNTIDMON HALL	U 1	2.448	pp	pp		✓	No	Entirely let off
52 ha : Livestock	2	0.884	pp	pp		✓	No	as summer grazing
Mainly let as summer	3	1.721	pp	pp		✓	No	- no benefit
keep	4	2.227	pp	pp		✓	No	perceived.
36% in Benefit	5	1.490	pp	pp		✓	No	Fields 4, 5, 6,
	6	3.522	pp	pp		✓	No	7 increased flood
	7	4.348	pp	pp		✓	No	liability,
	8	2.874	pp	pp		✓	No	perceived by
	9	1.846	pp	pp		✓	No	farmer.
	10	2.081	pp	pp		✓	No	
(V) PENTREPERFA	V 1	13.318	pp	pp		✓	No	
150 ha	2	5.27	pp	pp		✓ Up to	Yes	Extra grazing
612 SMD	3	6.021	pp	barley		✓ argaes	Yes	Continuous barley
1.63 Lu/ha	4	9.177	pp	pp		✓	Yes	Extra grazing
24% in Benefit	6	2.749	pp	pp			No	
(W) PENTRE HEYLIN MILL	W 1	3.455	pp	spring cereals			No	Land use change not attributable
55 ha	2	3.961	pp	"			No	to Morda - area drains to Weir
252 SMD	4	3.495	pp	"			No	Brook and
0.75 Lu/ac	5	3.309	pp	pp			No	protected by
55% in Benefit	6	4.847	pp	pp			No	argaes.
	7	9.496	pp	pp			No	
	8	1.800	pp	pp			No	

	FIELD NO.	SIZE ha	LAND USE (with dates)		FIELD, DRAINS cost and date	PREVIOUS LIABILITY TO FLOODING	BENEFIT PERCEIVED DUE TO SCHEME	
			Before	After			Yes/No	Type
(X) LYNWYGO SPECIALIST DAIRY 65 ha (162 ac) 572 DMS 0.9 Lu/ac 4% in Benefit	X 1 2	2.428 0.352	pp pp	pp pp			No No	Retired farmer
(Y/A) HAULAGE CONTRACTOR 100% in benefit	Y/A 1 2	1.016 1.684	pp pp	pp urban		✓	No No	Sheep grazing
(Y/B) OSWESTRY FARMER 5% in Benefit	Y/B 1 2	3.129 2.899	pp pp	pp pp		✓	Yes No	Grazing season for dry stock
(Y/C) MARKET GARDENER	Y/C 1	2.910	-	-			No	Pigs. some market gardening, orchard.
(Y/D) THE WOOD, OSBASTON. Retired Farmer		3.165	pp	pp			No	Sublet.

NB. Y/A, B, C, D, excluded from survey analysis.

APPENDIX G

Upper Severn Division

Sleap Brook : Fiddler's Bridge to Roden Confluence

STWA UPPER SEVERN DIVISION - SLEAP BROOK SCHEME

Report on the background to and development of the scheme and the nature and rate of uptake of agricultural benefits.

1. PHYSICAL BACKGROUND

The Sleap Brook is a tributary of the River Roden, the confluence being at Tilley, near Wem, in Shropshire. The Sleap and its tributaries drain an area of 51.75 km^2.

The catchment area is a hummocky plain, bound on three sides by higher ground; to the north by the remains of a terminal outwash fan (formed by glacial meltwaters from a static ice front during the last glaciation), that now stands as a south facing cresentic arc, running through Loppington; to the west by the belt of hummocky morainic deposits passing from Ellesmere through Cockshutt; and to the south by the chain of hills running from south west from Hawkstone through Grinshill to Nesscliffe, produced by faulting of the underlying Triassic formations. The boundary of the plain coincides with the 300 ft contour which marks the shoreline of a late glacial lake, that covered much of Shropshire, and produced a marked change in gradient.

2. SOILS AND LAND CAPABILITY

The soil distribution of the area is shown in Figure 1. Essentially there are 5 major groups: (Ref. 1)

(i) Newport Series Sandy Loam (44% of Benefit Area):

This brown earth, derived from glacial sand and gravel, has a low organic content, a loose consistancy and light texture. It is naturally free draining, is easily cultivated and is traditionally arable land used for cereals, potatoes and sugar beet. It is often acid, but may be corrected by liming, but, being poor in bases, requires regular fertilizing. During prolonged drought, some shortage of moisture may be encountered.

(ii) Organic Peat (20% of Benefit Area):

This fen peat of high organic content (60% organic matter) is found in association with the Newport Series sandy loam, occurring in the hollows and low ground. Traditionally it has been under permanent grass, and unless well drained, is often saturated.

(iii) Crewe Series Clay (18% of Benefit Area):

This gley soil has developed from lacustrine clays and heavy till. It is naturally poorly draining and water remains on the surface after heavy rain. It is difficult to cultivate, especially when wet and has therefore traditionally been under grass. It is found on the north west facing slopes of the Triassic ridge.

(iv) Mixed Alluvial Soils (9% of Benefit Area)

(v) Other Soil Types (9% of Benefit Area):

Mainly poorly drained gley soils of the Salop and Wem Series. These usually require underdrainage if arable crops are to be grown.

Figure 2 shows the agricultural land classification for the area. It can be seen that the peat and clay areas correspond to the grade 4 land, presumably because of their poor drainage. The sandy areas and higher ground were classified as grade 3 or grade 2.

3. LAND DRAINAGE HISTORY

Major alterations were carried out to the Sleap Brook by the Air Ministry when the airfield at Sleap was constructed in the 1939-45 war. This included the construction of a spillway at Ruewood connecting the Sleap Brook with the River Roden. Floodwater was diverted to the spillway be a deflection wall. This also served to reduce the level of flood flows passing to the old Tilley Bridge which had a low capacity. The Houlston Brook, a tributary of the Sleap, was culverted where it crossed the airfield, but unfortunately the culvert was placed at too high a level.

In 1951 the Salop County Council carried out an improvement scheme on the Sleap from Ruewood to Wackley, and in 1961/62 they executed a scheme from Tilley Bridge to Ruewood including work on the Houlston Brook and the replacement of the culvert through the airfield. This scheme gave a great deal of benefit to riparian farmers along the Sleap and much land was subsequently underdrained. Maintenance has been carried out on behalf of riparian owners by the County Council as follows:

1962	Ruewood to Burlton Drain
1964	Tilley Bridge
1968	Ruewood to Noneley

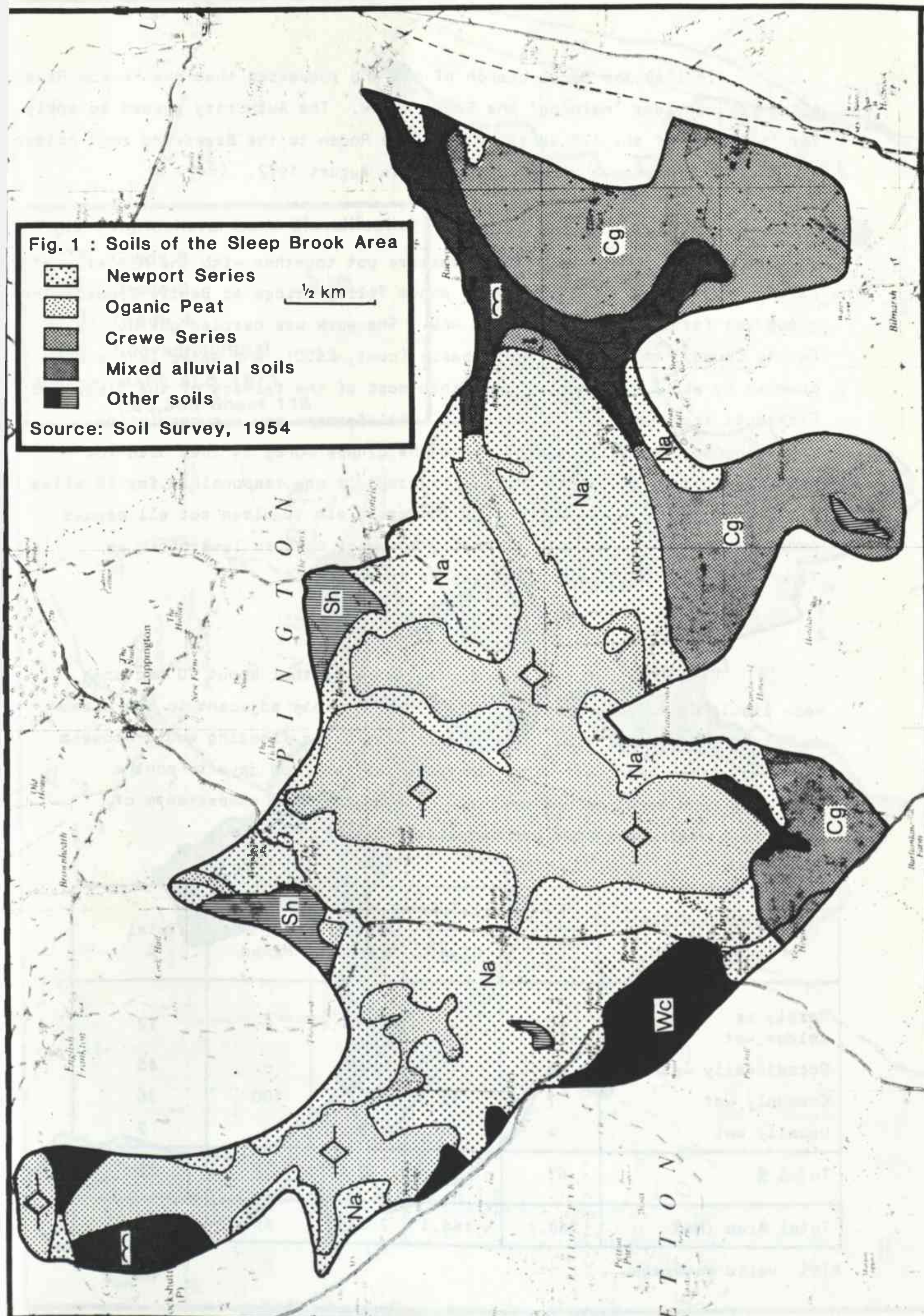


Fig. 1 : Soils of the Sleep Brook Area

In 1968 the local branch of the NFU requested that the Severn River Authority consider 'maining' the Sleap Brook. The Authority agreed to apply for 'maining' of the 4.5 km reach from the Roden to the Brandwood road bridge in 1969 and Ministry approval was given in August 1972. (Ref. 3).

In 1967 a group of five farmers got together with the Ministry of Defence to improve the Sleap Brook above Tilley Bridge to Bently Brook. The group was formed with the help of NFU. The work was carried out by the County Council on a rechargeable basis (cost, £600), and water levels were lowered by about two feet. Since then most of the farmers of the Sleap and Cockshutt area have joined the group. All farmers pay a subscription according to the area of benefit and the groups money is then used for regular watercourse maintenance. The group is now responsible for 18 miles of watercourse (see Figure 3). The group aim to clean out all brooks once every three years, but generally they are cleaned less often as finance restricts the work that can be done.

4. PRE-SCHEME LAND DRAINAGE STATUS

The results of the farm survey indicate that about 70 hectares were liable to flooding prior to the scheme (mainly adjacent to the Sleap downstream of Fiddler's bridge), and in most cases flooding would occur a number of times each year with durations varying from days to months depending upon location and weather. The qualitative assessments of pre-scheme drainage status are summarized in Table 1 below.

Drainage Class	Soil Type (% of area)				Total %
	Sandy Loam	Clay	Peat	Mixed	
Rarely or seldom wet	27	-	6	-	12
Occasionally wet	66	-	56	-	43
Commonly wet	7	72	30	100	36
Usually wet	-	28	8	-	9
Total %	67	80	92	87	78
Total Area (Ha)	268.1	164.4	258.6	49.3	740.8*

*78% valid coverage.

Table 1 : Pre-scheme Drainage Status

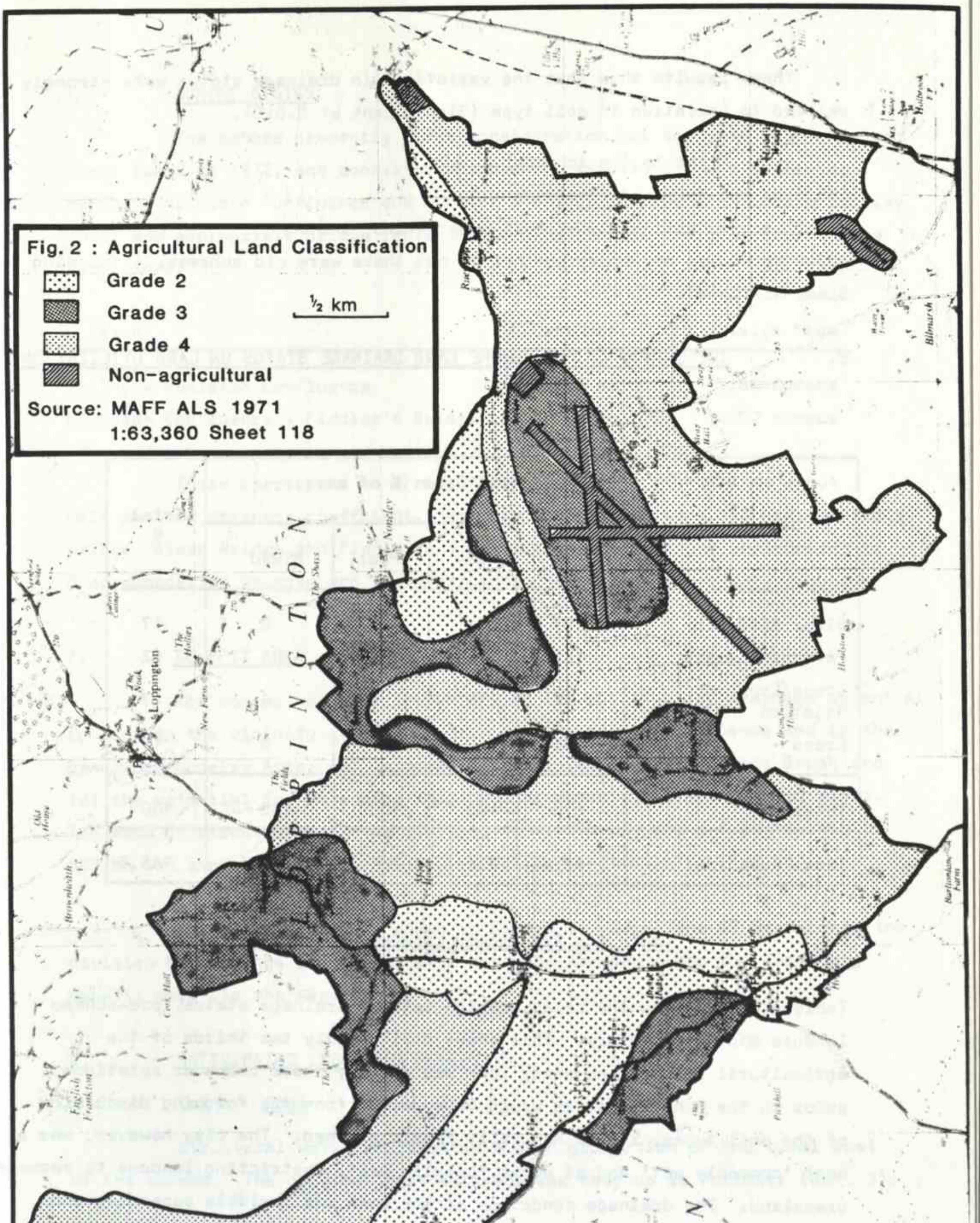


Fig. 2 : Agricultural Land Classification

These results show that the variations in drainage status were strongly related to variation in soil type (Significant at 0.01%).

Prior to the scheme:

284.6 ha had been underdrained;

332.7 ha were definately without underdrains; and on

303.8 ha it was not known whether or not there were old schemes, (including Sleap Airfield).

5. THE IMPACT OF PRE-SCHEME LAND DRAINAGE STATUS ON LAND UTILIZATION

Landuse Class	Soil Type (% of area)				Total %
	Sandy Loam	Clay	Peat	Mixed	
Sleap Airfield	27	11	0	0	17
Permanent Grass	26	81	93	100	62
Grass/Crop Rotation	12	8	0	0	7
Crops	35		7	0	17
Total %	100	100	100	100	100
Total Area (Ha)	401.2	206.0	281.7	56.6	945.5

Table 2 : Pre-Scheme Landuse by Soil Type

Tables 1 and 2 show the relationships between drainage status, pre-scheme landuse and soil texture. This shows that roughly two thirds of the agricultural land on the sandy loam was already under crops or rotations prior to the scheme and, as would be expected from the forgoing discussion of the soil types, it was naturally freely drained. The clay however, was at best 'commonly wet' and at worst 'usually wet', restricting landuse to permanent grassland. The drainage condition of the peat was variable depending upon local outfall conditions and although 93% was under permanent grass crops could be grown in places. The mixed soils were all classified as commonly wet and were entirely under permanent grass.

6. SCHEME DESIGN

The scheme presently under consideration was designed by the Severn River Board in 1972, and consisted of channel resectioning and regrading between the Roden Confluence and Fiddler's Bridge (on the Brandwood - Noneley road) and appropriate bridge replacement. The channel design criteria were as follows:

Reach	Catchment	Design Flow
Tilley - Houlston Confluence	51.75 km^2	7.65 cumecs
Houlston Confluence - Fiddler's Bridge	27.20 km^2	4.02 cumecs

These correspond to a run-off of 12.8 mm in 24 hours or about half an inch drainage coefficient. New highway bridges were planned for Tilley Bridge, Sleap Bridge and Fiddler's Bridge in addition to the replacement of 5 accommodation bridges and the underpinning of 3 others.

7. BENEFIT AREA

The scheme was intended to afford (a) satisfactory drainage potential to land in the vicinity of the Lyon's Wood watercourse confluence and in the Brandwood/Noneley Area; (b) improvement potential to the Houlston Brook and (c) the potential for extending improvements above the limit of main river. The area of direct benefit was assessed to be 550 ha, and a further area of 650 ha was expected to derive improved drainage potential. (Ref. 3).

The Benefit Area is shown in Figure 3. Grid line 47 represents the division between the primary benefit area (to the east) and the secondary benefit area (to the west).

8. ANTICIPATED COSTS AND BENEFITS

(a) Cost

Structural works represented a high proportion of the total cost of the scheme. The original cost estimate was made up as follows: (Ref. 3).

	£
Channel excavation and ancillary works	10,205
Highway Bridges	12,000
Accommodation Bridges	5,400
Contingencies	2,795
	30,400

It was anticipated that the County Council would contribute 25% of the cost of the replacing Tilley Bridge.

(b) Benefits

The Engineers Report (Ref. 3) made no mention of any assessment of benefits, other than to define the benefit area.

9. THE SCHEME

Work commenced in January 1974. By April channel excavation had been completed between Fiddler's Bridge and Sleap Bridge and all channel excavation had been completed by February 1975 and outfalls had been made good. It is unusual to work downstream on such a scheme, but in this case it was made necessary by a delay in the replacement of Tilley Bridge (the downstream limit of the scheme), being undertaken by the County Council.

Further delays were encountered in the replacement of Fiddler's Bridge. As a result of supervision difficulties within the Authority, the County Council were requested to take on responsibility for the Bridge. This they declined to do, and following pressure from the NFU, STWA agreed to carry out the work using direct labour. The whole scheme was not completed until November 1977.

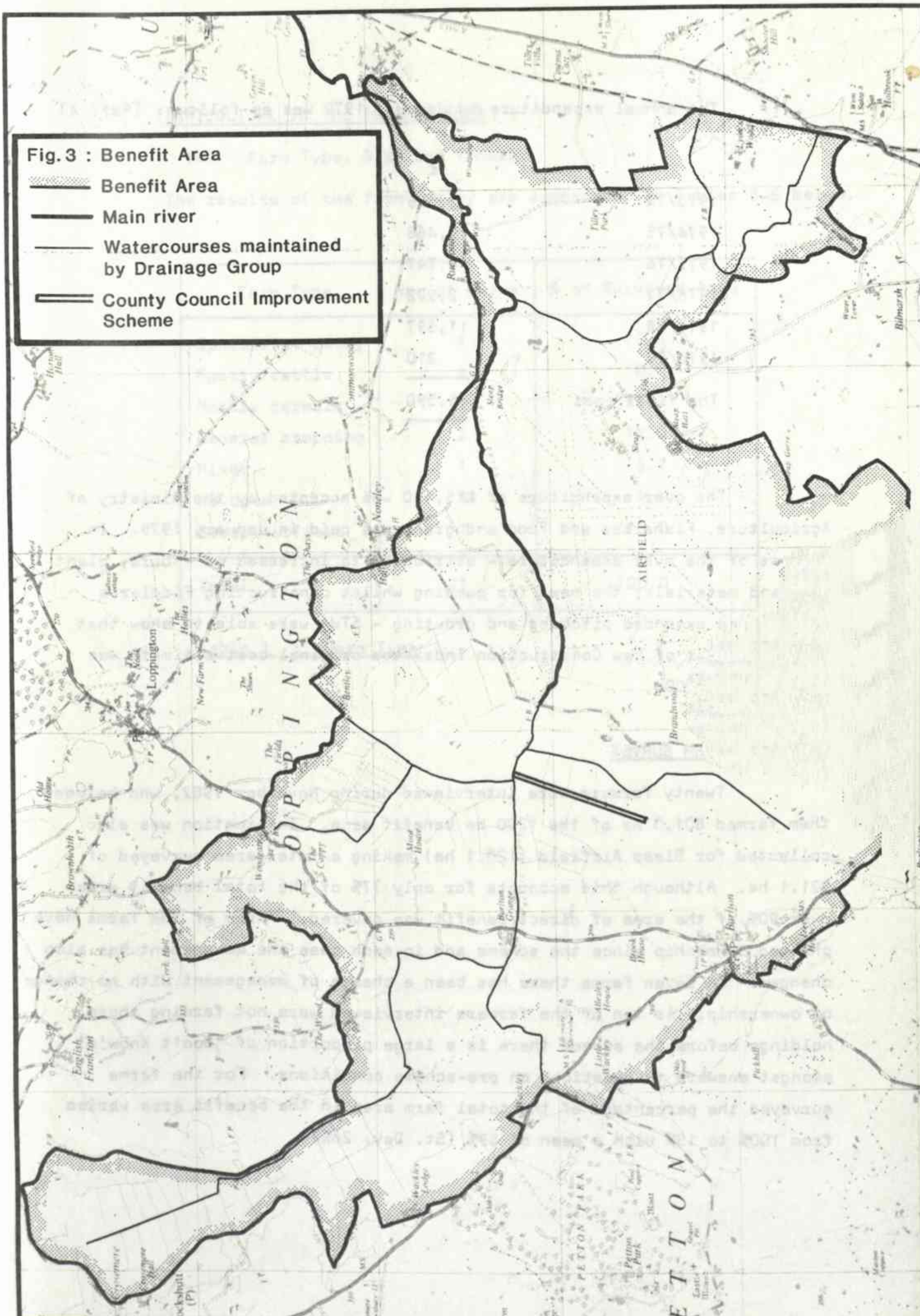


Fig. 3 : Benefit Area
Benefit Area
Main river
Watercourses maintained by Drainage Group
County Council Improvement Scheme
LOPPINGTON
AIRFIELD
Loppington

The annual expenditure to January 1979 was as follows: (Ref. 4)

	£
1973/74	2,596
1974/75	19,468
1975/76	8,747
1976/77	2,972
1977/78	11,597
1978/79	210
The final cost	£45,590

The over expenditure of £15,190 was accepted by the Ministry of Agriculture, Fisheries and Food and grant was paid in January 1979. In defence of the over expenditure - attributed to increased man-hours, plant hire and materials; the need for pumping whilst constructing Fiddler's Bridge; and extended pitching and grouting - STWA were able to show that using the Cost of New Construction Index the original cost estimate was equal to £47,000.

10. FARM SURVEY

Twenty farmers were interviewed during November 1982, who between them farmed 801.0 ha of the 1200 ha benefit area. Information was also collected for Sleap Airfield (120.1 ha) making a total area surveyed of 921.1 ha. Although this accounts for only 77% of the total benefit area, over 90% of the area of direct benefit was covered. Three of the farms have changed ownership since the scheme and in each case the management has also changed. On seven farms there has been a change of management with no change of ownership. As ten of the farmers interviewed were not farming those holdings before the scheme there is a large proportion of 'Don't Know's' amongst answers to questions on pre-scheme conditions. For the farms surveyed the percentage of the total farm area in the benefit area varies from 100% to 15% with a mean of 59% (St. Dev. 26%).

11. <u>AGRICULTURE IN THE BENEFIT AREA</u>

(a) Farm Type, Size and Tenure

The results of the farm survey are summarized in Tables 3-6 below.

Farm Type	No. of Farms	% of Surveyed Area
Specialist dairy	9	40.6
Mostly cattle	2	10.3
Mostly cereals	2	16.3
General cropping	2	12.0
Mixed	1	3.7
No data	4	4.1
Sleap Airfield	1	13.0
Total	21	100.0

Table 3 : Farm Type

Management Status	% of Farm Owned						Total
	0	1-25	25-50	50-75	75-99	100	
Sole proprietor	1					4	5
Partnership	1		2		1	7	11
Manager						1	1
Total	2	0	2	0	1	12	17

NB Data were unavailable for three farms and Sleap Airfield.

Table 4 : Farm Management and Tenure

Farm Size (ha)	No. of Farms	% of Surveyed Area
5 - 10	1	1.0
10 - 20	1	2.1
20 - 30	0	0.0
30 - 40	2	5.7
40 - 50	0	0.0
50 - 100	9	42.4
100 - 200	5	28.6
200 - 300	1	6.7
No data	1	0.5
Sleap Airfield	1	13.0
Total	21	100.0

Mean = 83.1 ha St. Dev = 55.3 ha

Table 5 : Farm Size (Hectares)

Farm Size (SMD)	No. of Farms	% of Surveyed Area
250	0	0.0
250 - 500	5	40.6
500 - 1000	6	10.3
1000 - 1500	3	16.3
1500 - 2000	1	12.0
2000 - 3500	0	3.7
3500	1	0.0
No data	4	4.1
Sleap Airfield	1	13.0
Total	21	100.0

Mean = 948 SMD St. Dev = 896 SMD

Table 6 : Farm Size (Standard Man Days)

The dominant farm type is 'Specialist Dairy' with nine farms accounting for 40% of the area surveyed. With the 10% in 'Mostly Cattle', livestock farms account for half the area surveyed. Four farms are in arable classes, accounting for 28% of the area surveyed. Thirteen percent of the area surveyed is currently within the bounds of Sleap Airfield (see 13 below for details).

Table 4 shows that the majority of farms are owner occupied with only two being wholly rented. Over half of the farmers are in partnerships (usually family). One was a full-time manager.

Fourteen of the farms surveyed are of sizes between 50 and 200 ha and accounted for 70% of the area surveyed. The average farm size is 83 ha. None of the farms surveyed is within the category of 'part-time' farms (ie. less than 250 Standard Man Days) and most are within the range 250 - 1500 SMD. The average for the 16 valid cases is 948 Standard Man Days.

(b) Dairy Enterprises

The dominant farm type is Specialist Dairy (9 farms) although 13 farms have dairy enterprises. Herd size varies from 40 to 200 cows (mean 98 cows, St. Dev 43 cows) and milk yield averages 5723 litres per cow (St. Dev 699 litres). The current stocking rate on Specialist Dairy farms averages

2.06(St. Dev 0.4) Livestock Units (LU) per hectare of grass.[1] Traditionally dairy has been the most important enterprise and the area was severely hit by the outbreak of Foot and Mouth disease in 1967. During the 1970's three of the farms surveyed went out of dairying and switched to arable enterprises. In two cases this was achieved with the aid of EEC support.

(c) Beef Enterprises

Eleven farms keep cattle for beef although only two farms fall within the category of 'Mostly Cattle'. Beef herds range from 12 to 144 cattle (mean 70 cattle, St. Dev 54 cattle). Many of the dairy farms breed their own replacements and sell a number of steers. The average stocking rate on 'Mostly Cattle' farms is 0.84 LU per hectare of grass[1] although the standard deviation is high 0.9 LU). Beef cattle are also kept on mainly arable farms; in some cases this has been because of the regulations associated with EEC support for going out of dairy. Stocking rates on 'Mostly Cereals', 'General Cropping' and 'Mixed' farms average 2.06 LU per hectare of grass.[1] There is no preference of beef system; there are intensive cereal beef systems, 18 month systems, suckler herds and store finishing systems in addition to the irregular sale of surplus dairy calves.

(d) Arable Enterprises

Four of the farms surveyed are classified as 'Mostly Cereals' or 'General Cropping' and one as 'Mixed'. Fourteen of the farms surveyed have arable enterprises within the benefit area (those that did not were all dairy farms). The main crops grown are spring cereals (sometimes for stockfeeding), winter cereals, and roots. Some fodder crops are also grown. Current average crop yields are as follows:

Crop	Yield range
Spring barley	2.5 - 5.0 t/ha
Winter barley	5.6 - 6.4 t/ha
Winter wheat	6.3 - 7.5 t/ha
Sugar beet	34.6 - 44.5 t/ha
Potatoes	37.1 - 39.5 t/ha

Table 7 : Average Crop Yields

1 Weighted by area in benefit

12. EFFECTS OF THE SCHEME ON FLOODING AND LAND DRAINAGE

Following the improvement works the Sleap Brook has not flooded and flooding has been alleviated on arterial watercourses that have now been given an improved outfall at the confluence with the Sleap following the scheme. There is potential for the improvement of all watercourses in the area to provide sufficient freeboard from field drainage throughout the area.

13. AGRICULTURAL BENEFITS OF THE SCHEME

(a) Land Use Change

NB All figures refer to the total area surveyed with full information, but excluding land that in 1974 was in non-agricultural use (eg. Sleap Airfield).

The major change has been a reduction in the area of permanent pasture and corresponding increase in the areas of arable land uses. Roughly 50% of the area (281.7 ha) of permanent pasture in 1974 has now been ploughed and is used as follows:

- 26% Temporary Grass
- 40% Grass/crop rotation
- 34% Crops

This change has occurred on all soil types, and roughly to the same degree on each. However, the direction of the change has varied according to the soil type.

(i) On the sandy loam 45% (47.7 ha) of the permanent pasture has been ploughed; 60% of this has gone into a grass/crop rotation and 23% into temporary grass. Seventeen percent is now under crops.

(ii) On the clay 49% (81.4 ha) of the permanent pasture has been ploughed. Sixty-five percent has been reseeded as temporary grasses and 35% has gone into a grass/crop rotation.

(iii) On the peat 53% (121.5 ha) of the permanent pasture has been ploughed. Only 6% has been reseeded as temporary grass. Forty-five percent has gone into a grass/crop rotation and the remaining 49% into continuous crops. A small area (3.2 ha) has changed from crops to permanent pasture.

(iv) On the remaining area of sand or mixed alluvial soils, all permanent pasture has been ploughed (59.4 ha) and reseeded as temporary grass or taken into a grass/crop rotation.

Other changes of land use have been relatively minor, 48.6 ha of 'crops' has become 'grass/crop rotation' and vice-versa on 19.8 ha. This has all taken place on the sandy loam.

1982 Land Use / Pre-scheme Land Use	Permanent Grass	Temporary Grass	Grass/Crop Rotation	Crops	Total
Permanent grass	268.5	73.6	115.4	95.9	553.4
Temporary grass		6.9			6.9
Grass/crop rotation			40.7	19.8	60.5
Crops	3.2		48.6	112.2	164.0
Total	271.7	80.5	204.7	227.9	784.8

NB Woodland = 9.5 ha

Table 8 : Land Use Change 1974-82 (excluding Sleap Airfield)

	% Area Before	% Area After	Net Change (ha)
Permanent grass	69.9	34.3	- 281.7
Temporary grass	0.9	10.1	+ 73.6
Grass/crop rotation	7.6	25.8	+ 144.2
Crops	20.7	29.7	+ 71.2

Table 9 : Net Land Use Change 1974-82 (excluding Sleap Airfield)

The present land use pattern is as follows

Land Use \ Soil Type	Sandy loam	Clay	Peat	Other	Total
Permanent grass	19%	47%	43%	38%	35%
Temporary grass	4%	28%	3%	15%	10%
Grass/crop rotation	25%	25%	23%	47%	26%
Crops	52%		31%		29%
Total area (ha)	294.8	183.8	239.9	66.3	784.8

Table 10 : Land Use in 1982

Figure 4 shows that the rate of change of land use was more rapid in the early years of the scheme. In all 335.2 ha of the area surveyed has changed land use. Seventy percent of this change occurred within the first two years after the scheme. However, four farms accounted for nearly all of this, and in each case there were important extraneous circumstances; either a recent change of management or a wholesale change of enterprise (eg. from dairy to arable).

(b) Sleap Airfield

Sleap Airfield was sold by the Ministry of Defence in 1972 when it was purchased by Don International who use the perimeter track for testing vehicle brakes. The runways are presently used by a local aero-club. Land beyond the perimeter track was sold to local farmers and large areas of concrete (aircraft standing bays and bomb dumps) have been broken up and put down to grass again (these areas appear on the questionnaire returns for individual farmers).

The area between the runways and perimeter track (87.7 ha) was let off in 1972 to a local farmer under a three-year mowing licence and hay was cut and sold to Welsh farmers. When the licence was renewed in 1976 permission was granted by the owners to plough the land and 71.6 ha were brought into an arable rotation. The remaining 16.1 ha were left under grass. Since 1982 the land has been let to a different farmer under an annual lease and all is under winter cereals.

Table 11 : Field Drainage Installations

Date of Drainage	Pre-scheme Drains	Land Use			Soil Texture	Field Size (Ha)
		Pre-Scheme	Post-Scheme	Date of Change		
1974	Yes	Permanent Grass	Crops	1981	Peat	2.0
1976	No	Permanent Grass	Grass/crops	1975	Peat	4.9
	No	Permanent Grass	Grass/crops	1975	Peat	6.5
	Yes	Permanent Grass	Permanent Grass	-	Peat	15.8
1978	Yes	Permanent Grass	Crops	1978	Peat	3.2
	Yes	Permanent Grass	Crops	1978	Peat	4.5
		Permanent Grass	Crops	1978	Sandy Loam	4.5
1979	No	Permanent Grass	Crops	1979	Peat	21.9
	No	Permanent Grass	Crops	1979	Sandy Loam	11.3
	No	Permanent Grass	Crops	1979	Clay	16.2
	Yes	Permanent Grass	Permanent Grass	-	Peat	2.8
1980	Yes	Grass/Crops	Grass/crops	-	Clay	2.8
	Yes	Grass/crops	Grass/crops	-	Clay	3.2
	Yes	Grass/crops	Grass/crops	-	Clay	4.5
		Airfield	Crops	1976	Clay	4.0
1981		Permanent Grass	Temporary Grass	1975	Clay	12.1
	No	Permanent Grass	Permanent Grass	-	Clay	2.8
		Permanent Grass	Crops	1981	Peat	25.1
		Airfield	Crops	1976	Sandy Loam	12.1
1982	Yes	Permanent Grass	Grass/crops	1982	Clay	5.3
	No	Permanent Grass	Permanent Grass	-	Clay	6.9
	Yes	Permanent Grass	Crops	1982	Peat	6.9
	Yes	Crops	Crops	-	Peat	15.4
Unknown	Yes	Permanent Grass	Permanent Grass	-	Sandy Loam	1.2

Fig 4 LANDUSE CHANGE

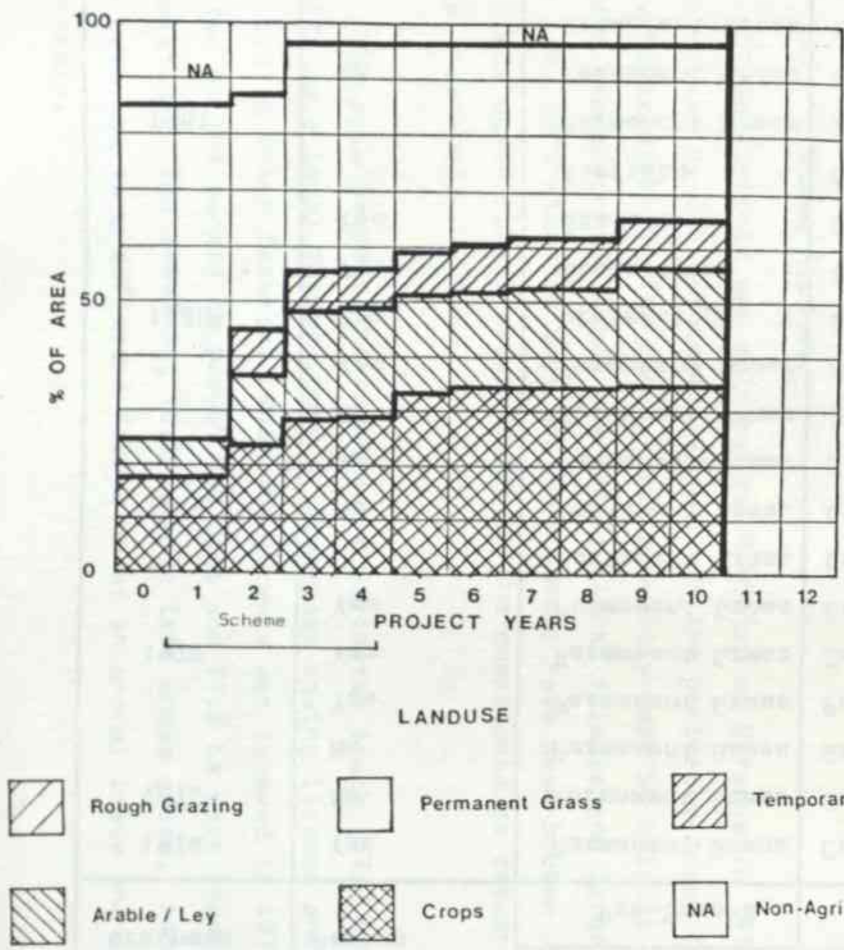
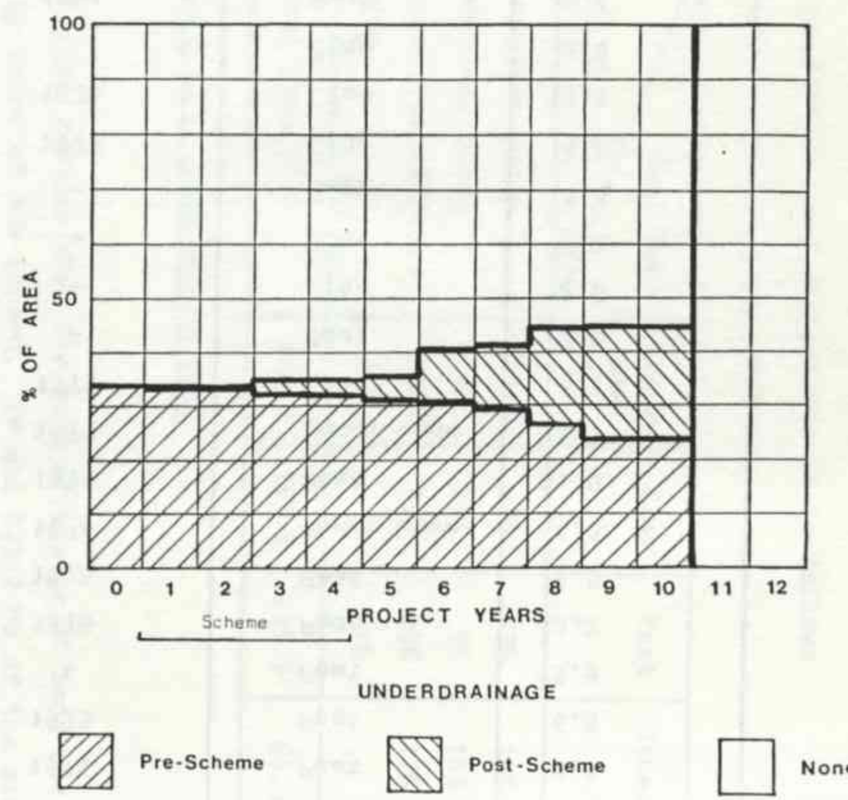


Fig 5 INSTALLATION OF UNDERDRAINAGE



(c) Field Drainage Installation

Prior to the scheme 31% of the area already had field drains installed, 36% definitely had no working drains. On the remainder either the occuper didn't know if there were old drains or not, or there were old drains that were unlikely to be working. The proportion of the areas of soil types that was already drained is higher on the peat and clay (over 40% of each) and lower on the sand (about 20%).

Since the scheme 195 ha (21% of the area surveyed) have been drained by 24 schemes (see Table 11). Two-thirds has been 'new' drainage (ie. no previous drains) and one-third has been redraining (ie. replacement or upgrading of existing systems).

Fifty-five percent of the post-scheme drainage (by area) was in the peat and 30% in the clay. Fifteen percent was in the sandy loam.

Seventy-one percent of the redrained area is on the peat and 26% on the clay. Sixty-two percent of the new drainage has been in the peat and 26% in the clay.

Thus at present 45% of the area has working drains (either new or old). The remaining 55% either has no drains or has old drains that are judged by the farmer to be inadequate. This is equal to 71% of the sandy loam, 39% of the clay, 33% of the peat and 85% of the other soil types. Most drainage work, in terms of area, has taken place on arable farms, ie. Mostly Cereals or General Cropping (see Table 12), however a larger number of schemes has been on dairy farms.

Farm Type	Ha	%
Dairy	49	25
Mostly Cattle	7	4
Mostly Cereals	72	37
General Cropping	39	20
Mixed	7	3
'Don't Know'	21	11
Total	195	100

Table 12 : Field Drainage by Farm Type (at time of drainage)

Drainage installation has not always been associated with land use change, although in only five schemes (30 ha) has land stayed under permanent grass after drainage. In nine cases (99 ha) drainage and land use change took place concurrently, in one (2 ha) drainage preceeded change, and in four (20 ha) drainage followed, up to five years after, a change of land use. In four cases (26 ha) the land was already under arable use.

Eleven blocks of land, totalling 165.6 ha (18% of the area surveyed) were identified by the farmers as being in need of drainage work. The reasons for not draining are summarized below:

Reason	Area (ha)
Insufficient outfall	2.0
Couldn't afford to drain	54.3
There would not be enough benefit to justify the cost	15.8
Other reasons	93.5

Table 13 : Reasons for not draining

Other reasons include - a belief that drainage of peat is generally unsuccessful, change of ownership of land, and waiting to see what effect other, especially arterial works, will have. (5.7 ha of the above were due for drainage in 1983.)

The rate of installation of field drains is shown in Figure 5. The average rate is about 20 ha/year but the rate of installation has not been constant; being slower in the early years (1974-78) and more rapid since.

(d) Arterial Drainage Work

(i) By Individuals

Twelve of the 20 farmers for whom data were collected have carried out work on the arterial drainage of their land. In most cases this was ju routine maintenance of the ditches, carried out every 2-5 years. A group of farmers in the Noneley area have got together to install a piped main across their land directly into the improved section of the Sleap at a gross cost of £15,000. This pipe, over 1 ft. in diameter, is approximately 1 m lower than the existing main it replaces.

(ii) Sleap and Cockshutt Drainage Group

The Drainage Group has maintained the major arterial ditches (see Figure 3), roughly every five years since the mid-1960's. Although most of the work has been of a maintenance nature, a significant improvement has been achieved over the years.

(iii) Salop County Council

In 1977 the Salop County Council were requested by the riparian owner to carry out an improvement scheme under Section 99 of the Land Drainage Act (1976). The scheme was planned to commence at the upstream limit of STWA works at Fiddler's Bridge and include 0.366 km of the Sleap and then about 2 km of the Burlton Drain (see Figure 3). The scheme to resection and regrade the brook had become necessary because of the shrinkage of the peat soils. The scheme lowered water level in the Burlton Drain by about 1 m, taking full advantage of the STWA scheme. The scheme was completed in February 1979 at a total cost of £15,513 (gross) towards which 50% MAFF grant was paid. According to the design, 69 ha were expected to benefit; 28 ha of which were peat moor which previously was waterlogged for much of the year and 41 ha of 'potentially good arable land'. A further 20 ha east of the Burlton Drain were expected to benefit from the increased channel depth. About 50 ha of the benefit area have since been underdrained (Ref. 5).

(d) Rate of Benefit Uptake

A financial assessment of the Sleap Brook improvement scheme has been undertaken by identifying, on the basis of farmer interview, the change in farm enterprise gross margins attributable to drainage improvements, net of any additional fixed costs, and including the benefit of extended grazing if relevant. The procedures used for this purpose are described in Annexe V.

A summary of extra financial net returns (before field drainage costs) by farm is given in Table 14. Of seventeen potential beneficiaries, twelve perceived benefits had accrued. Two farmers on 17%, derived over 60% of the benefits in 1983/4. The overall average rate of uptake on the area surveyed (925 hectares) is shown in Figure 6. Extra annual net returns attributable to the scheme and related improvements were £66 per hectare in 1983/4.

Table 14 : Distribution of Benefits by Farm

SCHEME 32 NET AGRICULTURAL BENEFIT

FARM CODE	YEAR FIRST	YEAR 3	YEAR 7	YEAR LAST	% OF BENEFITS	% OF AREA
2	45	135	943	2374	4	2
3	100	302	605	1995	3	7
4	0	0	0	0	0	6
5	0	0	14139	14139	24	7
6	0	0	0	0	0	5
7	0	0	0	0	0	6
8	0	0	0	0	0	5
9	291	-745	421	1295	2	7
10	0	0	0	0	0	7
11	598	784	1064	1064	2	2
12	0	0	340	340	1	7
13	0	0	6727	6727	12	4
14	54	163	326	1051	2	7
15	0	0	1012	1523	3	4
16	0	713	1694	5513	9	11
17	210	768	768	768	1	4
18 *	8128	17496	17496	21705	37	10
TOTAL				58500	100	880

* Sleap Airfield

FIGURE 6 : Degree and Rate of Financial Uptake

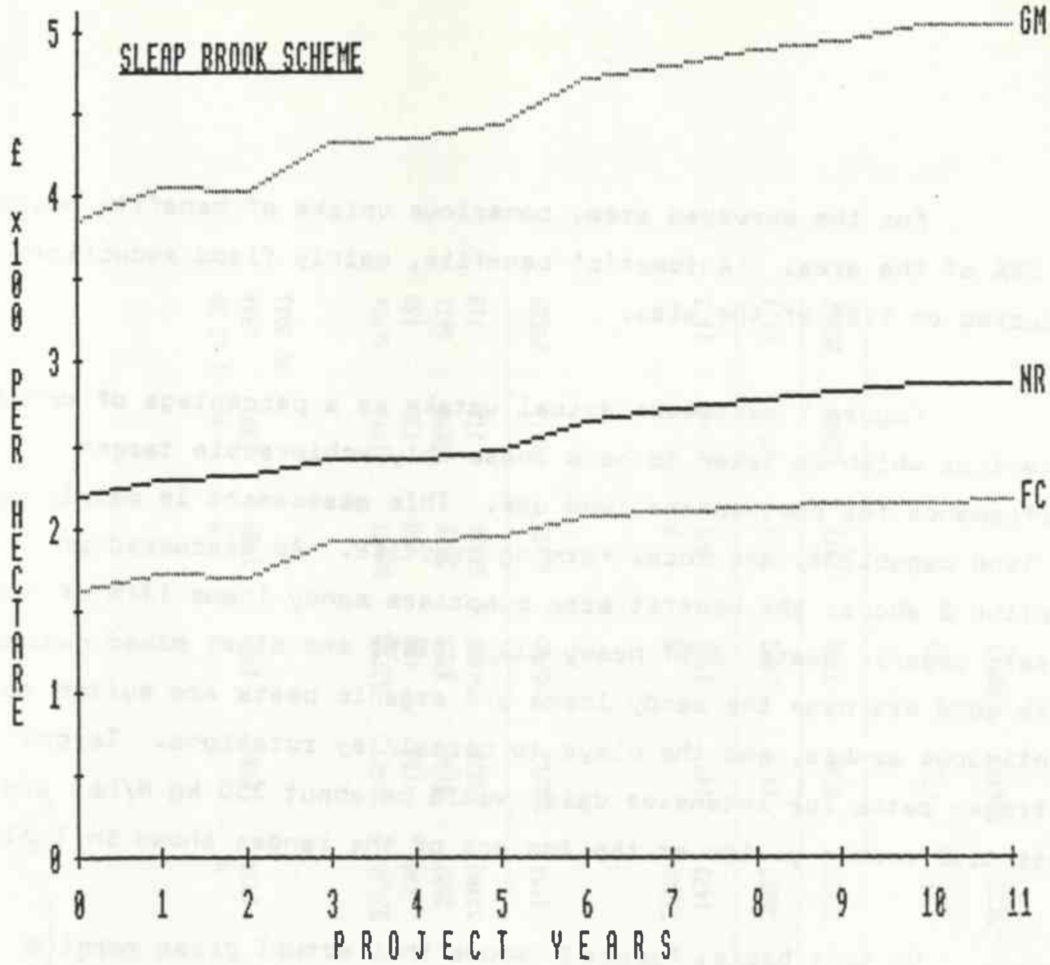
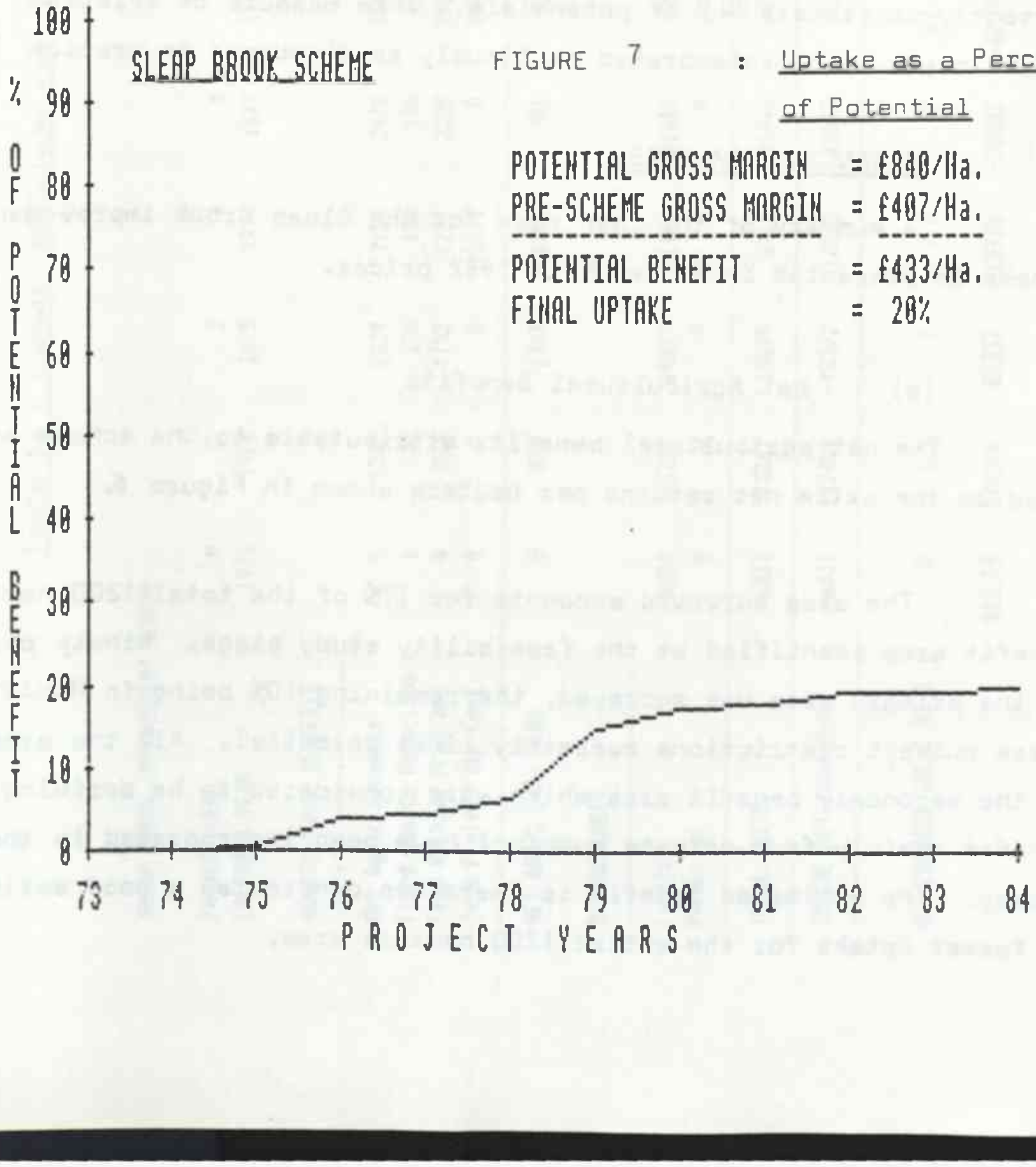


FIGURE 7 : Uptake as a Percentage of Potential



For the surveyed area, conscious uptake of benefits occurred on 38% of the area. 'Automatic' benefits, mainly flood reduction occurred on 1.8% of the area.

Figure 7 expresses actual uptake as a percentage of scheme potential which is taken to be a reasonably achieveable target performance for post-scheme land use. This assessment is mainly based on land capability and local farming practice. As discussed in section 2 above, the benefit area comprises sandy loams (44% of total area), organic peats (20%) heavy clays (18%) and other mixed categories. With good drainage the sandy loams and organic peats are suited to continuous arable, and the clays to cereal/ley rotations. Target nitrogen rates for intensive dairy would be about 350 kg N/ha, and potential arable yields at the top end of the ranges shown in Table 6.

On this basis, Figure 7 shows that actual gross margins presently constitute 20 % of potentials. This measure of relative uptake needs to be interpreted cautiously as discussed in section IX 4 (d)

14. FINANCIAL ANALYSIS

A summary of the cash flow for the Sleap Brook improvement scheme is presented in Table 15 in 1982 prices.

(a) Net Agricultural Benefits

The net agricultural benefits attributable to the scheme are based on the extra net returns per hectare shown in Figure 6.

The area surveyed accounts for 77% of the total 1200 hectare benefit area identified at the feasibility study stage. Ninety percent of the primary area was surveyed, the remaining 10% being in Houlston where culvert restrictions currently limit potential. All the areas in the secondary benefit area which were considered to be deriving benefit (mainly from private pumping) have been incorporated in the survey. The estimated benefit is therefore considered a good estimate of farmer uptake for the entire 1200 hectare area.

Table 15 : Summary of Scheme Cash Flow and NPU

SLEAP BROOK IMPROVEMENT SCHEME												
PROJECT YEAR	0	1	2	3	4	5	6	7	8	9	10	11 TO 30
CALENDAR YEAR	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984 TO 2003
AGRICULTURAL BENEFITS												
Net Agric Benefits	0	1301	2329	2124	2979	7441	22435	28045	33755	36593	41094	36796
Flood Damage Reduction	0	130	130	130	130	130	130	130	130	130	130	130
less Without Proj Ben	0	573	1152	1737	2328	2924	3527	4136	4750	5371	5998	6631
less Field Drain Cost	0	0	0	6671	0	3892	53492	13826	34900	37750	710	710
NET AGRIC CASH FLOW	0	858	1307	-6154	781	755	-34454	10213	-5765	-6398	34516	29585
SCHEME COSTS												
Capital	6831	43262	19879	6461	21443	323	37210	0	0	0	0	0
Recurrent	0	0	0	0	0	0	1473	1473	1473	1473	1473	1473
TOTAL COSTS	6831	43262	19879	6461	21443	323	38683	1473	1473	1473	1473	1473
SCHEME NET CASH FLOW	-6831	-42404	-18572	-12615	-20662	432	-73137	8740	-7238	-7871	33043	28112
NET PRESENT VALUE AT %	0	2.5	5	7.5	10	12.5	15	17.5	20			
	415119	199296	81337	15928	-20503	-40575	-51231	-56390	-58312			

Benefits are assumed to continue at their 1984 level over remaining project life. No predictions of future uptake are made. The senestivity of the scheme to benefit assumptions are considered in section 14 (g).

(b) Capital and Recurrent Costs

Total capital costs were £135,410 in 1982 prices including land drainage investments by the Noneley farmers group (£18,290) and Salop County Council (£18,920). This represents an average expenditure of £212 per hectare of direct benefit (550 ha) or £113 per hectare in total (1200 ha).

Recurrent costs for the scheme have been assumed at 1½% of gross capital per year.

(c) Field Drainage Costs

The total cost of field drainage installations since the scheme has been £149,621 in 1982 prices, an average £770 per hectare drained, and an average expenditure of £162 per hectare over the 925 hectares deriving benefit.

Prior to the improvement scheme, farmers and farmer groups undertook regular ditch maintenance and no incremental maintenance expenditure on their part is assumed. About 30 hectares of land are pumped drained at an estimated cost of £15/ha/year. Moling schemes have been implemented on 28 hectares, and moling costs of £30 per hectare every four years are assumed.

(d) Flood Damage Reduction

Only one farmer reported pre-scheme flood damages, in this case relating to the loss of 6 ha of hay. At an estimated return period of one in 15 years, the removal of flood risk saves £130/year.

(e) Without-Project Benefits

It is assumed that on farms where post-scheme takeup has materialised, farming financial performance would have improved without the scheme at the rate of 1% compound per year. In the case of the Sleap Brook, benefits have been taken up on 37% of the area surveyed. Without-project benefits are therefore estimated at 1% compound of the pre-scheme net returns (£212,335) multiplied by 37%, ie £78,139 x 1% compound per year.

(f) Project Worthwhileness

Table 13 shows that 37% of the benefits measured were on Sleap Airfield. This is largely because the Airfield was not used for agriculture prior to the scheme. Its subsequent management has been dictated by the owners of the land and is only partially a response to improved drainage (see Section 13 (b)). The project has therefore been evaluated without taking into account the benefits to the airfield, which have been considered in the sensitivity analysis below.

Assuming benefits continue at their present level over a 30 year project life the net present value of the scheme at the 5% discount rate is £81,337 in 1982 prices. The internal rate of return of the scheme is 8.3%. This relatively high rate of return reflects the characteristics of the scheme: namely, the large benefit area and relatively low costs per hectare of benefit, the scheme was incremental in nature enabling fuller exploitation of earlier investments, and farmers have been quick to exploit the arable potential of the land.

(g) Sensitivity Analysis

Table 16 examines the sensitivity of the scheme to selected benefit and cost assumptions. Agricultural benefits would need to decline by more than 20% of their present estimated level to make the scheme unprofitable at 5% discount rate. If the increase in net returns on Sleap Airfield and included the Net Present Value at 5% rises to £325,997 and the Internal Rate of Return to 20%.

Table 16

Sleap Brook - Sensitivity Analysis

Run No.	Agricultural Benefits Factor	Without Project Benefits Compounding Factor	Flood Damage Reduction Factor	Capital Works Cost Factor	NPV at 5% £	IRR %	Switching Value %*
1	1	1	1	1	81337	8.3	0.8
2	1	0	1	1	151778	11.1	0.6
3.	1	0.5	1	1	117316	9.8	0.7
4.	1	1.5	1	1	43777	6.9	0.9
5.	1	1	0	1	79434	8.4	0.8
6.	X	1	1	1	325997	20.0	0.5

X including Sleap Airfield

* The factors show the weights applied to the original estimates eg a factor of 1.5 for the without-project benefits indicates that the new value is 1.5 x 1% compound per year (the original value) ie 1.5% compound.

* Switching value : change in agricultural net benefits needed to make the project breakeven at 5% discount rate eg a 1.5 switch value shows an increase of 1.5 x the original estimated is required.

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1. Soil Survey of Great Britain (1954)
The Soils of the Wem District of Shropshire (Sheet 138), HMSO, London.

2. Ministry of Agriculture, Fisheries and Food (1971)
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3. Severn River Authority (1972)
Sleap Brook Improvement Scheme. Memorandum by the Engineer, L.W. Haines, August 1972 (unpublished).

4. Severn River Authority/STWA (1972-79)
Sleap Brook Improvement Scheme. Scheme Files, LDW.

5. Salop County Council (1977-79)
Burlton Drain Improvement Scheme (No. 1649). Scheme Files, LDW 31400.

APPENDIX H

Lower Trent Division

River Trent : Beckingham Marshes

SILSOE COLLEGE

STWA LOWER TRENT DIVISION - BECKINGHAM MARSH

Report on the background to, and development of the scheme and the nature and rate of uptake of agricultural benefits.

1. Physical Background

The Beckingham Marsh is an area of 1,000 hectares on the left bank of the River Trent in North Nottinghamshire opposite Gainsborough (Lincs.) and about 20 miles south east of Doncaster (S. Yorks.). It lies at the division between the upper, predominantly fluvial, and lower, predominantly tidal, Tidal Reach of the River Trent.

The present study relates to an area of 919 ha (2,270 ac) bound on the east by the River Trent between Saundby Beck and Marsh Road Drain, and on the west by the main railway line. The whole area, at an elevation of less than 6 m (20 ft) AOD (N), is within the Laneham Internal Drainage District and is drained by an intensive arterial network draining to the Beckingham Pumping Station at Point Farm.

2. Soils and Land Capability

The soils of 70% of Beckingham Marsh have been surveyed in detail by the Soil Survey (ref. 1). The results of the survey are shown in Figure 1 and summarized in Table 1 below.

Table 1 : Soils of the Beckingham Marsh

Soil Series	Dominant Tecture	Area (ha)	% Area
Fladbury) Stixwould)	Clay	499	79%
Blacktoft	Silty Clay Loam	40	6%
Brockhurst) Spetchley)	Sandy Clay Loam	57	9%
Stockwith	Silty Clay Loam	19	3%
Whimple) Worcester)	Clay Loam	16	2.5%
Spetchley	Clay	3	0.5%
		634	100%

The soils are described in detail in Appendix I.

The dominant soil type is the clay of the Fladbury series and Fladbury/Stixwould complex. Rising groundwater and a moderately low permeability cause wetness problems which necessitate comprehensive drainage and effective arterial control. The available water capacity is moderately large and can be supplemented by groundwater in dry seasons. Such soils are suitable for grass or cereals although cultivation is difficult and timeliness is critical. The clay is classified as class 3 with wetness and soil limitations paramount. The recommended underdrainage treatment is; drains at 70-90 cm depth, spaced at 14-20 m. Permeable fill and subsoiling are essential (ref. 1).

Immediately adjacent to the river is a band (up to 250 m width) of silty clay loam of the Blacktoft Series. This tidal warp soil is permeable and has a high available water capacity. Cultivation is easy and a wide range of arable and horticultural crops may be grown. This series is classified as class 1 or 2 depending on location.

The Stockwith Series is found where the tidal warp overlies less permeable alluvial clay. Timing of cultivation is fairly flexible and cereals or roots may be grown.

Along the western margin of the Beckingham Marsh, on slightly higher ground is an area of clay loam of the Worcester, Whimple and Brockhurst Series. Underdrainage is generally essential as the subsoil has a low permeability. Cultivation is difficult to very difficult; autumn ploughing, essential; and timeliness critical. These soils are classified as class 3 and are suitable for grass or cereals.

Although the remaining 30% of the Beckingham Marsh has not been surveyed in detail, the National Soils Map (Ref.5) suggests that the tidal warp is not present upstream of the loop opposite Morton (where the tidal influence is less marked) and the Fladbury/Stixwould Complex predominates.

3. <u>Land Drainage History</u>

The floodplain of the Trent Tidal Reach has been protected from inundation to varying degrees over the last 600 years and land drainage has been improved, particularly since steam driven pumps became available.

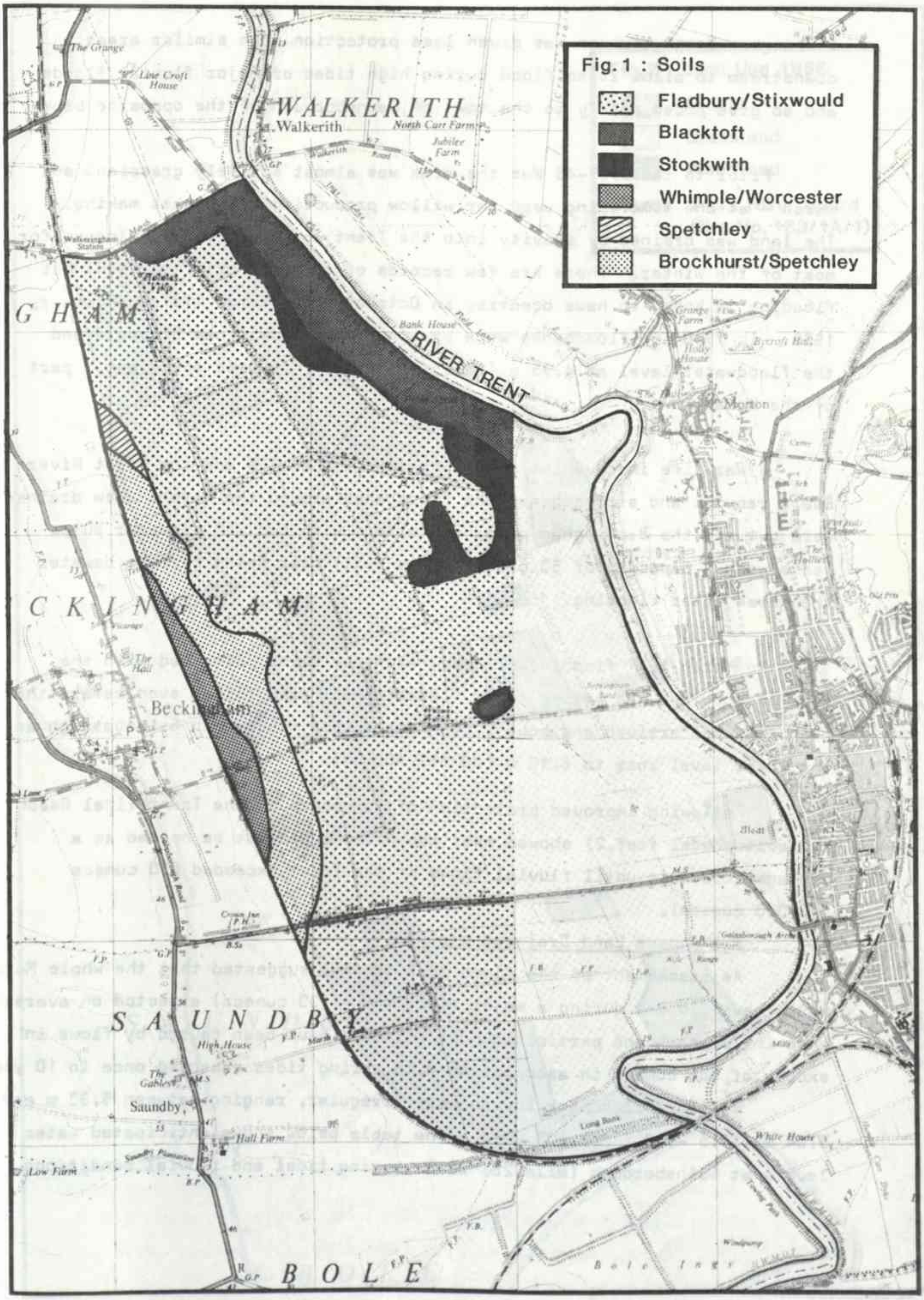


Fig. 1 : Soils
Fladbury/Stixwould
Blacktoft
Stockwith
Whimple/Worcester
Spetchley
Brockhurst/Spetchley
WALKERITH
RIVER TRENT
SAUNDBY
BOLE
Beckingham
Morton
Saundby

Beckingham Marsh however was given less protection than similar areas downstream to allow it to flood during high tides or major fluvial floods and so give added safety to the town of Gainsborough on the opposite bank.

Prior to the 1939-45 War the area was almost entirely grassland and marsh - at one time being used for willow production and basket making. The land was drained by gravity into the Trent and would be waterlogged for most of the winter. There are few records of flooding prior to 1940, but flooding is known to have occurred in October 1935, March 1937 and January 1938. In 1940 the floodbanks were breached near Beckingham Shipyard and the floodwater level at 4.95 m (16.25 ft) AOD (N) covered the greater part of the Marsh.

A War-time improvement scheme by the Laneham IDB and the Trent River Board rebuilt and strengthened the floodbanks around the Marsh. New drains were cut and the Beckingham pumping station, with two 36" diameter pumps (each with a capacity of 50 cusecs), was built near Point Farm to dewater the Marsh after flooding.

In March 1947 flooding occurred as heavy rains coincided with the thaw of snow and the spring tides. Beckingham Marsh filled even before the high tide had arrived and about 2,000 houses were flooded in Gainsborough as the water level rose to 6.10 m (20 ft) AOD (N).

Following improved protection of Gainsborough the Trent Tidal Reach Hydraulic Model (ref.2) showed that the Marsh would not be needed as a storage reservoir until fluvial flows in the Trent exceeded 850 cumecs (30,000 cusecs).

4. <u>Pre-scheme Land Drainage status</u>

As assessment of the flood risk in 1954 suggested that the whole Marsh would have flooded during a major flood (850-1133 cumecs) expected on average once in 20 years and partial inundation would have been caused by flows in excess of 566 cumecs in association with spring tides expected once in 10 years.

In 1960, floodbank levels were irregular, ranging between 5.33 m and 5.64 m (17.5 - 18.5 ft) AOD (N). The table below shows anticipated water levels at Gainsborough (mile 26) with varying tidal and fluvial conditions.

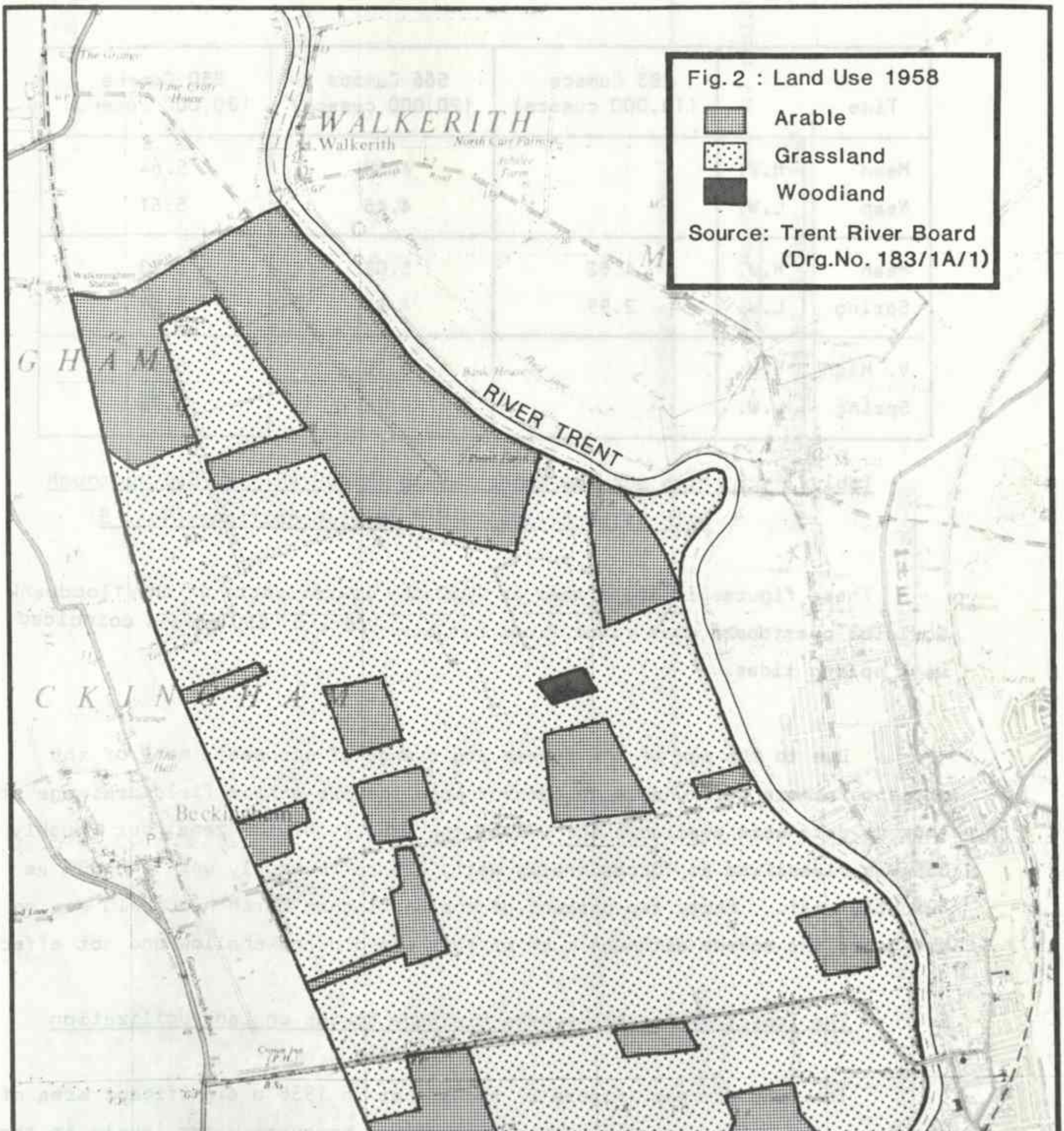


Fig. 2 : Land Use 1958
Arable
Grassland
Woodland
Source: Trent River Board
(Drg.No. 183/1A/1)
WALKERITH
RIVER TRENT
SAUNDBY
BOLE
Saundby

Tide		283 Cumecs (10,000 cusecs)	566 Cumecs (20,000 cusecs)	850 Cumecs (30,000 cusecs)
Mean	H.W.		4.60	5.64
Neap	L.W.		4.45	5.61
Mean	H.W.	4.82	5.09	5.73
Spring	L.W.	2.99	4.54	5.67
V. High	H.W.		5.70	6.13
Spring	L.W.		4.75	5.76

Table 2. : High and Low Water Levels (M.AOD (N)) at Gainsborough with Varying Tidal and Fluvial Conditions (Ref. 2)

These figures indicate that in 1960 the lowest parts of the floodbank would be overtopped when river flows between 566 and 850 cumecs coincided with spring tides.

Due to the age of the scheme and change of occupant, many of the present farmers were unable to comment upon the pre-scheme field drainage status thus no data were available for 67% of the area. Of the remainder roughly 35% was classified as 'Occasionally wet', 22% as 'Commonly wet' and 43% as 'Usually wet'. Forty two percent of the Beckingham Marsh had field drains that pre-dated the scheme although much of this was old and shallow and not effective.

5. The Impact of the Pre-scheme Drainage Status on Land Utilization

The land use map (Figure 2) shows that in 1958 a significant area of the Marsh was being used for arable production; however, water levels in the main drains were being kept deliberately high to provide drinking points for grazing cattle. The effect of a high water table in wet months was to make arable farming difficult and reduce the outfall for tile underdrainage.

The results of the farm survey show that only 2% of the Marsh was recorded as being free from all flood risk. This is an area of slightly higher ground adjacent to the railway line near Beckingham. Of the rest of the Marsh, floods would be expected less often than once in five years with water remaining on the land for days or weeks, depending upon location factors.

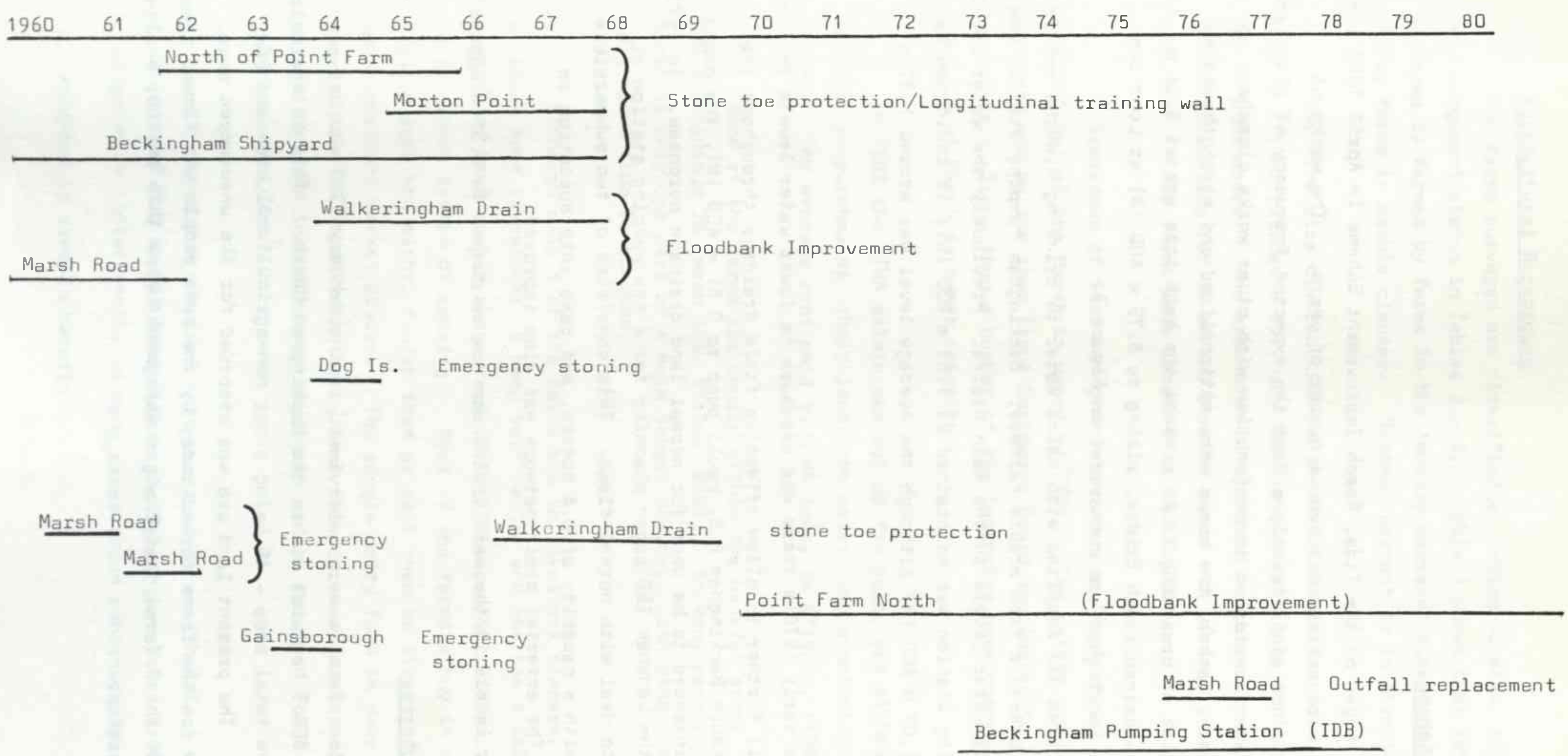


Fig. 3 SUMMARY OF IMPROVEMENT WORK BECKINGHAM MARSH 1960-80

6. The Scheme

Work began on the Tidal Reach Improvement Scheme in April 1960 (see ref. 2), and were carried out over a number of years. The works at Beckingham did not significantly affect the expected frequency of floodbank overtopping when considered in conjunction with other works elsewhere on the tidal reach, rather, the banks were rationalized and strengthened to reduce the risk of breaching. At present the bank tops are at 5.64 m AOD (N) below Gainsborough Bridge, rising to 5.79 m AOD (N) at Long Bank. The works at Beckingham are summarized in Figure 3.

In 1961 the area was supplied with mains water to drinking troughs and in response to pressure from arable farmers, Beckingham Pumping Station was used to lower water levels in the main drains. Previously the water level at the Pumping Station was maintained at 1.83 m AOD (N); it could now be lowered to 1.07 m AOD (N) although the average level was around 1.37 m AOD (N).

In the early 1970's there was pressure to lower water levels in the ditches still further to allow effective field drainage throughout the Marsh. Although Beckingham P.S. could pump to 0.61 m AOD (N), the pumps were never intended to be used for normal land drainage purposes. In 1971 therefore, the Laneham IDB began planning for a new pumping station at Beckingham to deal with normal flows. This consisted of two submersible units each with a capacity of 0.4 cumecs, and came into operation in July 1979. The arterial drain network was also improved.

Water levels in the main drains can now be pumped to 0.31 m AOD (N).

7. Farm Survey

Fourteen farmers were interviewed during January 1983 who between them farmed 800.9 hectares within the Beckingham Marsh. This is equivalent to 87% of the total area - 4% being under non-agricultural uses and 9% unsurveyed. The present land use was recorded for the unsurveyed area. In only 6 cases are the farms farmed today by the same people who farmed them in 1960. Of the 8 farms that changed management over this period, 6 also changed ownership.

8. Agricultural Background

The farms surveyed are classified according to size, type, tenure and management status in Tables 3 - 6. Table 3 shows that 78% of the area surveyed is farmed by farms in the 'mostly cereals' class and a total of 84% by farms in arable classes. Sixteen percent is in livestock classes.

The farm size distribution is shown in tables 4 and 5. The average size is 174 ha (St.Dev = 187) but farms range from 8 ha smallholdings to 650 ha businesses. The breakdown of standard man days shows that 5 of the farms (accounting for 3% of the benefit area) are of less than 250 standard man days. Four farms were larger than 1,000 SMD.

A breakdown of farm management and tenure if given in Table 6. Over 60% (565 ha) of the Marsh is owned by STWA. The estate was purchased about 40 years ago by the then Trent Catchment Board and leased to the previous occupiers. Since then a number of the tenancies have changed hands. Less than 20% of Marsh is owner occupied.

In 1982 the STWA estate was put up for sale, but although many expressed an interest in purchasing their land, the estate was eventually withdrawn from the market. The average rent paid to STWA today is £119/ha. (1982)

None of the farms lie wholly within the benefit area; the maximum being 78% and minimum 7% (mean 30%, St.Dev. 21%). In many cases, land within the Marsh is only one part of a much larger business with other land often situated many miles from Beckingham.

Although only 4 of the farms are in livestock classes, 9 farms keep at least some livestock; 8 keep beef cattle and one has a dairy herd. The numbers of beef cattle range from 10 to 450 (mean 99, St.Dev. 173) and there is no common system of rearing. Most of the farmers buy in store cattle at various ages and either finish them or sell them as strong stores depending upon prevalent market prices. The single dairy farm is away from Beckingham and land in the Marsh tenanted by that farm is used for cereal production. Dairy farms are therefore not important on the Marsh. The average stocking rate is 3.23 Lu/ha[1].

All farms but one (and that was an 8 ha smallholding) had some arable land and most had arable land within the Beckingham Marsh area. The main crop grown is winter wheat, in many cases grown continuously, and in others

1. Weighted by area in benefit

Table 2 : Farm Type

Farm Type	No. of Farms	% of Surveyed Area
Mainly Dairy	1	1%
Mostly Cattle	2	14%
Cattle and Sheep	1	1%
Mostly Cereals	7	78%
General Cropping	2	2%
Mainly Vegetables	1	4%
	14	100%

Table 3 : Farm Size (Hectares)

Farm Size (ha)	No. of Farms	% of Surveyed Area
5 - 10	1	0.1
10 - 20	0	0.0
20 - 30	2	2.0
30 - 40	0	0.0
40 - 50	2	5.0
50 - 100	1	1.0
100 - 200	4	11.5
200 - 300	1	13.4
300 - 500	2	41.7
500 - 700	1	25.3
	14	100%

Modal Class = 100 - 200 ha

Mean = 174.1 ha

St. Dev. = 187.9 ha

Table 4 : Farm Size (SMD)

Farm Size (SMD)	No. of Farms	% of Surveyed Area
< 99	3	2.8
100 - 174	1	3.8
175 - 249	1	0.3
250 - 499	3	7.5
500 - 999	2	5.1
1000 - 1499	3	55.2
1500 - 1999	1	25.3
	14	100%

Mean = 641.4

St. Dev. = 595.9

Table 5 : Management and Tenure

Management Status	% of Farm Owned						Total
	0	1-25	25-50	50-75	75-99	100	
Sole Proprietor	0	2	1	1	0	1	5
Partnership	0	2	2	2	2	0	8
Other	0	0	0	1	0	0	1
Total	0	4	3	4	2	1	14

broken by barley, rape, peas, sugar been and/or potatoes. Arable enterprises today are by far the most important on the Marsh.

9. Effects of the Scheme on Flooding and Land Drainage

In 1976 an assessment of flood risk at Point Farm suggested that complete inundation of the Marsh could be expected once in 30-35 years, with serious flooding (on the scale of the 1960 flood) once in 15-20 years and limited flooding once in 8-12 years. In March 1977 the Marsh was completely inundated to a depth of about 2.13 m and for a period ranging from one week on the higher land to three weeks on the lowest. Floodwater overtopped the banks at the upstream end of the Marsh. However, there was a significant drop in water levels in the Trent below Gainsborough and gravity dewatering would have been possible at Misterton were it not for the existing sluice which was too small to have any effect. The Misterton Sluice has since been replaced. The physical damage to property caused by the flood was limited to one house on the Marsh but fences, gates and footbridges were lost and the litter and debris brought by the floodwater was a common problem. The damage to crops was variable. Some winter wheat, rape and barley was lost completely, some crops recovered and gave 'poor' to 'reasonable' yields and where remedial action was prompt, crops yielded well. Where the duration of flooding was longest however (about 3 weeks), most winter sown crops were written off and spring crops were sown.

In the present scheme it is difficult to identify a point in history at which the land drainage status changed markedly, especially if one is looking for an improvement. It appears however that the installation of piped-mains water supply in the early 1960's marks a turning point. As mentioned earlier, the provision of mains water to grazing land meant that the water levels in ditches could be lowered - the ditches no longer being needed for cattle drinking - thus allowing field drains to be installed at an effective depth. The present study proposes therefore to look at the rate of change over the period 1960-83.

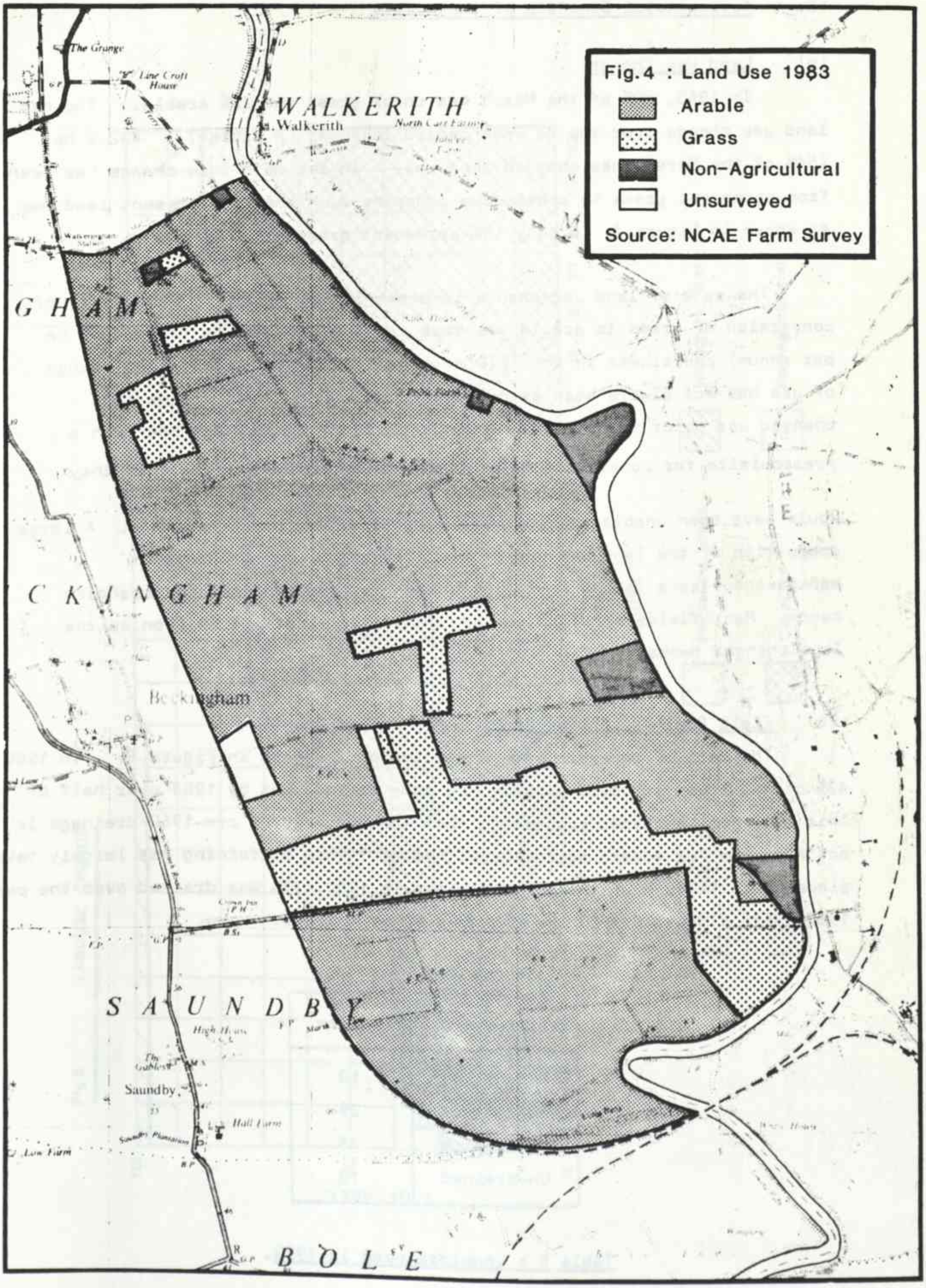


Fig.4 : Land Use 1983
Arable
Grass
Non-Agricultural
Unsurveyed
Source: NCAE Farm Survey
WALKERITH
Walkerith
The Grange
Line Croft House
North Carr Farm
G H A M
C K I N G H A M
Beckingham
S A U N D B Y
High House
Saundby
Hall Farm
B O L E

10. Agricultural Benefits of the Scheme

(a) Land Use Change

In 1960, 72% of the Marsh was under grass and 28% arable. The net land use change over the 23 year period is shown in Table 7. 432.2 ha (54% of the Marsh) has changed land use. In the main this change has been from permanent grass to continuous cropping such that the present land use as shown in Figure 4, is only 18% permanent grass with 82% crops.

The rate of land use change is shown in Figure 5. The rate of conversion of grass to arable was more rapid in the 1960's (around 35 ha per annum) and slower in the 1970's (around 8 ha per annum). The change of use has not always been associated with underdrainage - some land changed use prior to draining - but generally underdrainage has been a prerequisite for conversion to arable. Most farmers believe that they would have been unable to grow arable crops without underdrainage. A large proportion of the land use change was associated with a change of management - sons taking over from aging fathers or tenancies changing hands. Many fields were drained and converted to arable as soon as the land changed hands.

(b) Field Drainage Installation

The rate of underdrainage installation is shown in Figure 6. In 1960 42% of the areas surveyed already had some drains, but by 1983 over half of this had been redrained suggesting that the standard of pre-1960 drainage is not adequate for modern agricultural needs. This redraining has largely taken place since 1974. Of the 58% undrained in 1960, 77% was drained over the perio 1960-1983; thus in 1983 the breakdown is as follows:

Drainage	% Area
Old drains	13
Re-drained	29
New drains	45
Un-drained	13

Table 8 : Underdrainage in 1983.

Fig 5 **LANDUSE CHANGE**

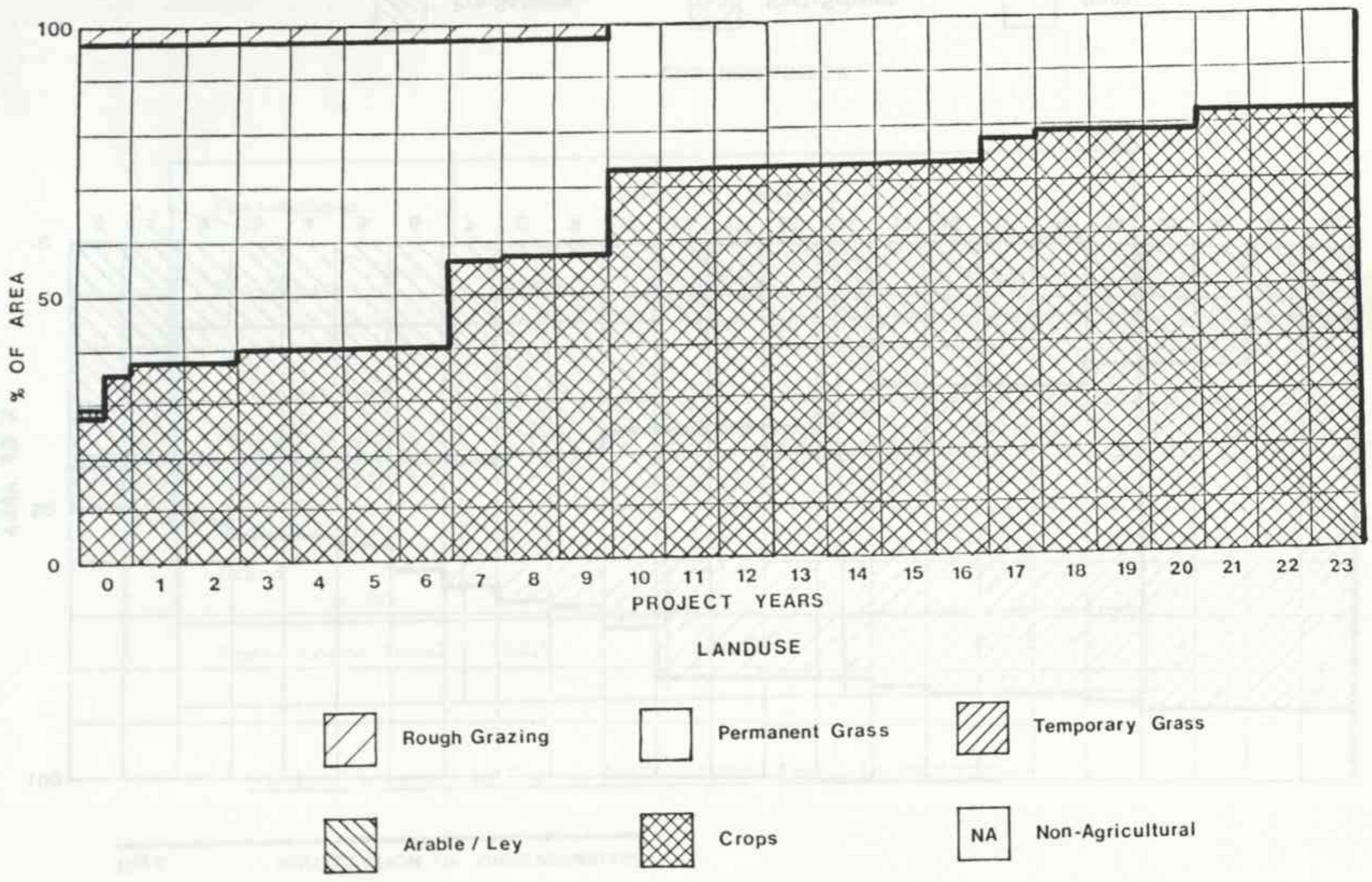
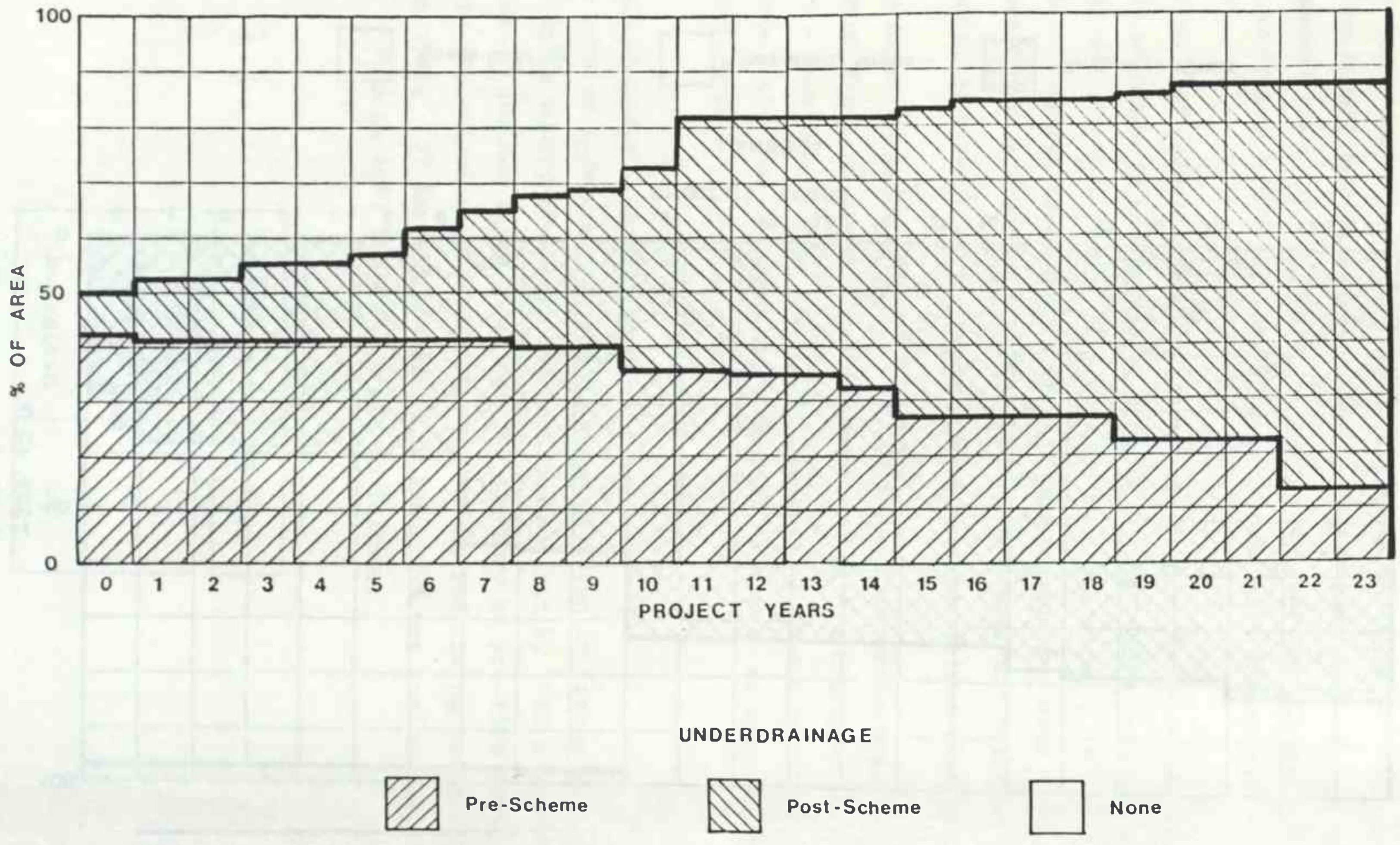


Fig 6 INSTALLATION OF UNDERDRAINAGE



Pre-Scheme \ Post-Scheme	Permanent Grass	Crops	Pre-Scheme Total
Rough grazing	-	27.5	27.5
Permanent grass	146.9	393.8	540.7
Temporary grass	-	7.7	7.7
Grass/crops	-	3.2	3.2
Crops	-	221.8	221.8
Post-Scheme total	146.9	654.0	800.9

Table 7 : Land Use Change 1960 - 1983 Areas in Hectares

Of the 112 ha remaining undrained in 1983, 13% was judged not to need draining (for the present use), 80% had not been drained because the owners do not believe that the benefits of draining that land would justify the cost, and 7% had not been drained for other reasons. Of the 43 ha which had been drained before 1960, but were deemed to be in need of further drainage, 7 ha have not been drained because anticipated benefits would not justify the cost, and 36 ha because the farmers were unwilling to invest in land belonging to STWA.

To date, STWA or their predecessors have contributed towards the cost of underdrainage on STWA land, by paying for the cost of materials (after grant) s s it was felt that such investment helped increase the value of the land.

(c) Improved Production from Existing Land Use

The arable land in 1960 was generally farmed in a rotation of spring or winter cereals with beans. peas. potatoes or sugar beet and grass. Cereal yields averaged 2.75-4 t/ha for spring barley and 3.75-4.37 t/ha for winter wheat. Much of the arable land today is under continuous winter wheat. or wheat with short breaks of peas, rape or barley. Some roots - potatoes or sugar beet - are grown. Winter wheat yields today are high, averaging 6.25-7.5 t/ha although yields of up to 8 t/ha have been achieved.

Although most of the grassland in 1960 was of reasonable quality, with around 6 months grazing, some, largely due to neglect, was only of rough grazing standard, with poor species dominating. Where land was farmed by distant farmers, it was used for hay cutting. In 1983, the remaining grassland where it is actively farmed, allows a grazing season of 7-8 months depending upon its drainage status. On undrained grassland, grazing seasons are limited by wetness, but underdrains can give at least an additional week at either end of the season. There are still some small blocks of poor grassland, used presently for ponies and excluded from the survey.

(d) Rate of Benefit Uptake

A financial assessment of the Beckingham Marsh scheme has been undertaken by identifying, on the basis of farmer interview, the change in farm enterprise gross margins attributable to drainage improvements, net of any additional fixed costs, and including the benefit of extended grazing if relevant. The procedures used for this purpose are described in Annexe V.

A summary of benefits (before field drainage costs) by farm in the benefit area is given in Table 9. Ten of the twelve farmers interviewed with significant areas in potential benefit, recorded actual benefits. Eighty two percent of all benefits accrued to three farmers on 66% of the area.

Figure 7 shows the rate of uptake of financial benefits attributable to the scheme over a 24 year period. Net returns have increased in real terms by some £230 per hectare in 1982 prices. Benefits have accrued on 78.4% of the scheme's area.

Figure 8 expresses actual gross margin improvement as a percentage of potential. The latter is largely based on an assessment of land capability and local farming practice. For Beckingham Marshes, most of the area is suited to arable, cereals with break crops such as peas and rape. Continuous wheat is widely grown, with some field vegetables on the warp land. Typical gross margins per hectare vary from £700 per hectare for continuous cereals to over £1000 per hectare for cereal, root, and vegetable rotation. The potential for livestock production rests with intensive beef reliant upon multi cut silage systems.

Figure 8 shows that there has been a 70% uptake of potential gross margin to date. This measure of relative uptake requires cautious interpretation as discussed in Annex IX section 4.4.

11 FINANCIAL ANALYSIS

A summary of the cash flow of the Beckingham Marsh scheme is contained in Table 10 in 1982 prices.

SCHEME 41 NET AGRICULTURAL BENEFIT

FARM CODE	YEAR FIRST	YEAR 8	YEAR 17	YEAR LAST	% OF BENEFITS	% OF AREA
1	578	6833	16215	23316	13	23
2	153	1072	2617	9175	5	14
3	0	0	0	0	0	1
4	0	29815	52199	82597	44	23
5	0	0	1152	8433	5	4
6	0	0	0	-2252	-1	4
7	500	3502	8006	9507	5	6
8	0	0	45	45	0	<1
9	0	2138	3673	3937	2	2
10	0	0	291	3621	2	1
11	0	0	1135	1135	1	1
12	-256	-256	29492	46132	25	20
13	0	0	0	0	0	<1
14	0	0	0	0	0	1
TOTAL				185652	100	800

Table 10 : Distribution of Benefits by Farm

FIGURE 7 : Degree and Rate of Financial Uptake

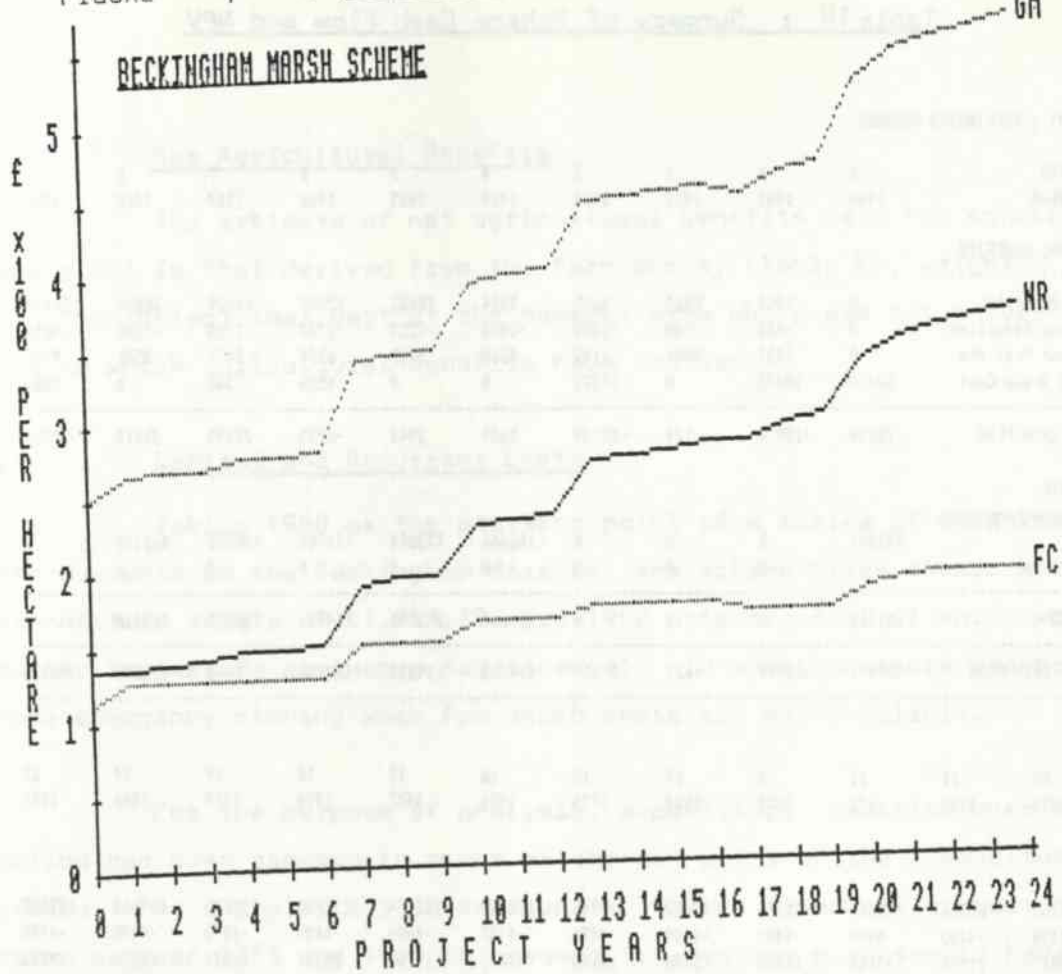


FIGURE 8 : Uptake as a Percentage of Potential

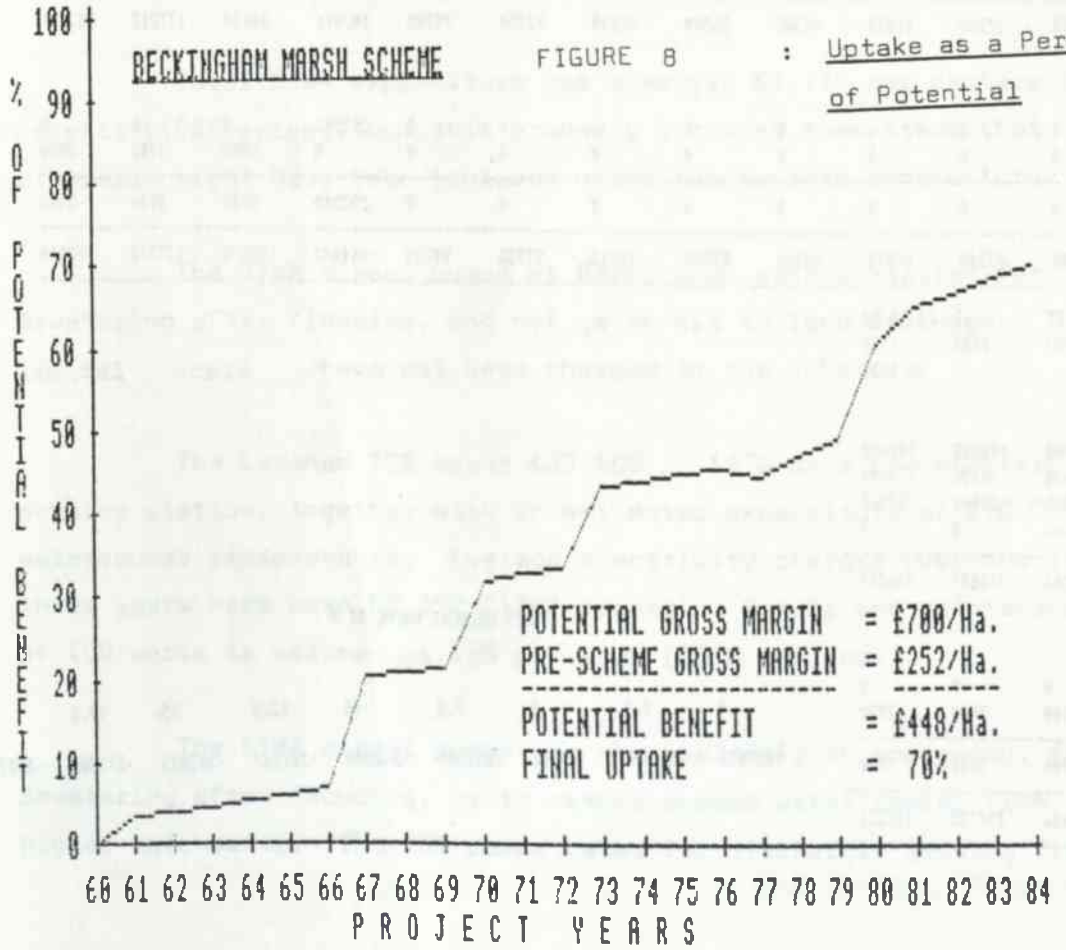


Table 10 : Summary of Scheme Cash Flow and NPV

RIVER TRENT : BECKINGHAM MARSHES

PROJECT YEAR	0	1	2	3	4	5	6	7	8	9
CALENDAR YEAR	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969
AGRICULTURAL BENEFITS										
Net Agric Benefits	0	1045	2860	4675	8614	10483	12353	46124	48804	50673
Flood Damage Reduction	0	-450	-900	-1350	-1800	-2250	-2700	-3150	-3600	-4050
less Without Proj Ben	0	1037	2084	3142	4210	5289	6379	7479	8591	9713
less Field Drain Cost	18130	18473	0	19322	0	0	9500	7300	0	6886
NET AGRIC CASH FLOW	-18130	-18914	-124	-19139	2604	2944	-6225	28195	36613	30024
SCHEME COSTS										
Capital	141361	0	0	0	166666	122094	154706	128235	462118	0
Recurrent		0	0	0	0	0	0	0	0	0
TOTAL COSTS	141361	0	0	0	166666	122094	154706	128235	462118	0
SCHEME NET CASH FLOW	-159491	-18914	-124	-19139	-164062	-119150	-160931	-100040	-425505	30024

PROJECT YEAR	10	11	12	13	14	15	16	17	18	19	20	21
CALENDAR YEAR	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
Net Agric Benefits	77860	80506	82416	115173	117082	119946	122969	123384	132643	138335	169663	181188
Flood Damage Reduction	-4490	-4490	-4490	-4490	-4490	-4490	-4490	-4490	-4490	-4490	-4490	-4490
less Without Proj Ben	10847	11993	13149	14318	15498	16690	17893	19109	20337	21577	22830	24095
less Field Drain Cost	19955	41763	2941	0	11500	26551	7236	0	0	22650	5132	0
NET AGRIC CASH FLOW	42588	22260	61835	96365	85594	72215	93250	99785	107816	89618	137212	152604
Capital	0	0	0	0	0	0	0	0	252248	0	0	0
Recurrent	0	0	0	0	0	0	0	0	0	3940	3940	3940
TOTAL COSTS	0	0	0	0	0	0	0	0	252248	3940	3940	3940
SCHEME NET CASH FLOW	42588	22260	61835	96365	85594	72215	93250	99785	-144432	85678	133272	148664

PROJECT YEAR	22	23	24 TO 30
CALENDAR YEAR	1982	1983	1964 TO 1990
Net Agric Benefits	187008	192828	198648
Flood Damage Reduction	-4490	-4490	-4490
less Without Proj Ben	25373	26663	27967
less Field Drain Cost	33600	0	0
NET AGRIC CASH FLOW	123546	161675	166171
Capital	0	0	0
Recurrent	3940	3940	3940
TOTAL COSTS	3940	3940	3940
SCHEME NET CASH FLOW	119606	157735	162251

NET PRESENT VALUE AT %

0	2.5	5	7.5	10	12.5	15	17.5	20
1459425	453520	-27202	-251209	-348040	-381567	-383873	-371301	-352244

(a) Net Agricultural Benefits

The estimate of net agricultural benefits used for scheme appraisal is that derived from the farm survey (Table 9), weighted by 1.07 to reflect that part of the benefit area which was not surveyed but to which agricultural benefits have accrued.

(b) Capital and Recurrent Costs

Taking 1960 as the starting point of a series of embankment improvements on the Beckingham Marshes, the scheme files record a total expenditure todate of £1,619,124 (in 1982 prices), much of which would appear to qualify as 'heavy maintenance'. In addition there has been some emergency stoning work for which costs are not available.

For the purpose of analysis, expenditure committed over a period has been assumed to occur at the mid-point of the expenditure period. For example, the reconstruction of the floodbank at Norton Point between 1965 and 1969 is assumed for costing purposes to have occurred in 1967.

Total STWA expenditure has averaged £1,799 per hectare in benefit (1982 prices) but this probably includes some items that otherwise might have been included under maintenance expenditure.

The STWA diesel pumps at Beckingham were installed for dewatering after flooding, and not as an aid to land drainage. Their capital costs have not been charged to the scheme.

The Laneham IDB spent £39,500 in 1978 on a new electric pumping station, together with an estimated expenditure of £10,000 on watercourse improvements. Average electricity charges over the last three years have been £3,050 (1982 prices). Repair and maintenance of IDB works is assumed at 1½% per year (£890 per year).

The STWA diesel pumps are now used only in emergency, for dewatering after flooding, or to remove excess water coming from higher catchments. The IDB pumps cater for discharges arising from the Beckingham Marsh area itself. STWA pumping costs when they do occur have not therefore been charged against the scheme.

A number of investments have been made in the course of the assumed 30 year project life, which will retain some residual value at the end of this period.

Assuming a 30 year write-off period, the IDB pump station will have 60% of its potential life remaining, equivalent to a terminal value of £29,700. Works carried out by STWA during the 1960's and late 1970's also have a remaining value, representing about 20% and 60% of their respective initial capital cost. Making such allowances provides a terminal value of £386,589 in year 30. The sensitivity of the scheme to this assumption is tested in section 8.6.

(c) Field Drainage Costs

Some 467 hectares have been underdrained since 1960. Ministry records were located for 185 hectares which totalled £113,277 in 1982 prices, an average £610 per hectare. Whilst the dates and areas of the remaining 282 hectares of field drainage are known, full information is not available on cost and design details. It has been assumed that these have been drained at an average cost of £500 per hectare on the basis that some of them are likely to have been random rather than systematic schemes.

Total estimated expenditure on field drainage is therefore £254,277, an overall average of £544 per hectare drained, and an overall average investment of about £280 per hectare of the benefit area.

No incremental field drainage maintenance costs have been assumed.

(d) Without-Project Benefits

It is assumed that on the area deriving benefits from the improvement scheme, farming performance would have increased at the rate of 1% compound per year. Seventy-eight percent of the area recorded deliberate benefit uptake. Without-project benefits are therefore charged at 1% compound per year of 78.4% of £132,248, the pre-scheme net return.

(e) Flood Damage Reduction

Only 2% of the area was reported by farmers as being free of flood risk, and major flood events, such as in March 1977, result in complete inundation. Assuming flood risk for major events have not changed pre- and post- 1960, the cost of flood events will largely reflect the change in cropping pattern over the intervening period. With reference to section 3 above a one in 30 year event results in complete inundation, a one in 20 year event is assumed to inundate about 200 hectares, and a one in 10 event about 50 hectares. Assuming also that winter/spring and summer flood distribution is in the ratio 9:1, and that winter/spring floods result in losses of £200 per hectare costs on arable (arising from depressed yield, reseeding costs, or delayed spring sowing) and £100 on improved grassland (£50 on unimproved grass), the following estimate is made:

Pre-scheme 1960; one in 30 year event:

900 ha inundated: 30% cereals

70% grass (unimproved)

	£
Winter/spring flood (90%)	
900 ha x .3 x £200/ha x .9	48,600
900 ha x .7 x £50/ha x .9	28,350
Summer flood (10%)	
£201,562 (pre-scheme gross margin x 0.1)	
	20,156
Total in flood event	97,106
Average per year over 30 years	£ 3,236

Post-scheme; one in 30 year event:

900 ha inundated: 75% cereals

25% grass (improved)

		£
Winter/spring flood (90%)		
900 ha × .75 × £200/ha × .9		121,500
900 ha × .25 × £100/ha × .9		20,250
Summer flood (10%)		
£451,151 (post-scheme gross margin)	× .1	45,115
Total in flood event		186,865
Average per year over 30 years	£	6,228

The extra average annual cost of a 30 year flood event is therefore £2,993.

Using the same procedure the extra costs associated with a one in 20 year event and a one in 10 year event on the inundated areas previously quoted would be £998 and £499 respectively.

On this basis, post-scheme annual average flood damage costs are higher by £4,490. Damage and debris collection costs are assumed constant. The sensitivity of the project to this assumption is tested in section (g).

(f) Project Worthwhileness

Assuming benefits continue at their 1983/4 level for the remainder of project life, and that terminal values for interim investments by STWA and IDB are included, the project has a net present value of -£27,202 at the 5% discount rate, giving an internal rate of return of 4.6%.

Whilst the project appears marginal at the 5% discount rate, about 60% of total field drainage expenditure has occurred since 1970, and will offer returns beyond the assumed 30 year scheme life, thus improving the likely return of the scheme. Extending the project life to 50 years, and excluding terminal values, would give a net present value of £433,032 at 5%, and an internal rate of return of about 7%.

(g) Sensitive Analysis

Table 11 shows the sensitivity of the scheme to changes in cost and benefit parameters.

A two percent in cereal in the estimated net returns is needed to make the scheme breakeven.

If the residual values referred to in Section (b) are removed, the internal rate of return of the scheme reduces to about 4%.

TABLE 11

Beckingham Marsh - Sensitivity Analysis

Run No.	Agricultural Benefits Factor	Without Project Benefits Compounding Factor	Flood Damage Reduction Factor	Capital Works Cost Factor	NPV at 5% £	IRR %	Switching Value %*
1	1.0	1	1	1	-27202	4.6	1.02
2	1.0	0	1	1	163835	6.2	0.84
3	1.0	0.5	1	1	72079	5.6	0.95
4	1.0	1.5	1	1	-134679	3.8	1.11
5	1.0	1	0	1	-22382	5.2	0.98

* The factors show the weights applied to the original estimates eg a factor of 1.5 for the without-project benefits indicates that the new value is 1.5 x 1% compound per year (the original value) ie 1.5% compound.

* Switching value : change in agricultural net benefits needed to make the project breakeven at 5% discount rate eg a 1.5 switch value shows an increase of 1.5 x the original estimated is required.

REFERENCES

1. Soil Survey (1981) — *Soils in Nottinghamshire IV* Soil Survey Record No. 72 (Gringley on the Hill)

2. Nixon, M. (1960) — *Report on the Tidal Reach Improvement Scheme* Trent River Board

3. Trent River Board/ STWA (various) — Files on the Beckingham Estate

4. Trent River Board/ STWA (various) — Files on the Beckingham Marsh

5. Soil Survey (1983) — National Soils Map at 1 : 250,000 Soil Survey, Harpenden.

APPENDIX I : SOILS

Soil Series	Dominant Texture	LUCC class	Cultivation Class	Drainage Requirements		
				Depth (cm)	Spacing (m)	Secondary Treatment
Fladbury	Clay	3ws/2	V	70-90	14-20	P.F. and subsoiling essential
Stixwould	Clay	3ws/2	V	70-90	14-20	Selective use of permeable fill
Blacktoft	Silty clay loam	1/2	II	90-130	10-20	-
Brockhurst	Sandy clay loam	3sw/2	IV	75-90	20-30	P.F. and subsoiling or moling
Spetchley	Sandy clay loam	3sw/2	V	75-90	20-30	"
Stockwith	Silty clay loam	2sw/3	III	90-130	10-20	P.F. would be advisable.
Whimple	Clay loam	3sw/1	III	75-90	20-40	P.F. and subsoiling with wider spacings
Worcester	Clay loam	3sw/1	IV	75-90	20-40	Sometimes subsoiling alone is sufficient

<u>Cultivation Classes</u>:
- II Easy. Autumn ploughing not essential. Timeliness important.
- III Moderate. Autumn ploughing desirable. Timeliness important.
- IV Difficult. Autumn ploughing and timeliness essential.
- V Very Difficult. Autumn ploughing essential. Timeliness critical.

Source: Soil Survey (1981)

APPENDIX I

Lower Trent Division

River Idle : Idle Stop to Bawtry

SILSOE COLLEGE

STWA LOWER TRENT DIVISION - RIVER IDLE SECTIONS 2 AND 3

IDLE STOP TO BAWTRY

Report on the background to, and development of, the scheme and the uptake of agricultural benefits.

1. Physical Background

The River Idle turns east from Bawtry, skirts the Keuper outcrop at Prospect Hill (Harwell) and joins the Trent at West Stockwith. The present scheme relates to the stretch of the Idle from Idle Stop to the A631 road bridge at Bawtry.

The River Idle and its tributaries flow north east towards the River Trent, draining most of north Nottinghamshire. The area of the combined catchment of the River Idle and the River Ryton, which joins it just upstream of Bawtry is 842 sq. km. This area is mostly rural although the towns of Retford, Worksop and Mansfield lie within the catchment. A large proportion of the catchment is formed of Bunter Sandstone which is very permeable, bears few streams and supports large tracts of woodland on a thin coverage of soil.

Downstream of Bawtry the Idle is embanked above the adjoining land. The pre-scheme bed gradient along this reach was shallow (1 in 12,000) and the adjacent washlands are less than 5 m above sea level. Low lying areas to the north and south of the Idle, known as Carrs, depend on a well-developed arterial system for their drainage and this system, administered by various Internal Drainage Boards, has been radically affected by the Idle improvements. The present study, however, is restricted to the former washlands of the Idle, lying even lower than the Carrs.

2. Soils and Land Capability

MAFF have classified as grade 4 the land close to the river and also the washlands on both sides of the river between Bawtry and Newington. The washlands, east and west of Mission are classified as grade 3. (See Figure 1).

Field survey and borehole data (Ref. 1) showed that there are two main soil types in the benefit area - peat and clay - with a higher zone of sandy soil in Mission East washland. The National Soils Map (Ref. 7) classifies the peat as being of the Altcar Association. It is a deep fen peat soil which is permeable and, in places, acid. The clay was classified as of the Foggathorpe Association, being a pelo-stagnogley surface water gley soil developed in glaciolacustrine clay. It is slowly permeable and seasonally waterlogged. The sand is a typical brown earth of the Newport Association and is deep and well drained occurring locally over gravel.

Drought is a hazard on the peat and irrigation has already been used on other peaty land nearby.

3. Land Drainage History

As a result of Vermuyden's diversion of the Idle in the 1620's at Idle Stop, such that its outfall was moved south, further upstream on the Trent, discharge of the Idle was severely restricted by both high tide levels and fluvial floods in the Trent. The construction in 1938 of a sluice-gate at West Stockwith kept the Trent waters from backing up the Idle but meant that in times of high water in the Trent water was ponded in the Idle upstream to Bawtry. Discharge of the Idle was thus impeded and wet weather kept water levels high, flooding the washlands and restricting drainage of the Carrs. Major improvements were impossible until the deficiencies of the Idle's outfall system were improved, and work was limited to the raising and strengthening of floodbanks and some regrading between Misterton Soss and Bawtry.

The washlands between Bawtry and Newington on both banks have been affected by mining subsidence and have no gravity outfall into the Idle. These areas probably had the worst drainage status of all before the scheme.

4. Pre-Scheme Land Drainage Status

Before the scheme was enacted the Idle flooded the washlands annually, several times during most years. The farm survey (see 10 below) found that fields covering roughly 90% of the benefit area defined in 7 below were liable to flooding. Twenty-seven percent would flood once and 56% several times annually. In general the flood would remain on the land for a number of weeks, but on 15% of the benefit area it would regularly remain for months. Every ten years or so a rarer event would inundate the entire area for several months.

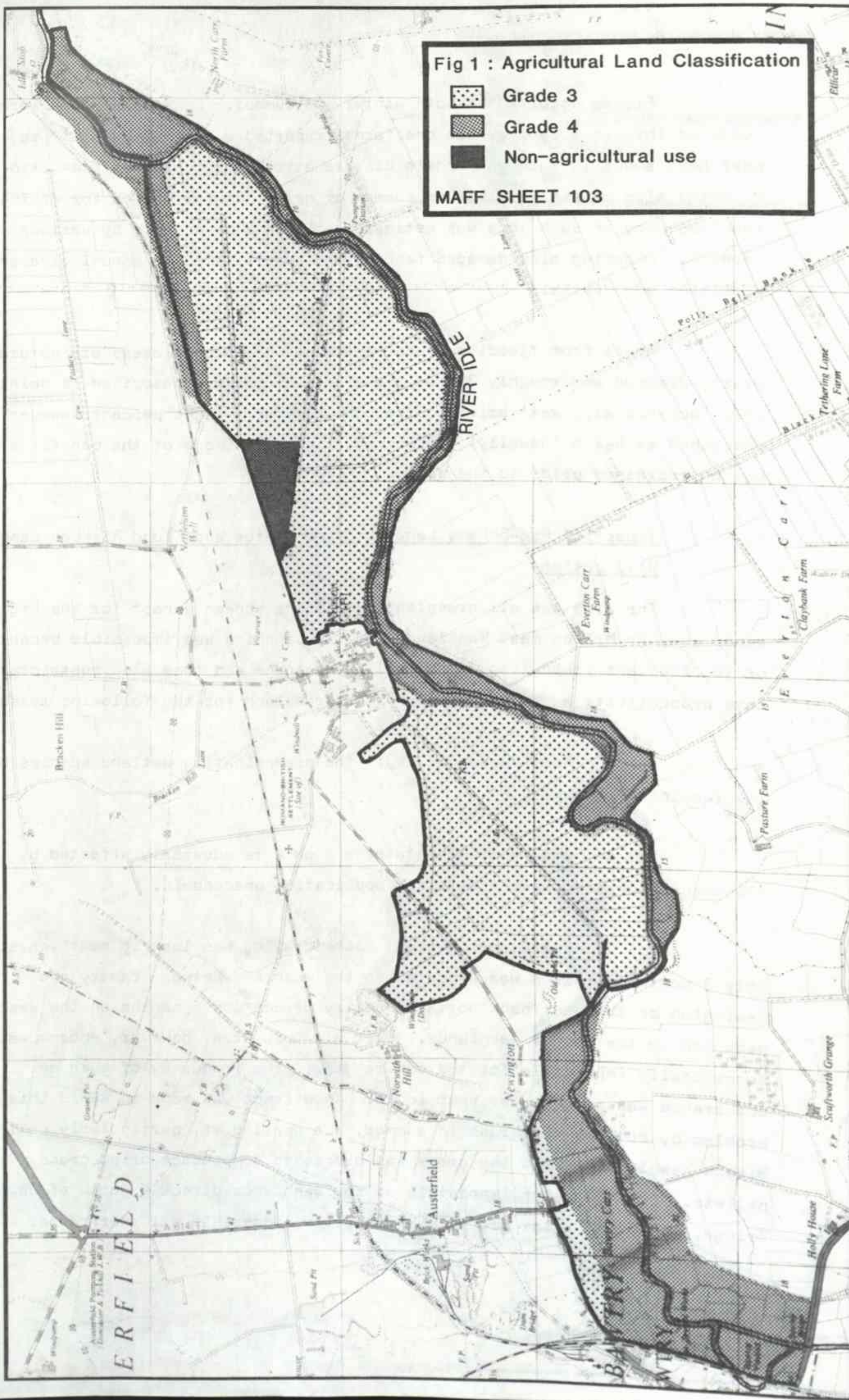


Fig 1 : Agricultural Land Classification
Grade 3
Grade 4
Non-agricultural use
MAFF SHEET 103
RIVER IDLE

Floods occurred in both winter and summer. No stock losses were reported through drowning, but one farmer reported a loss of 3-4% of his beef herd annually through Johne's disease attributed to the wet conditions. Flooding also caused the loss in summer of grass cut for hay or for drying; the frequency of such loss was estimated at 1 in 3 or 4 years by various farmers. Flooding also damaged fencing and necessitated an annual clearance of litter and debris.

Apart from flooding, much of the sandy and peat areas are naturally freely drained and roughly 25% of the area surveyed was described as being only 'occasionally wet' prior to the scheme. Forty-eight percent however was described as being 'usually' or 'permanently wet'. None of the benefit area was underdrained prior to the scheme.

5. Impact of Pre-Scheme Land Drainage Status and Flood Risk on Land Utilization

The area was all grassland before the scheme except for the higher sandy area in Misson East Washland. Arable cropping was impossible because of the frequent inundation and poor land drainage and this also restricted both productivity and utilization of the grassland for the following reasons:

(a) Poor sward quality: the predominating wetland species had low feeding quality.

(b) Soil nutrient status and pH were adversely affected by flooding which also made fertilizer application uneconomic.

(c) Restricted access: some grazing was lost in most years. Only 3 months' grazing was expected on the washland between Bawtry and Newington on the east bank north of Bawtry Bridge and 6 months on the west bank and on the Misson Washlands. Over all this area, however, access was occasionally impossible for the entire year; the frequency of such an occurrence was roughly one year in 15. An attempt was made to avoid this problem by cutting the grass in summer, not grazing it, particularly on the Misson Washlands, where the grass was processed to produce dried grass pellets. Even this was impossible on the washlands directly north of Bawtry Bridge, where vehicular access was generally impossible all year round.

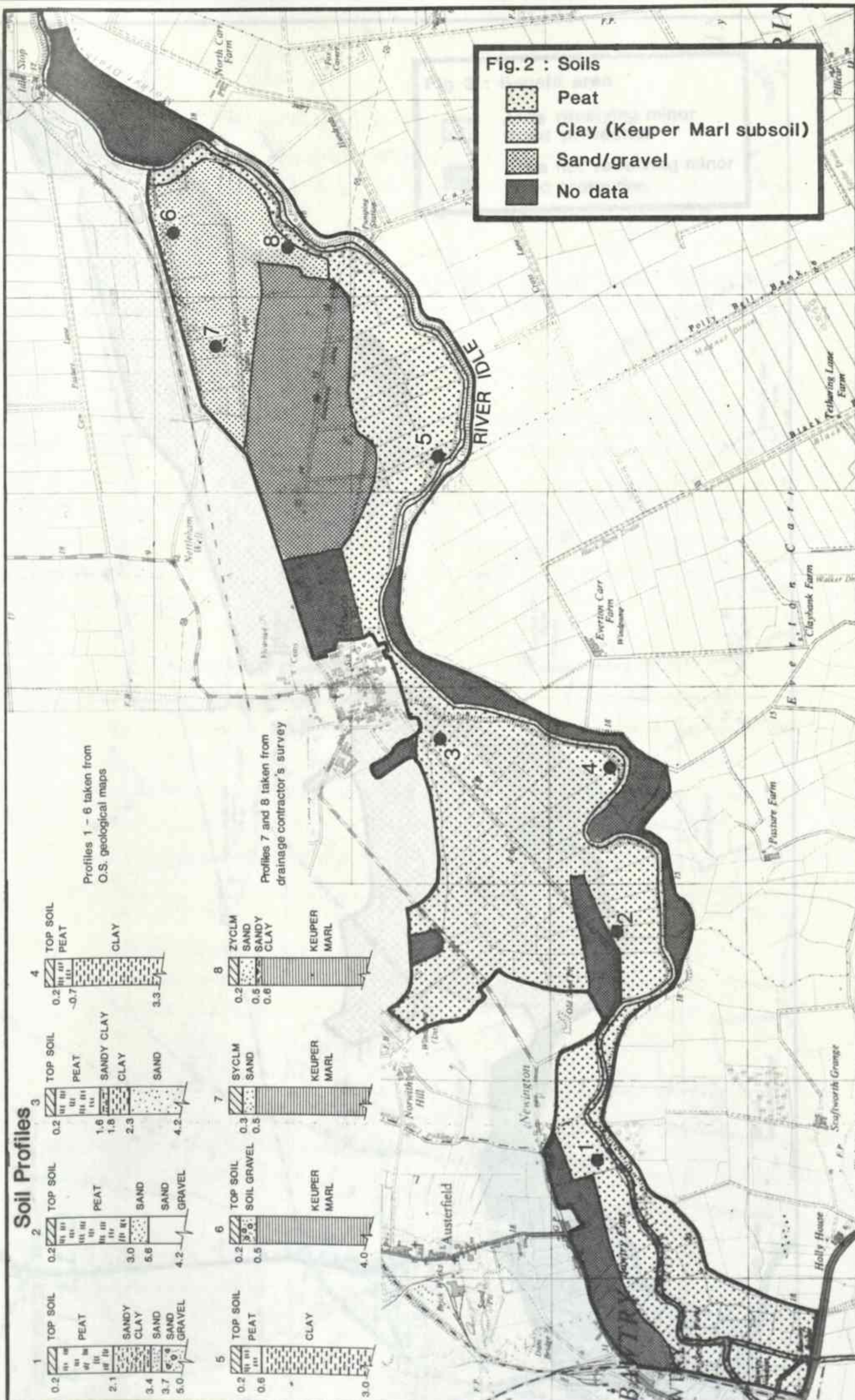


Fig.2 : Soils
Peat
Clay (Keuper Marl subsoil)
Sand/gravel
No data
RIVER IDLE
Soil Profiles
1 0.2 TOP SOIL PEAT 2.1 SANDY CLAY 3.4 SAND 3.7 SAND GRAVEL 5.0
2 0.2 TOP SOIL PEAT 3.0 SAND 5.8 SAND GRAVEL 4.2
3 0.2 TOP SOIL PEAT 1.6 SANDY CLAY 1.8 CLAY 2.3 SAND 4.2
4 0.2 TOP SOIL PEAT 0.7 CLAY 3.3
5 0.2 TOP SOIL PEAT 0.6 CLAY 3.0
6 0.2 TOP SOIL 0.5 SOIL GRAVEL KEUPER MARL 4.0
7 0.3 SYCLM 0.5 SAND KEUPER MARL
8 0.2 ZYCLM 0.5 SAND 0.6 SANDY CLAY KEUPER MARL
Profiles 1 - 6 taken from O.S. geological maps
Profiles 7 and 8 taken from drainage contractor's survey
Austerfield
Newington
Everton Carr Farm
Pasture Farm
Claybank Farm
Holly House
Scaftworth Grange
Tethering Lane Farm
North Carr Farm
Idle Stop

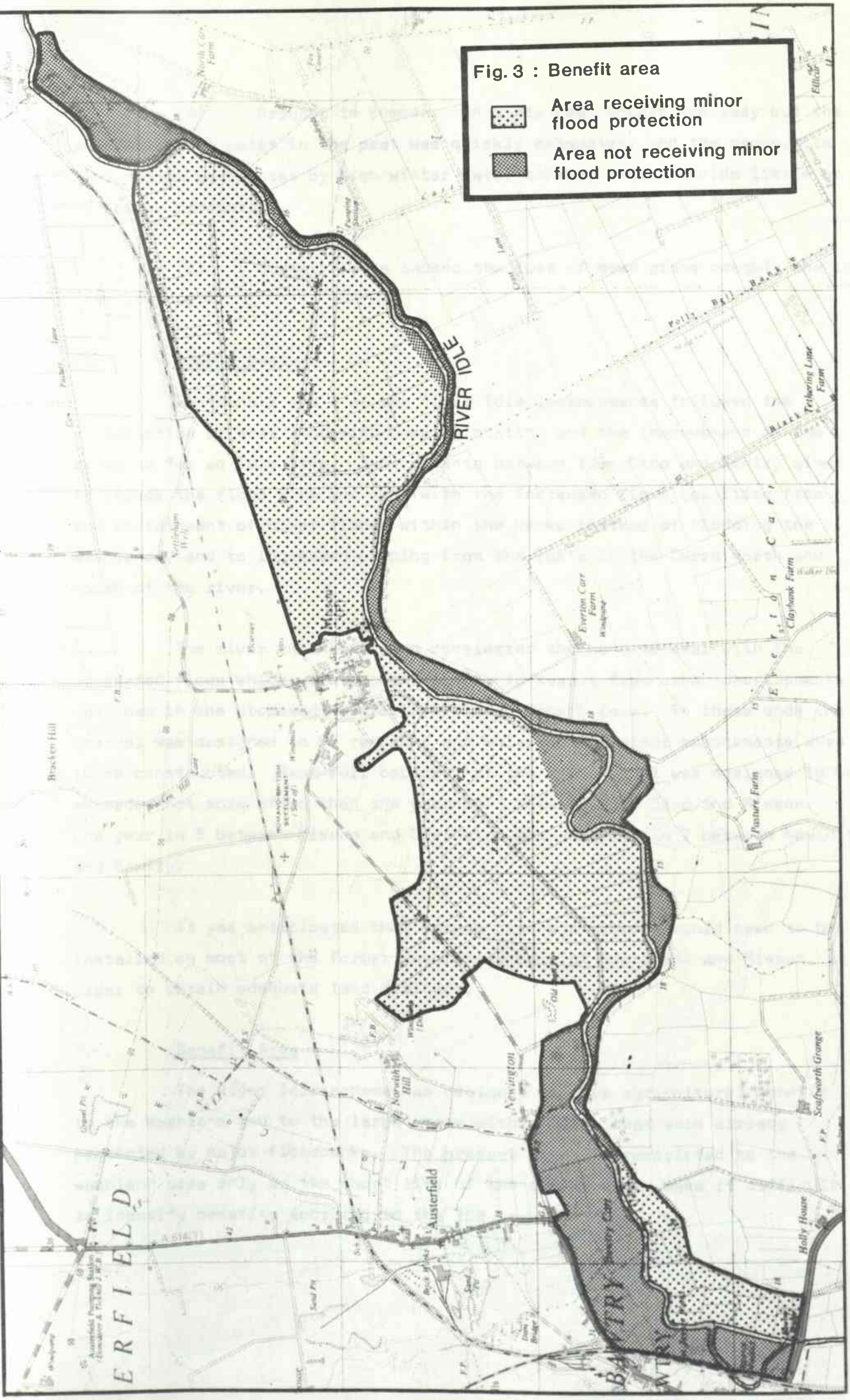


Fig. 3 : Benefit area
Area receiving minor flood protection
Area not receiving minor flood protection
RIVER IDLE
Austerfield
Newington
Everton Carr Farm
Claybank Farm
Pasture Farm
Scaftworth Grange
Holly House
Bracken Hill

(d) Drought in summer: in a dry year access was easy but the available soil water in the peat was quickly exhausted, and the grass, its root system restricted by high winter water tables, would provide little or no summer production.

(e) Summer floods caused the loss of mown grass roughly one in year in 3 or 4.

6. Scheme Design

Sections 2 and 3 of the River Idle improvements followed the construction of West Stockwith pumping station and the improvement of the river as far as Idle Stop. Improvements between Idle Stop and Bawtry aimed to reduce the flood risk and deal with the increased flows resulting from the containment of minor floods within the banks instead of flooding the washlands, and to increased pumping from the IDB's in the Carrs north and south of the river.

The river engineers also considered the need to deal with the increased flows which were thought likely to result from urban developments upstream in the proposed Mansfield-Alfreton Growth Zone. To these ends the channel was designed to be regraded and enlarged and minor embankments were to be constructed. Bank-full capacity of the new channel was designed to be exceeded not more often than one year in 3 between Idle Stop and Misson, one year in 5 between Misson and Newington and one year in 7 between Newington and Bawtry.

It was anticipated that pumped drainage schemes would need to be installed on most of the former washlands, both at Newington and Misson, in order to obtain adequate land drainage.

7. Benefit Area

The River Idle scheme was designed to give agricultural benefit to the Washland and to the large areas within IDB's that were already protected by major floodbanks. The present study is restricted to the washland area only as the short life of the scheme would make it difficult to identify benefits accruing to the IDB areas.

The benefit area was defined as the area previously subject to minor flooding, taken on a whole field basis. Records of the 1977 flood, field survey data and the Section 24(5) maps were used in combination to identify the flood line. In places the major floodbank forms the boundary of the benefit area and elsewhere it ties into high ground. The benefit area covers 480 ha of agricultural land (Figure 3) and 24 ha of non-agricultural land.

The benefit area identified in the first feasibility report (1, p. 47) covered 400 ha on the Misson Washlands and 80 ha between Bawtry and Newington, and this conforms well to the area identified in the present study.

8. Anticipated Costs and Benefits

No separate appraisal was carried out for sections 2 and 3 of the River Idle scheme and costs and benefits must be viewed in the context of the whole scheme. Appendix I contains a summary of the pre-scheme appraisal and the method used.

It was estimated that improved profitability over the washlands, both at Misson and between Bawtry and Newington would be £25 per acre (£62 per ha) giving a benefit of £30,000 per annum. This estimate assumed that land use would change from grass to arable cropping and that pumped drainage would be installed. No soil survey or detailed investigation of the agricultural potential of the land had been carried out, but the authors of the feasibility report (1, p. 47) considered it reasonable to assume from comparison with neighbouring land that, with efficient drainage and adequate flood protection, the whole area would be capable of growing cereals, root and vegetable crops.

9. The Scheme

Works on section 2 (Idle Stop to Misson) were enacted between August 1979 and August 1980 and those on section 3 (Misson to Bawtry) between August 1980 and November 1981 (Figure 4). The new bed level at Bawtry is 0.8 m lower than before the scheme and water levels downstream of Bawtry are estimated to have been lowered by 0.3 m. Flood protection from the minor floodbanks is now rated at one in 3 years on section 2, one in 5 years on Misson West Washlands and one in 7 years on the east bank between Bawtry and Newington.

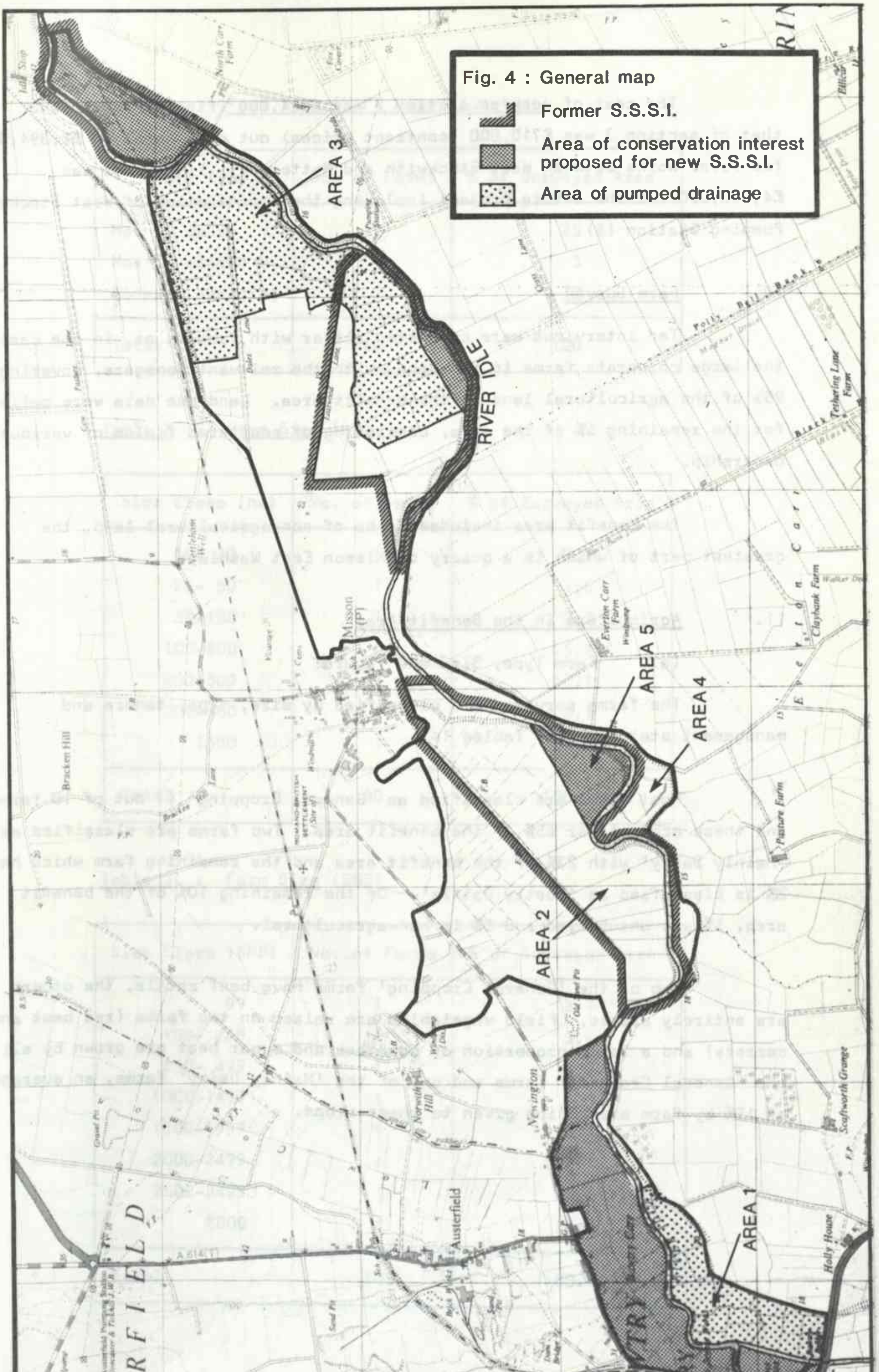


Fig. 4 : General map
Former S.S.S.I.
Area of conservation interest proposed for new S.S.S.I.
Area of pumped drainage
AREA 1
AREA 2
AREA 3
AREA 4
AREA 5
RIVER IDLE
Misson
Newington
Austerfield
Bracken Hill

The cost of work on section 2 was £624,000 (final account) and that of section 3 was £710,000 (contract prices) out of a total of £2,394,000 for river works between West Stockwith and Mattersey; final cost was £4,800,000 for the entire project including the construction of West Stockwith Pumping Station (5).

10. Farm Survey

Ten interviews were conducted either with farmers or, in the case of the large corporate farms in the area, with the relevant managers, covering 95% of the agricultural land in the benefit area. Land use data were collected for the remaining 5% of the area, consisting of scattered fields of various ownership.

The benefit area includes 24 ha of non-agricultural land, the greatest part of which is a quarry on Misson East Washland.

11. Agriculture in the Benefit Area

(a) Farm Type, Size and Tenure:

The farms surveyed are classified by size, type, tenure and management status below, Tables 1-4.

Most farms are classified as 'General Cropping' (7 out of 10 farms) and these account for 65% of the benefit area. Two farms are classified as 'Mainly Dairy' with 23% of the benefit area and the remaining farm which has 2% is classified as 'Mostly Cattle'. Of the remaining 10% of the benefit area, 5% was unsurveyed and 5% is non-agricultural.

Two of the 'General Cropping' farms have beef cattle, the others are entirely arable. Field vegetables are raised on two farms (red beet and carrots) and a large proportion of potatoes and sugar beet are grown by all the 'General Cropping' farms and one of the 'Mainly Dairy' farms, an average of 15% by farm area being given to these crops.

Table 1 : Farm Type (MAFF Classification)

Farm Type	No. of Farms	% of Surveyed Area
Mainly dairy	2	25
Mostly cattle	1	3
General cropping	7	72
Total	10	100

Table 2 : Farm Size (ha)

Size Class (ha)	No. of Farms	% of Surveyed Area
10- 20	1	2.7,
20- 50	1	3.6
50-100	1	0.3
100-200	2	16.4
200-300	3	50.1
300-500	1	2.1
1500	1	24.8
Total	10	100.0

Table 3 : Farm Size (SMD)

Size Class (SMD)	No. of Farms	% of Surveyed Area
99	1	2.7
100- 249	1	3.6
250- 499	1	0.3
1000-1499	1	6.9
1500-1999	1	8.4
2000-2499	1	2.1
2500-3499	3	50.1
8000	1	24.8
Total	10	100.0

Table 4 : Land Tenure and Management - Breakdown of Farms

Management Status	Land Tenure					
	Missing	All Tenanted	% Owned			
			1-25	25-50	50-75	100
Sole Proprietor		2	1		-	-
Manager	1	1	-	-	-	1
Patnership		-	-	2	1	-
Other Arrangements		-	-	1	-	-

The farms are of varying sizes by area but are generally large; 6 out of 10 are over 200 ha. Standard Man Day requirements vary similarly and 5 farms have a requirement in excess of 2000 SMD. Two farms are classified as part-time, their requirement being less than 250 SMD.

Tenure and management are both very variable. Only 3 farms have a sole proprietor, of which 2 are wholly tenanted and one partly owned. There are 3 partnerships, all in farms which are partly owned. The remaining 4 farms are run on a corporate basis; all have local managers but 3 of them are supervised from outside offices.

(b) Dairy Enterprises:

The 2 farms classifed as 'Mainly Dairy' have herd sizes of 200 and 120 dairy cows. Milk yields are 5,000 and 6,200 litres/head per annum respectively and both enterprises are seeking to increase productivity either by increasing milk yield or expanding the herd size. The cows are Friesian or Friesian-Holstein. Stocking rates are 1.67 LU/ha and 1.48 LU/ha (mean = 1.61 LU/ha) on dairy farms.

(c) Beef Enterprises:

Beef enterprises consist of 2 very small suckler herds and one winter finishing herd. Stocking rates are 1.28 LU/ha on the one Livestock farm.

(d) Arable Enterprises:

Two types of rotation are in use. Some farmers are sowing 3 years of winter cereals with either one or two years of break crops (potatoes, sugar beet or oilseed rape). Others are concentrating on root crops, mainly potatoes and in 1982 67 ha of red beet were grown on Misson West Washland. The areas of peat seem likely to be mainly cropped for roots, although perhaps not continuously as in the first seasons after ploughing up the grass, soil nitrogen conditions are very favourable.

Arable enterprises on areas which are still unprotected by minor floodbanking are more hazardous. Spring cereals are grown in order to minimise the risk, flooding being less frequent in summer and costs relatively low. Nevertheless, some potatoes have been grown.

In 1983 potatoes were being grown on more than 100 ha in the benefit area, largely on Misson West Washland.

Few yield data are yet available because the scheme was completed so recently. It is worth noting, though, that in the first year after the scheme (1982) potatoes yielded 40 t/ha on one farm, compared with a national average of 32.5 t/ha (6).

(e) Other Enterprises:

Prior to the scheme 214 ha of the Misson Washlands were occupied by Nottinghamshire Crop Driers who cut the grass during the summer for pelleting. This involved high rates of nitrogen application and regular cutting. In the years immediately preceding the scheme however the pelleting business closed down and the Washlands were put up for sale.

12. Effect of the Scheme on Flooding and Land Drainage

The scheme has so far prevented flooding on the area protected by minor floodbanking, but it is too soon after completion of the scheme to estimate the return period of overtopping. Flooding has been reduced on some unprotected areas but has increased on others. Bawtry Carr, on the west bank up to Newington, floods as often now as before the scheme but the water level falls quicker, usually receding in only 2 days. Attempts to improve this grassland by reseeding have failed, and the reseeded area is reverting to meadow grass. One farmer claims that flooding is worse on

Table 5 : Change in Flood Frequency and Duration of Area (ha)

Post-scheme flood frequency \ Post-scheme flood duration	Did not flood	No flood since	Reduced	Unchanged	Increased	No response	Total
Did not flood	63						63
No flood since		352					352
Reduced			32				32
Unchanged			34				34
Increased					11		11
No response						11	11
Total	63	352	66		11	11	503

the unprotected area in the curve of the river on the south bank opposite Misson West Washland, known locally as the "Flag Piece" (Figure 4, Area 4). This farmer anticipated an improvement, planted potatoes and lost them in a summer flood. He has subsequently attempted to construct his own riverside floodbank without the permission of the Water Authority. The unprotected land opposite (Figure 4, Area 5) has been left as grazing, by agreement between the tenants and the Nature Conservancy Council, but here and on other washlands left for conservation purposes, flooding has been reduced, certainly in duration, by the change in river level behaviour. Flooding is said by another farmer to be less frequent so far on the narrower strip of unprotected land on the south bank running from the "Flag Piece" to Misson. Table 5 summarises changes in flood frequenty and duration over the benefit area.

Some of the floodbanks in the peat area between Misson and Bawtry have settled by up to 0.5 m during the first year after construction (5). Some of this settlement is due to the nature of the dredged material used to form the floodbanks. No settlement has occurred on section 2 between Idle Stop and Misson. The need for future maintenance will have to be closely monitored.

Three areas have been significantly improved by the scheme. Firstly, the very low area on the east bank at Bawtry is now drained by a comprehensive underdrainage scheme which is pumped into the Idle. This area was previously completely inaccessible by vehicles, but now is in a grass-crop rotation (Figure 4, Area 1). Secondly, Misson West Washland has had improvement of the ditch system although no underdrainage has yet been installed (see section 13) and farmers have pumped out the ditches when necessary. A permanent pumping station is needed here, and its construction would undoubtedly stimulate underdrainage activity, but so far funds have not been raised, either through Idle and Ryton IDB or independently (Figure 4, Area 2). Misson East Washland has been underdrained over most of the area which needs it and ditches have been improved. A pumping station has been constructed here as part of the underdrainage scheme undertaken by the major landowner (Figure 4, Area 3). Pumped ditch systems on both washlands offer the interesting possibility, certainly on the peat areas, of creating favourable soil water conditions in summer by keeping ditch levels high, possibly by pumping out of the Idle, and thus supplying water to the plant roots. Penstocks have been incorporated in the dewatering sluices to allow River Idle water to flow

Table 6 : Land Use Change (ha)

Pre-scheme land use \ 1983 Land Use	Unused	Permanent grass	Grass/crop rotation	Crops	Other	No data	Pre-scheme Total
Non agricultural	20						20
Rough grazing		3	27				30
Permanent grass		127		290			416
Crops				30			30
No data						9	9
Post-scheme total	20	130	27	319		9	505

into the drains during drought conditions. Land drainage on the areas still unprotected by minor floodbanks remains unchanged.

13. Agricultural Benefits of the Scheme

The main benefit of the scheme has been the change of land use from permanent pasture, which was mostly of poor quality, to arable. This has often involved field drainage. It is too early to assess yields but they are expected to be above average for both cereals and roots.

(a) Land Use Change:

The main change has been the ploughing up of 317 ha of permanent grass for arable cropping (see Table 6). This is equivalent to 67% of the agricultural land within the benefit area. The change has been dramatic and extremely rapid. Figure 5 shows that much of the change took place in the first year of the scheme. Note that much of the area recorded as 'crops' will be brought into rotations in a few years. This has been taken into account in the financial analysis (section 14).

(b) Increased Productivity:

The small amount of pre-scheme arable cropping shown in Table 5 took place on land already suitable and productivity has been unaffected. Productivity of the remaining grassland has been increased by the improved drainage itself and by subsequent reseeding and increased fertilizer use. All 3 major livestock enterprises (excluding the 2 small suckler herds, that is) are looking for increased production. For the 2 dairy herds this means a higher milk yield in one case and in the other an increase of herd size from 120 to 160 dairy cows on the same forage area.

The beef enterprise is due to change from winter finishing of stores to the more profitable silage beef system. On this farm the improvement of 27 ha on the east bank at Bawtry, now pump-drained (Figure 4, Area 1), has resulted also in the release of 'insurance' grassland for arable use elsewhere on the farm.

(c) Field Drainage Installation:

Todate fields totalling 154 ha (equal to 32% of the agricultural benefit area) have been underdrained on 4 farms.

Fig 5 : LANDUSE CHANGE

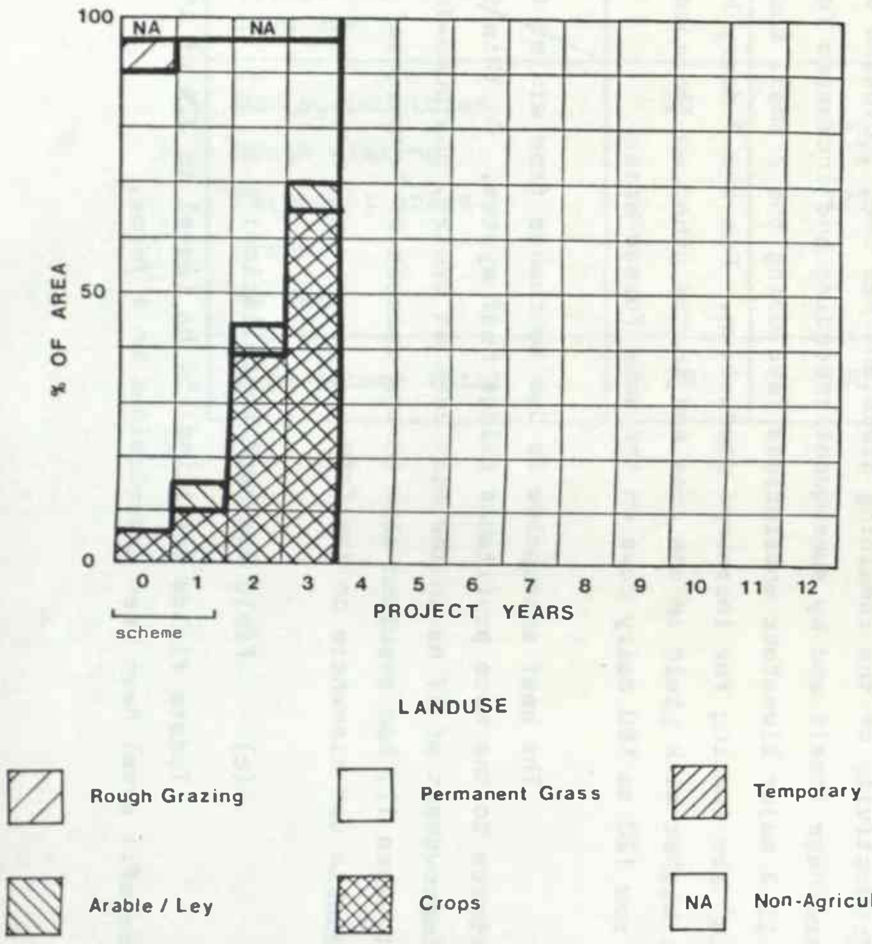
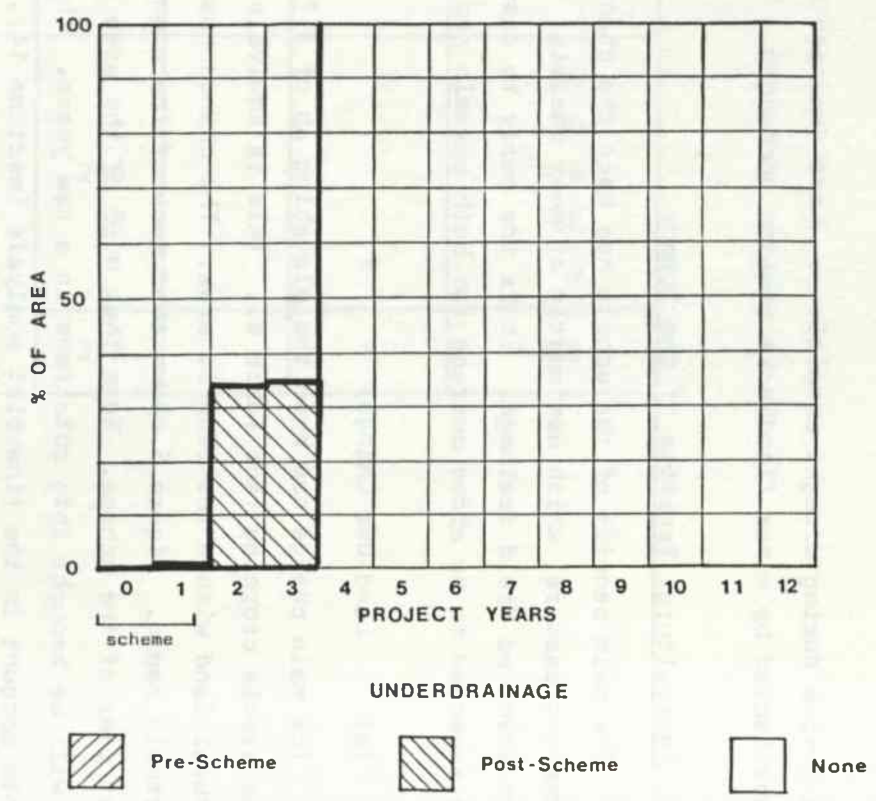


Fig 6 : INSTALLATION OF UNDERDRAINAGE



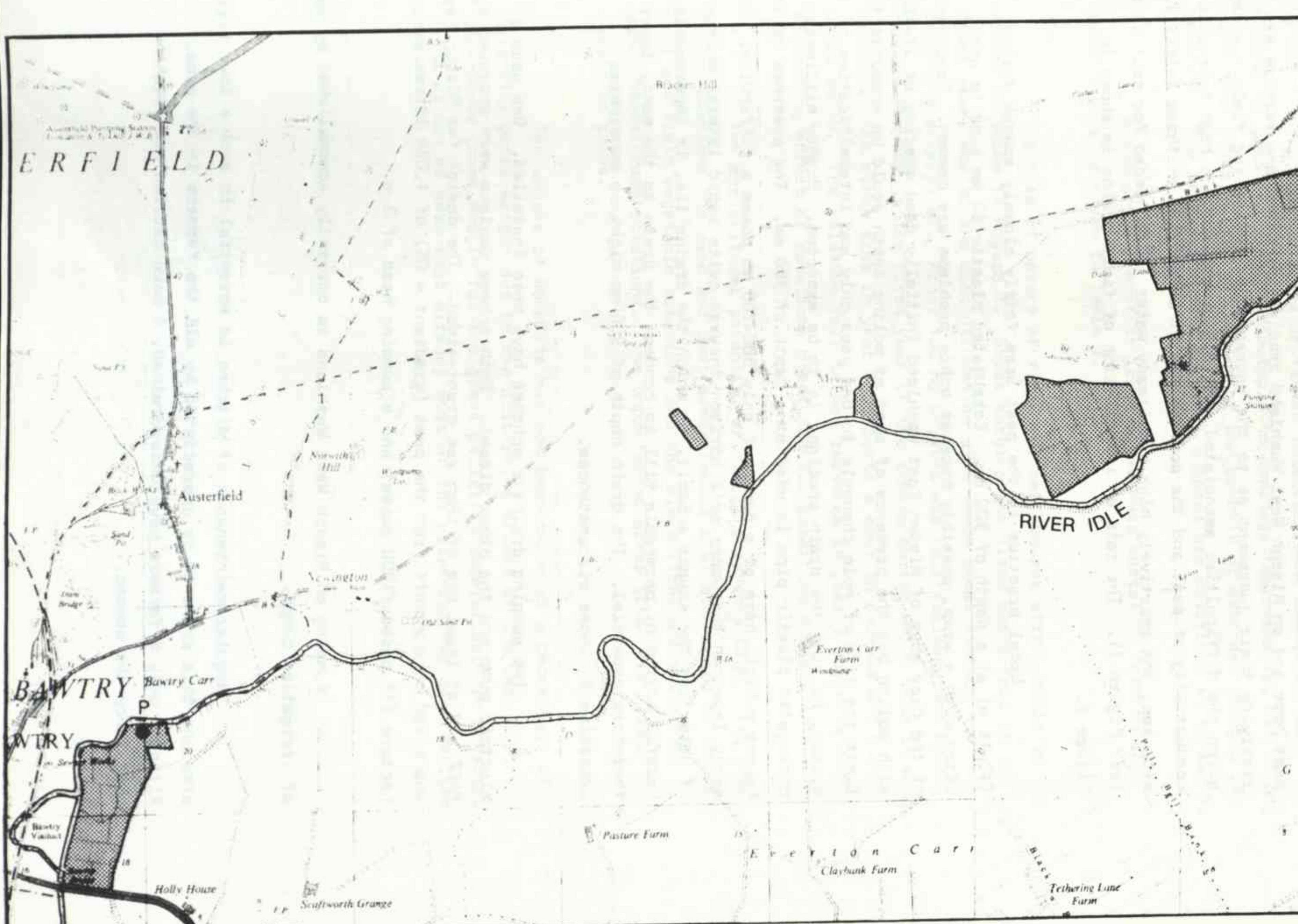


Fig. 7 : Field drainage installation

Field drainage installed since scheme

●P Pump installed

Field drainage has been installed on some of the areas of greatest need, namely the very low area affected by subsidence on the east bank at Bawtry and the clay area on Misson East Washlands. Much of the peat here and on Misson West Washland remains undrained and farmers are reserving their judgement as to the necessity of installing field drainage, given the difficulties associated with draining peat, the high hydraulic conductivity of peat and the possibility of obtaining, on these fairly flat expanses, the relatively high but steady water table needed for root crops (see Figure 7). The rate of installation of field drains is shown in Figure 6.

Local practice in the peat uses fairly closely spaced drains (17-18 m) at a depth of 900 mm. Corrugated plastic 80 mm pipe is used, often with a wrap, possibly because ochre problems are common. Drainage of the clay area of Misson East Washland initially used spacing of 37-40 m with moling but the presence of sand at moling depth would be expected to limit the life of mole channels to one year only and intensification of the system, halving the drain spacing, is to be expected. Eighty millimetre corrugated plastic pipe is used at a depth of 900 mm. The presence of the Keuper subsoil here at a depth of only 500-700 mm poses a difficulty. The sandy layer in the upper soil horizon ensures quite rapid lateral movement of water but the Keuper subsoil, in which the drains lie, is impermeable. Careful laying of permeable fill to connect the drain to the sandy layer is therefore essential. The drain depth of 900 mm might be considered excessive in thses circumstances.

Two pumping drainage schemes have been installed. One uses an electric pump and the other diesel. Both scheme designs were approved by MAFF and at least one of them was grant-aided. The design for Misson East was based on a runoff from the peat (gradient = 0%) of 1.038 litres/second/hectare (15 cusecs/1000 acres) and a pumping head of 2 m.

Pumping on Misson West Washland is currently accomplished by use of irrigation pumps.

Regular maintenance of ditches is essential in such a low, flat area and this seems to be appreciated by all the farmers in the area. Although only 4 farmers have underdrained, 8 have carried out ditching work since the scheme.

(d) Rate of Benefit Uptake:

A financial assessment of the Idle Stop scheme has been undertaken by identifying, on the basis of farmer interview, the change in farm enterprise gross margins attributable to drainage improvements, net of any additional fixed costs, and including the benefit of extended grazing if relevant. The procedures used for this purpose are described in Annexe V.

A summary of benefits (before drainage costs) by farm in the benefit area is given in Table 7.

The rate of uptake of financial net returns attributable to the scheme is shown in Figure 8. Gross margins and fixed costs fell in the first year, due to the discontinuation of a large grass cutting and pelleting enterprise. About 100 ha of this was half fallowed and half cropped for hay in the first year of the scheme during which time it was drained. The steep rise in year 2 reflects a move to cereals and high value roots. The relative fall in net revenues in year 4 reflects the moderating effect of rotations predicted for remaining project life.

The agricultural potential of the land is very high. For the Misson Washland the sand and peat areas (about 65%) are suited to cereal, root and field vegetable rotations and the clays (15%) are suited to grass/cereal/rape rotations. The unprotected areas (20%) are likely to remain in grass.

The uptake of benefits has not been shown as a percentage of potential gross margin due to the distorting effect of the very high pre-scheme gross margin for the grass pelleting enterprise. In physical terms it can be seen that already most of the potential has been realized.

FIGURE 8 : Degree and Rate of Financial Uptake

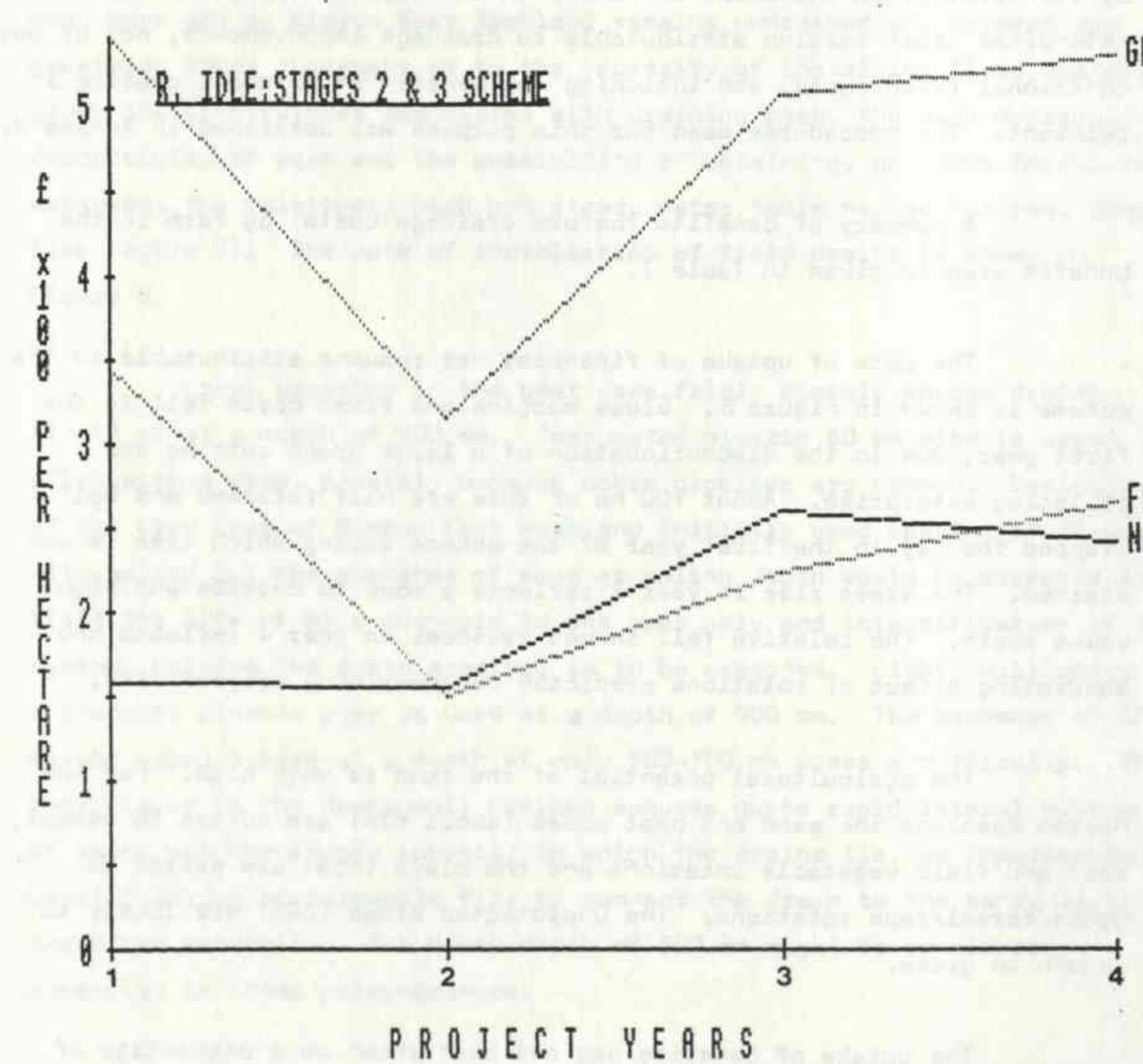


Table 7 : Distribution of Benefits by Farm

SCHEME 43 NET AGRICULTURAL BENEFIT
********* *************************

FARM CODE	YEAR FIRST	YEAR 2	YEAR LAST	% OF BENEFITS	% OF AREA
1	2410	2919	2991	8	9
2	-372	0	0	0	9
3	-21	399	493	1	7
4	-2994	22734	14528	38	26
5	4305	4305	4305	11	16
6	1555	1623	1623	4	4
7	324	373	373	1	3
8	1883	1883	1883	5	2
10	-8549	12492	12070	32	25
TOTAL			38269	100	456

14. Financial Analysis

A summary of the cash flow of the River Idle sections 2 and 3 scheme relating to the Misson Washlands is given in Table 8, in 1982 prices.

(a) Capital and Recurrent Costs:

The total capital cost of the entire River Idle scheme, West Stockwith to Mattersey, including the pumps at West Stockwith was as follows:

Year	Reach	Cost £'000	1982 prices £'000
1978/9	Pumping Station, West Stockwith to Idle Stop	2671	3257
1979/80	Idle Stop to Misson	624	678
1980/1	Misson to Bawtry	710	807
1981/2	Bawtry to Mattersey	795	795
		£4800	£5537
Less contribution from NCB			170
			£5367

As discussed in Appendix I the pre-scheme benefit assessment identified benefits relating to flood damage reduction (£195,000 per year, 1974 prices) and to improved land drainage (£163,600 per year, 1974 prices).

Most of the benefit area surveyed on the Misson washlands falls within the Idle and Ryton IDB. The pre-scheme feasibility study identified that land drainage benefits accruing to the Idle and Ryton IDB area of 1255 hectares would be £53,000 per year. The washlands (up to the major floodbacks) were not seen as a major beneficiary of flood damage reductions. It is possible to apportion a share of the

Table 8 : Summary of Scheme Cash Flow and NPV

RIVER IDLE : IDLE STOP TO BAWTRY

PROJECT YEAR	0	1	2	3	4	5	6	7	8	9	10 TO 30
CALENDAR YEAR	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991 TO 2011
AGRICULTURAL BENEFITS											
Net Agric Benefits	0	-1453	46733	38270	38270	38270	38270	38270	38270	38270	38270
Flood Damage Reduction	0	0	0	0	0	0	0	0	0	0	0
less Without Proj Ben	0	449	903	1362	1825	2292	2765	3242	3724	4210	4702
less Field Drain Cost	0	64029	623	2442	2442	2442	2442	2442	2442	2442	2442
NET AGRIC CASH FLOW	0	-65931	45207	34466	34003	33536	33063	32586	32104	31618	31126
SCHEME COSTS											
Capital	246240	0	0	0	0	0	0	0	0	0	0
Recurrent	0	6928	6928	6928	6928	6928	6928	6928	6928	6928	6928
TOTAL COSTS	246240	6928	6928	6928	6928	6928	6928	6928	6928	6928	6928
SCHEME NET CASH FLOW	-246240	-72859	38279	27538	27075	26608	[illegible]	25658	25176	24690	24198

NET PRESENT VALUE AT %	0	2.5	5	7.5	10	12.5	15	17.5	20
	410219	186222	53983	-27062	-78405	-111849	-134106	-149130	-159329

total cost of the river improvement to the Idle and Ryton IDB area, on the basis of the share of total benefits derived, as follows:

£53,000 benefits/year accruing to Idle and Ryton IDB

£163,600 benefits/year (drainage) + £195,000 benefits/year (flooding)

= 0.147 (share of benefits to Idle and Ryton IDB

£5,537,000 total cost of Idle improvement × 0.147

= £813,939 (in 1982 prices)

£813,939 ÷ 1255 ha (Idle and Ryton IDB area)

= £649 per hectare cost attributable to drainage improvement

less NCB contribution at £136 per hectare results in a capital cost of £513 per hectare.

Capital costs are therefore taken at £246,240 (480 ha × £513/ha). Incremental maintenance costs have been taken at 1½% of the gross capital cost before contributions. A share of the annual cost of operating the Stockwith pumps has been apportioned to the scheme using the same criteria as for capital costs. These approximate to £4.7 per hectare of benefit: £2,256 per year.

(b) Field Drainage Costs:

Some 112 hectares were drained[1] in 1982/3 at a total cost of £34,098, an average cost of £305 per drained hectare, and an average investment of £71 per hectare in benefit. Two grant aided pumping schemes have been installed on 27 hectares, and 84 hectares, and one mobile pump set has occasionally been used on a further 100 hectares. On the basis of farm records, pumping costs to cover energy, repairs and maintenance, and pump replacement, average £22 per hectare per year. A number of farmers have rehabilitated existing or cut new watercourses, the cost of which is included in the total field drainage costs given above.

(c) Without-Project Benefits:

It is assumed that without-project improvements in the financial performance of farming would equate to an annual increase of

1 This area refers to the actual area underdrained and therefore does not agree with the 154 ha quoted in section 13(c) which is the total area of fields receiving underdrainage treatment, some of which were only drained in parts.

1% compound of the pre-scheme farming net returns. This charge has been levied only against those areas for which some post-scheme benefit uptake has been ascertained. In the case of the Idle sections 2 and 3, uptake has occurred on 37.8% of the area in the first three years of the scheme. Without-project benefits are therefore charged at 1% compound of 37.8% of the pre-scheme net returns, namely, £118,842 x .378 x 1% compound.

(d) Flood Damage Reduction:

Pre-scheme flooding occurred annually during the winter periods resulting in costs of fence repair and debris clearance; 28 man days at £46.4 for a man and tractor, plus a total of £650 on fencing materials; a total of £1,950. Summer flooding reportedly severely damaged the hay crop once every 3.5 years, resulting in complete loss on 93 hectares, equivalent to £9,964 per year. A grand total of £11,914 per year for pre-scheme flooding costs.

There has been no flooding in the benefit area since the scheme. If floods do occur, the cost per event is likely to be greater given the move to higher value cropping.

Winter/spring floods, depending on timing and duration, may result in a depression of yields of say 20-30%, or the need to reseed with spring sown crops. Losses due to such events are likely to range between £150 to £200/hectare for winter sown arable crops, and about £100 for grass. Spring floods could delay crop planting with similar yield penalties. Summer floods are likely to result in complete crop loss.

Bankfull design capacities are one in 3, one in 5, and one in 7 year return periods for Idle Stop to Misson, Misson to Newington and Newington to Bawtry. The return period for flood events resulting in significant inundation is likely to be greater. STWA engineers report that given the nature of the catchment, and the river scheme, significant flood events are likely to be 90% winter/spring, 10% summer.

During the course of the farm survey farmers reported pre-scheme flood liability on some 240 hectares. Assuming significant flood events occur at about 1½ times the design return period intervals, that winter/spring summer floods occur in the ratio 9:1, that winter/spring floods result in a penalty of £200 per hectare on arable and £100 per hectare on grass, and that summer floods result in the complete loss of the standing crop (for which the gross margin can be used as a proxy for gross revenue lost minus uncommitted expenditure), the following costs are ascertained.

	Flood Return Period	Area at Risk (ha)	Cropping	Gross Margin £/ha
Idle Stop to Misson	1:5	80	Cereal/rape	800
Misson to Newington	1:8	100	Cereal/roots	1000
Newington to Bawtry	1:10	60	Cereal/leys	600

On this basis, with-project annual flood damage costs are about £10,300 per year before miscellaneous repair/clearing costs.

On balance, it is considered that pre-scheme flood damage costs will equate to post-scheme flood damage costs. This assumption is tested in the sensitivity analysis.

(e) Project Worthwhileness:

In Table 8, the 1984 cash flow represents a prediction of likely cropping performance over the remaining 30 year project life. The estimate is based on uptake over the three years todate, and discussions with the farmers concerned. Net return estimates are based on anticipated rotations, many of which are underway.

The estimated net present value of the scheme at the 5% discount rate is £79,576 in 1982 prices, producing an internal rate of return of 7.4%.

(f) Sensitivity Analysis:

Table 9 examines the sensitivity of the scheme to cost and

TABLE 9

River Idle : Idle Stop to Bawtry - Sensitivity Analysis

Run No.	Agricultural Benefits Factor	Without Project Benefits Compounding Factor	Flood Damage Reduction Factor	Capital Works Cost Factor	NPV at 5% £	IRR %	Switching Value %*
1	1.0	0.01	1	1	79576	7.4	0.85
2	1.0	0.015	1	1	71996	7.2	0.87
3	1.0	0.005	1	1	86966	7.6	0.84
4	1.0	0.0	1	1	94169	8.0	0.82
5	1.0	0.0	1	1.34	0	5.0	0

* The factors show the weights applied to the original estimates eg a factor of 1.5 for the without-project benefits indicates that the new value is 1.5 x 1% compound per year (the original value) ie 1.5% compound.

* Switching value : change in agricultural net benefits needed to make the project breakeven at 5% discount rate eg a 1.5 switch value shows an increase of 1.5 x the original estimated is required.

benefit estimates. Benefits could reduce by 15% of their estimated level before prejudicing the scheme at the 5% discount rate.

With respect to flood damage costs, if the project resulted in additional flood damage costs due to the higher costs of less frequent flood events, at present benefit levels, an increased average annual flooding cost of £5,500 could be borne whilst enabling the scheme to break even. On the assumptions used in section 14.4, such additional costs would arise if extensive flooding resulted from bankfull capacity return periods but this is unlikely to be the case.

The share of the River Idle scheme costs apportioned to sections 2 and 3 could rise by 34% without prejudicing the project at the 5% discount rate.

15. Effect of the Scheme on Wildlife and Conservation

A large part of Misson Washlands were previously an SSSI, being an over-wintering area for Bewick swans. Some areas have been left unprotected by minor floodbanks and these are to be redesignated as SSSI along with Bawtry Carr. These areas, however, may be too small and in the latter case, too close to urban development to remain an attraction for the Bewick swans. They will, however, continue to attract other species. The area which remains unprotected on Misson West Washland is being managed in a fashion designed to encourage the swans, being grazed by sheep. The swans require shallow flooding of closely cropped grass since they graze at the water's edge, so the previous management of the washlands, when they were largely cut for dried grass, suited them very well. The failure of the NCC to retain the SSSI seems to have been due to a lack of resources and of vigilance on their part and it runs counter to their policy. In the event, however, the investment in West Stockwith pumping station had been made before any objections were made despite consultation at the feasibility stage, which represented an insuperable *de facto* argument in favour of completing the scheme as planned. There was in addition pressure from the landholders, particularly, perhaps, those who had acquired land in anticipation of the scheme. More strenuous objection from the NCC would have arisen had the full implications of the proposal to construct West Stockwith Pumping Station been realised. It should be noted that a comprehensive feasbility report was submitted to the NCC in 1975, ie. prior to the commencement of the design of the West Stockwith Pumping Station or the channel works, and no objections were received. The major landholders on both East and West Washlands have subsequently worked in cooperation with the NCC in establishing and supervising the remaining areas of washland as conservation sites.

The scheme contains several engineering features of conservation and amenity interest. These include low-level berms for fishermen, the construction of a fishing pond at Bawtry, of fish-breeding holes and of a wetland scrape at Bawtry and on Misson East Washland.

The reduction of flooding even on the unprotected areas left for conservation should not affect their value as wetland sites. Discussions are taking place with the NCC concerning the frequency and duration of flooding of the wetland areas.

References

(1) Severn Trent Water Authority; Trent River Management Division (1974) River Idle: Improved Drainage of the Lower Reach. A report on the feasibility of pumping the River Idle at West Stockwith.

(2) MAFF Agricultural Land Classification of England and Wales, Sheet 103.

(3) Severn Trent Water Authority; Lower Trent Division (1975) River Idle Supplementary Report.

(4) Severn Trent Water Authority (1980) Lower Trent Division and Nottinghamshire: Land Drainage Survey. Section 24(5) Water Act 1973.

(5) M. Dodson, STWA Senior Project Engineer, Nottingham. Personal communications (17.3.83 and 4.10.83).

(6) J. Nix (1981) Farm Management Pocketbook, 12th edition (1982). Wye College, University of London.

(7) Soil Survey (1983) National Soils Map at 1:250,000. Soil Survey, Harpenden.

APPENDIX I

PRE-SCHEME COST-BENEFIT ANALYSIS FOR THE RIVER IDLE SCHEME

The assessment of the costs and benefits of the River Idle Improvement Schemes was contained in 2 reports on the feasibility of pumping at West Stockwith.

(a) Cost

The first feasibility report (Ref. 1) estimated the total cost of works associated with the entire scheme (ie. sections 1 to 4 and the Pumping Station at West Stockwith) at £3.35 million (1974 prices). A second evaluation (Ref. 2) based upon smaller pumps reassessed the total cost as £2.95 million (1974 prices) including the cost of work to be carried out by IDB's and by farmers in IDB areas. This was made up as follows:

	£ million
West Stockwith Pumping Station	1.05
River Idle channel improvement	0.95
IDB works	0.54
Field drainage by farmers	0.41
	£2.95

Grants were obtained from FEOGA (£698,000 on final account) and MAFF (37%). A contribution of £170,000 was received from the National Coal Board in respect of mining subsidence in the vicinity of Bawtry.

(b) Predicted Benefits

The benefit assessment, after the benefits associated with future urban development had been omitted, fell into two categories, viz:

(i) Flood protection (= saving of the cost of damage),

(ii) Land drainage.

(i) Flood protection benefits

The assessment of major flood damage used unspecified agricultural information from MAFF and estimates of flood extent and effect based on the experience of the March 1947 flood. Protection of the washlands against minor floods was considered along with land drainage benefits, but protection of the A.631 road at Bawtry against minor floods was assessed separately, by considering the cost of the extra distance travelled by diverted vehicles.

The following method was used to assess flood protection benefits (see Table 1):

(1) Agricultural damage was estimated. The cost of damage was assessed separately for summer, spring and winter, taking account of variations in damage throughout the season. The following categories were considered:

(a) 100% loss of growing crops,

(b) Loss of stored crops, fodder, fertilizer, etc.,

(c) Extra cultivation following land dewatering,

(d) Loss of yield on growing and subsequent crops,

(e) Grassland damage,

(f) Livestock.

The North and South banks were assessed separately.

(2) To each season's total risk of agricultural damage were added non-seasonal damage costs, under the following categories:

(a) Reinstatement of drains, ditches, field drainage and pumping installations,

(b) Repair of damaged floodbank and roads,

(c) Flooding of property,

(d) The cost of emergency works and dewatering.

(3) The total of seasonal and non-seasonal damage costs during each season was aggregated over the period 1932-73 and the annual flood risk estimated by reference to the frequency of flooding during each season on each bank over that period, (Table 1. below). This gave a total annual value of flood risk. The method of calculation was not given and it has not been possible to duplicate these results exactly.

(4) The estimated value of the post-scheme annual flood risk was subtracted to give a net annual benefit due to the reduced risk of major floods.

(5) To this was added the annual benefit of protecting the A.631 road from minor floods, giving a total annual value of flood protection benefits. The first estimate of this annual value was £159,500, which was revised to £195,000 in the supplementary report.

(ii) <u>Land drainage benefits</u>

Land drainage benefits were assessed by considering the increased profitability per unit area from changes in land use or from improved drainage. Each Internal Drainage Board was considered separately and the assessment is summarised below:

Idle and Ryton IDB:

The area of benefit (1255 ha), which includes the area surveyed for the present study, consists of three areas which were originally assessed as follows (1):

(a) Misson Washlands (400 ha). Increased profitability due to a change in land use from grassland to arable cropping was estimated at £62 per ha by comparison with adjacent land, giving a benefit of £25,000 per annum from protection against minor flooding coupled with a pumped drainage scheme.

(b) Area between Bawtry and Newington (81 ha). A similar rate of benefit was assumed from the anticipated installation of a small pumped drainage scheme, giving a benefit of £5,000 per annum. This area has been affected by mining subsidence.

(c) Bawtry to Mattersey (769 ha). Improved profitability was estimated at £100 per acre (£247 per ha) from increased freeboard giving better gravity drainage, along with protection against minor floods, assuming that the land remained as grazing, giving a benefit of £19,000 per annum.

The total benefit on these areas was thus estimated originally at £49,000 per annum. This figure was revised to £53,000 in the supplementary report.

Everton IDB (3,238 ha):

The IDB was proposing drainage improvements over half the area (1,620 ha). It was thought that these would lead to increased profitability of £69,840 per annum (approximately £43.00 per ha). The source for this figure was given as,

"A detailed soil survey and investigation of potential agricultural benefits ... by Ministry agriculturalists",

but no reference was given.

Finningley IDB (931 ha):

It was assumed that benefit over this area would be obtained in a similar fashion at a similar rate, giving a benefit of £39,100 per annum over the area.

South Axholme IDB (40 ha):

Benefit at the same rate amounts to £1,700 per annum.

The annual value of land drainage benefits was initially estimated at £159,600, and was re-assessed at £163,600 after revision of the benefit in the Idle and Ryton IDB areas. It was assumed that the lower standard of flood protection given by the revised proposal involving smaller pumps at West Stockwith would not reduce the value of land drainage benefits (which, in this case, include protection against minor flooding). A summary of land drainage benefits is given in Table 2, below.

(c) <u>Comparison of Costs and Benefits</u>

For the purpose of comparison with costs the net present value of the benefits was calculated by discounting at 10% over the expected life of the benefit, as follows:

Estimated benefits:

		£ million
(i)	Reduced flooding risk £195,000 per year	
	Net present value at 10% over 30 years =	1.84
(ii)	Land drainage benefits £163,600 per year	
	Net present value at 10% over 20 years =	1.39
	TOTAL =	£3.23 million

Capital costs were estimated as follows:

	£ million	£ million
Works to be carried out by the Authority:		
West Stockwith Pumping Station	1.05	
River Idle Channel Improvement	0.95	2.00
IDB works		0.54
Field drainage in IDB areas		0.41
Total cost of works associated with proposed scheme		£2.95 million

The comparison of these totals gives a benefit/cost ratio of nearly 1.1. In the supplementary report it is stated that:

"If costs and benefits are discounted to take account of their being spread over a number of years the benefit/cost ratio will rise to about 1.28".

but this calculation is not given.

Maintenance costs were not included, only capital costs. Maintenance of floodbank levels is an ever-present problem on the River Idle due to settlement of the banks, which is one reason for increasing flood protection by lowering the flood level rather than by trying to increase the height of flood defences. It is possible that awareness of the need for future maintenance influenced the choice of 30 years and 20 years respectively as the periods of benefit for reduced flooding risk and land drainage benefits (including reduced minor flooding), but details of the choices are not given in the report.

Tables 1 to 4 below are taken from the Supplementary Feasibility Report (Ref. 2) and show the calculation and comparison of costs and benefits.

References

(1) Severn Trent Water Authority; Trent River Management Division (1974) River Idle: Improved Drainage of the Lower Reach. STWA, Nottingham.

(2) Severn Trent Water Authority; Lower Trent Division (1975) River Idle: Supplementary Report on the Feasibility of Pumping at West Stockwith. STWA, Nottingham.

Table 1

ESTIMATED FLOOD DAMAGE - NORTH BANK

Agricultural Damage	Summer	Spring	Winter
	£	£	£
100% loss of growing crops	816,300	80,300	93,600
Loss of stored crops	-	84,500	156,000
Extra cultivation following dewatering of flooded land	-	23,500	23,500
Loss of yield on growing and subsequent crops	15,100	175,100	77,900
Grassland	8,500	5,100	3,000
Livestock	36,000	36,000	36,000
TOTAL	875,900	404,500	390,000

Other Costs (Non-Seasonal)

	£
Reinstatement of internal drains, ditches, field drainage, pumping installations	250,000
Repair of embankment and roads	60,000
Allow for effect of flooding on property	95,000
Emergency Works	25,000
TOTAL	£430,000

ESTIMATED FLOOD DAMAGE - SOUTH BANK

Agricultural Damage	Summer	Spring	Winter
	£	£	£
100% loss of growing crops	463,400	89,000	91,500
Loss of stored crops, etc.	-	51,000	77,700
Extra cultivation following dewatering of flooded land	-	16,000	16,000
Loss of yield on growing and subsequent crops	-	112,600	37,500
Grassland damage including loss of grazing and grass for processing	51,500	20,000	1,000
Livestock	25,000	25,000	25,000
TOTAL	539,900	313,600	248,700

Other Costs (Non Seasonal)

	£
Reinstatement of drains, ditches, field drainage pumping installations	190,000
Repair of damaged floodbank and roads	60,000
Allow for effect of flooding on property	60,000
Allow for cost of emergency works	25,000
TOTAL	£335,000

Table 2

SUMMARY OF LAND DRAINAGE BENEFITS

Internal Drainage District	Area of Benefit (acres)	Benefit (£ per annum)
Idle and Ryton	3,100	53,000
Everton	8,000	69,800
Finningley	2,300	39,100
South Axholme	100	1,700

PRESENT ANNUAL VALUE OF LAND DRAINAGE BENEFITS £163,600

SUMMARY OF FLOOD PROTECTION BENEFITS

(i) MAJOR FLOODS

Season	SOUTH BANK No. of floods 1932-73	SOUTH BANK Estimated Flood Risk	NORTH BANK No. of floods 1932-73	NORTH BANK Estimated Flood Risk
		£		£
Summer	2	875,000	1	1,306,000
Spring	4	648,500	2	834,500
Winter	1	583,500	1	820,000
Annual Risk	7	117,300	4	90,400

	£
TOTAL ANNUAL VALUE OF FLOOD RISK	207,700
Flood risk with proposed scheme 1 in 50 years	29,700
NET ANNUAL BENEFIT DUE TO REDUCED RISK FROM MAJOR FLOODS	178,000

(ii) MINOR FLOODS

Scheme will reduce flooding to an average of $1\frac{1}{2}$ days per year	17,000
TOTAL ANNUAL VALUE OF FLOOD PROTECTION BENEFITS	195,000

APPENDIX J

Lower Trent Division

River Idle : Bawtry to Mattersey

Estimated Capital Costs (April 1974)

		£	£
(1)	**West Stockwith Pumping Station**		
	Provision and installation of 2 No. 450 cusec and 2 No. 175 cusec electric driven axial flow pumps and ancillary equipment	392,000	
	Construction of pumping station (civil engineering works)	580,000	
	Capital contribution to East Midlands Electricity Board	45,000	
	Site investigation, model tests, land purchase and compensation	20,000	
			1,037,000
(2)	**Channel Improvement**		
	Regrading and enlargement of River Idle channel between West Stockwith and Mattersey including construction of minor floodbanks and disposal of surplus spoil.	865,000	
	Land purchase and compensation	85,000	
			950,000
	Total Capital Cost to Authority		£1,987,000
		say	£2,000,000

Table 4

COST/BENEFIT COMPARISON

Estimated Capital Costs

	£ million	£ million
Works to be carried out by the Authority		
West Stockwith Pumping Station	£1.05	
River Idle Channel Improvement	£0.95	£2.00
Works to be carried out by I.D.B.'s		0.54
Field drainage in I.D.B. areas		0.41
Total cost of works associated with proposed scheme		£2.95

Estimated Benefits

		£ million	£ million
(i)	Reduced flooding risk £195,000 per year		
	Net present value at 10% over 30 years	£1.84	
(ii)	Land drainage benefits £163,600 per year		
	Net present value at 10% over 20 years	£1.39	
	Total land drainage and flood protection benefits from proposed scheme		£3.23

CONCLUSIONS

The comparison shows the benefit/cost ratio of the proposed scheme to be nearly 1.1 considering capital costs.

If costs and benefits are discounted to take account of their being spread over a number of years the benefit/cost ratio will rise to about 1.28

SILSOE COLLEGE

STWA LOWER TRENT DIVISION - RIVER IDLE SECTION 4 :
BAWTRY TO MATTERSEY

Report on the background to, and development of, the scheme and the nature and rate of uptake of agricultural benefits.

1. Physical Background

The River Idle and its tributaries flow north east through north Nottinghamshire towards the River Trent, joining it at West Stockwith. At Mattersey the Idle swings west to Bawtry, skirting the Keuper outcrop at Prospect Hill (Harwell), then turns east towards the Trent. The present scheme relates to the stretch of the Idle between Bawtry and Mattersey and the Ryton from its confluence with the Idle to Scrooby.

The area of the combined Idle and Ryton catchments is 842 sq. km. This area is mostly rural although the towns of Retford, Worksop and Mansfield lie within the catchment. A large proportion of the catchment is formed of Bunter Sandstone which is very permeable, bears few streams and supports large tracts of woodland on a thin coverage of soil.

The Idle forms a broad, flat valley with moderate river gradients. It is bounded on the west by hills rising to 180 m and to the east by a ridge of Keuper Marl. Downstream of Bawtry the Idle is embanked above the adjoining land. The pre-scheme bed gradient along this reach was shallow (1 in 12,000). Upstream of Bawtry to Retford the Idle channel is formed in alluvial gravels, its flood plain extending to 1.5 km. Pre-scheme bed gradients were approximately 1 in 4,000, along the stretch from Bawtry to Mattersey (1).

2. Soils and Land Capability

The land is classified by MAFF as grade 4 between Bawtry and Scrooby and grade 3 upstream to Mattersey (2) (see Figure 1). These classifications largely reflect the pre-scheme restrictions on land use imposed by frequent flooding and the lack of opportunity for dewatering, rather than restrictions imposed by the soil itself. There are two main soil types in the benefit area, a deep sandy peat which overlies gravel and

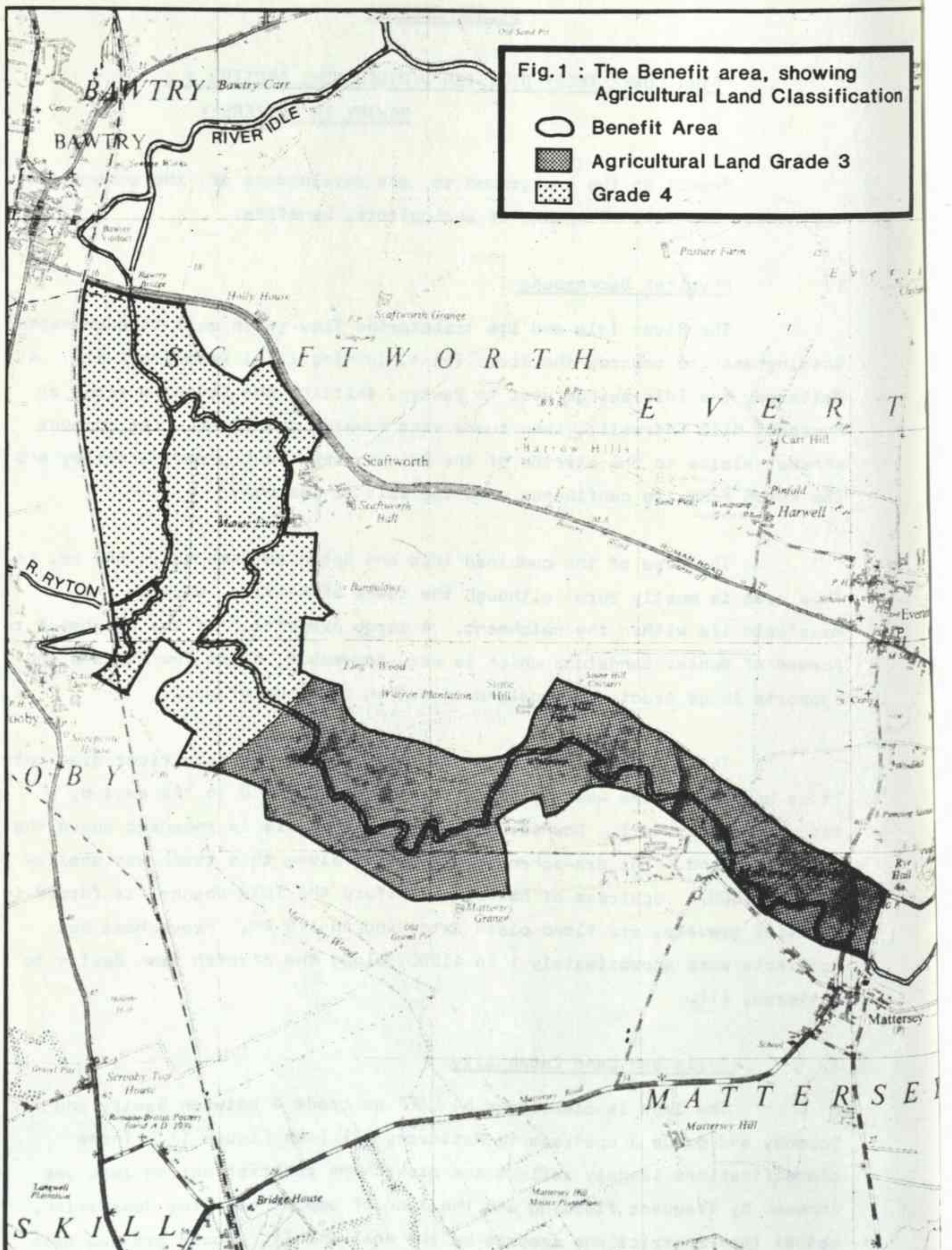


Fig.1 : The Benefit area, showing Agricultural Land Classification

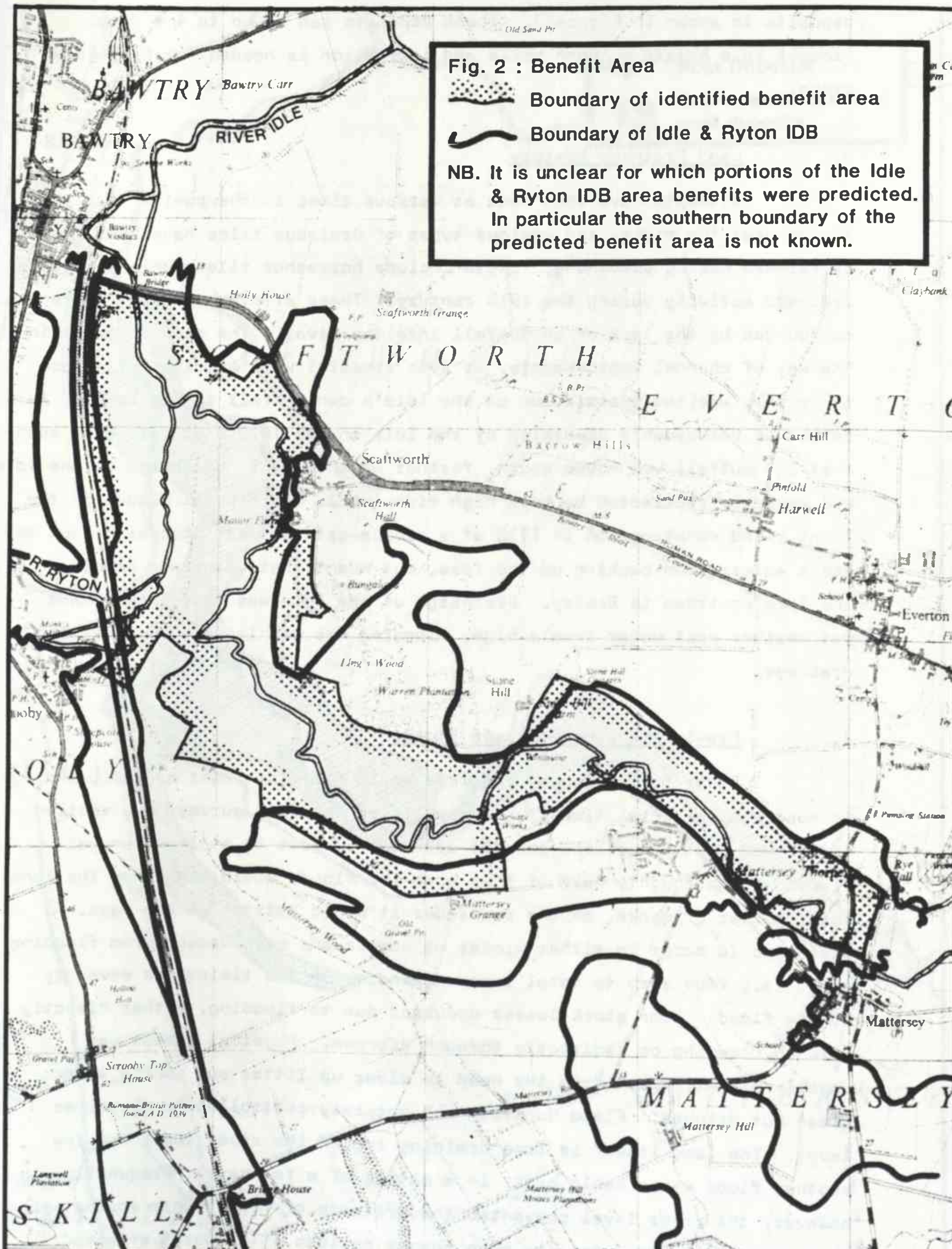


Fig. 2 : Benefit Area

a light sandy soil. Both soils are free draining. The extent of peat deposits is shown in Figure 3. These deposits can be up to 4 m deep. Drought is a hazard on both soils and irrigation is needed for high value crops.

3. Land Drainage History

Attempts have been made at various times in the past to drain fields near the river, and various types of drainage tiles have been found by farmers during ploughing; these include horseshoe tiles, which indicate drainage activity during the 19th century. These efforts, however, were confounded by the lack of an outfall into the river. The main obstacle in the way of channel improvements, or even remedial work to clear silt from the river, was the restriction on the Idle's own outfall to the Trent. As a result of Vermuyden's diversion of the Idle in the 1620's at Idle Stop such that its outfall was moved south, further up the Trent, discharge of the Idle was severely restricted by both high tide levels and fluvial floods in the Trent. The construction in 1938 of a sluice-gate at West Stockwith kept the Trent waters from backing up the Idle, but meant that water was ponded in the Idle upstream to Bawtry. Discharge of the Idle was thus impeded and wet weather kept water levels high, flooding the washlands and preventing drainage.

4. Pre-Scheme Land Drainage Status

Prior to the scheme the Idle would flood at least annually and in most years several times. The results of the farm survey (see section 10) showed that 90% of the benefit area was subject to at least annual flooding. On roughly half of this area the floods would remain on the land for a number of weeks, on the remainder it would retreat within days. Floods would occur in either winter or summer and crop damage from flooding could vary from zero to total loss, depending on the timing and severity of the flood. Some stock losses occurred due to flooding, either directly through drowning or indirectly through disease. Physical damage was usually slight, apart from the need to clear up litter and debris and to clean out ditches. Flood duration was entirely controlled by the river level. The land itself is free draining and if the river level was low enother flood water could drain in a matter of a few days. Frequently, however, the river level prevented the drainage of flood water so that the land remained under water for much longer periods. The worst affected portion was that between Bawtry and Scrooby, on both the Idle and Ryton.

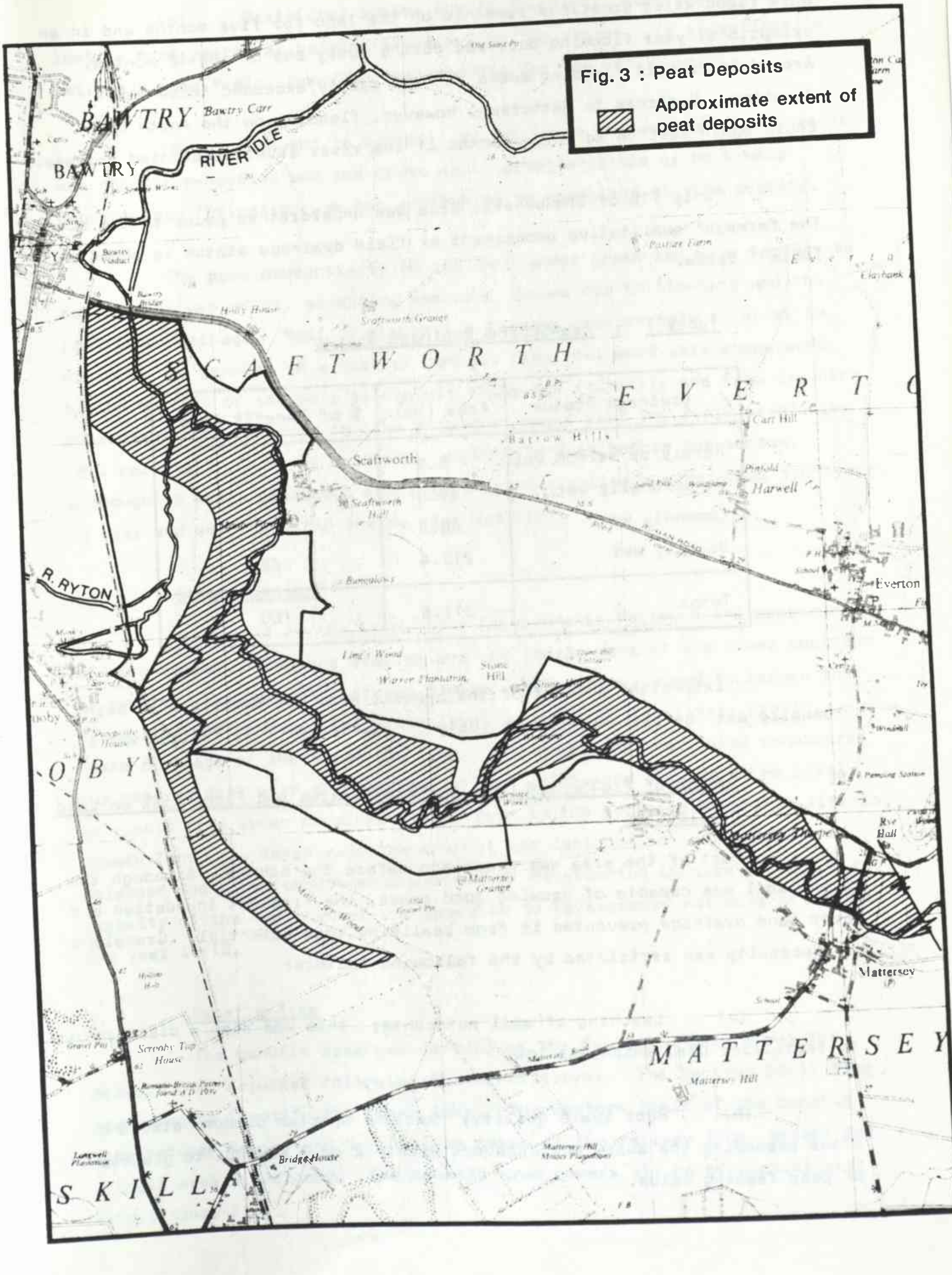


Fig. 3 : Peat Deposits
Approximate extent of peat deposits
BAWTRY
RIVER IDLE
R. RYTON
SCAFTWORTH
Scaftworth
EVERTON
Everton
Harwell
MATTERSEY
Mattersey
SKILL
Scrooby Top House
Bridge House
Stone Hill
Scaftworth Grange
Barrow Hills
Warren Plantation

Here flood water sometimes remained on the land for five months and in an exceptional year flooding occurred during every one of the 12 months. Around Stone Hill flooding seems to have rarely exceeded three weeks' duration. Upstream to Mattersey, however, flooding on the north bank could again last up to three months if the river levels prevented rainage.

Only 11% of the benefit area was underdrained prior to the scheme. The farmers' qualitative assessment of field drainage status is shown in Table 1 below.

Table 1 : Pre-Scheme Drainage Status

Drainage Status	Area (ha)	% of Benefit Area
Rarely or seldom wet	9.3	3
Occasionally wet	49.8	16
Commonly wet	40.3	13
Usually wet	212.4	68
Total	311.8	100

Sixty-eight percent of the benefit area was described as being 'Usually wet' before the scheme. Only 3% was 'Rarely' or 'Seldom wet'.

5. Impact of Pre-Scheme Land Drainage Status and Flood Risk on Land Utilization

Most of the area was grassland before the scheme. Although the peaty soil was capable of growing good grass, the frequent inundation and poor land drainage prevented it from realizing this potential. Grassland productivity was restricted by the following factors:

(a) Leaching of soil nutrients; this was also a disincentive to fertilizer use, which was low.

(b) Poor sward quality; wetland species predominated and after reseeding the sward would revert within 2 or 3 seasons to grasses of poor feeding value.

(c) Restricted access due to flooding; some grazing was lost in most years, at varying times during the season. In exceptionally wet years some fields remained inaccessible for the entire year.

(d) Drought in summer; in dry years the available soil water was quickly exhausted and the grass would provide little or no summer production. Irrigation was not worthwhile on grassland of this quality.

The poor productivity of the land under grass led some farmers to make arable use of it, accepting periodic losses due to flooding and the poor land drainage. Most of the arable farmers grew cereals in order to minimize the penalty of a lost or damaged crop, but some were encouraged by the quality of the soil to exploit fully its fertility and free draining characteristics in order to grow potatoes, sugar beet and field vegetables (eg. carrots). This was evidently worthwhile even before the scheme, although it was a hazardous operation; yields varied a great deal from year to year and sometimes the entire crop was lost.

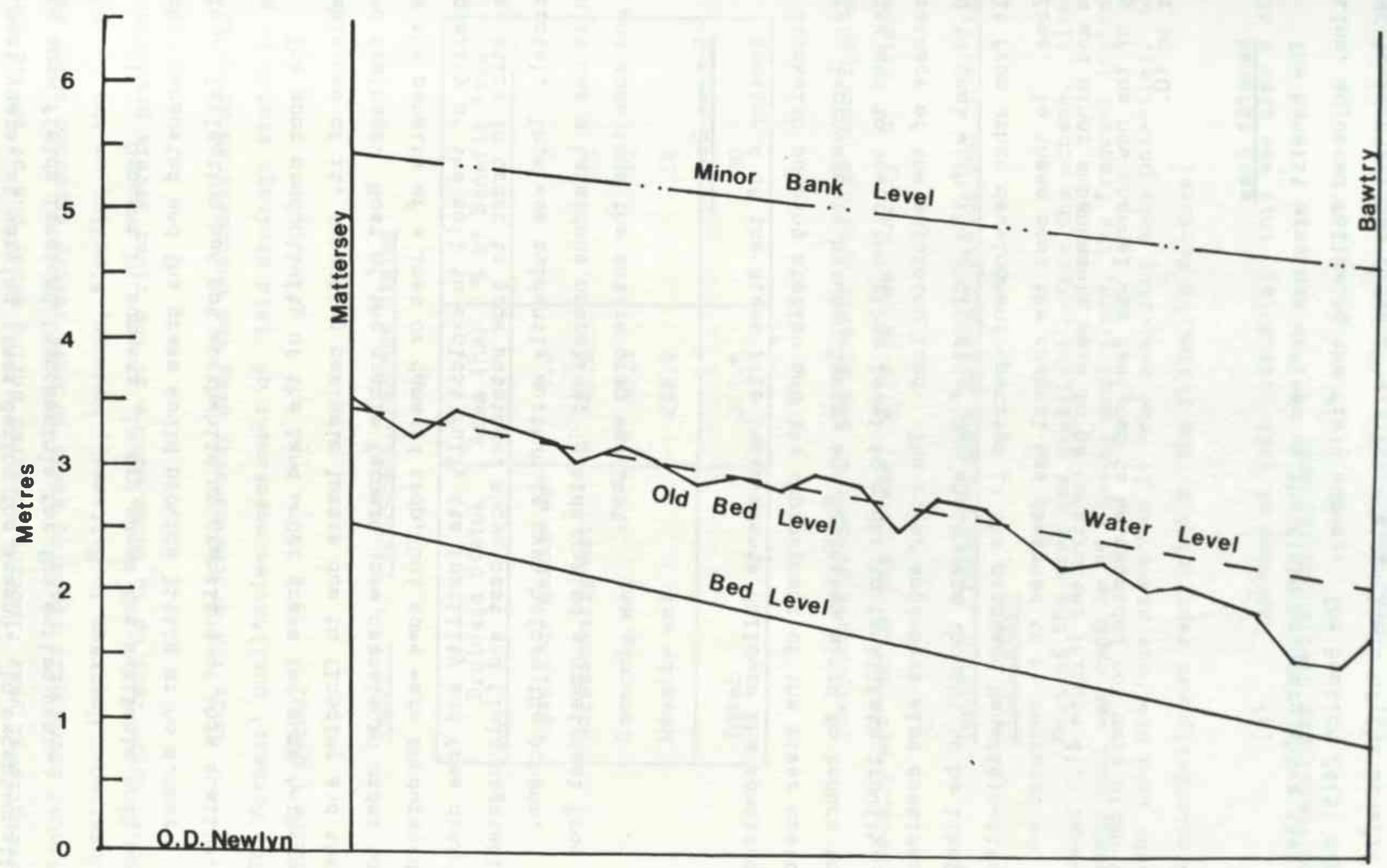
6. Scheme Design

Section 4 of the River Idle improvements followed the construction of West Stockwith pumping station and the improvement of the river upstream to Bawtry. Improvements between Bawtry and Mattersey aimed to reduce the flood risk and to lower the river level in order to facilitate gravity field drainage of the adjoining land. The river engineers also considered the need to deal with the increased flows which were thought to be likely to result from urban development upstream in the proposed Mansfield-Alfreton Growth Zone. To these ends the channel was designed to be regraded and enlarged and minor embankments were to be constructed (Figure 4). Bank-full capacity of the new channel was designed to be exceeded not more often than one year in 10.

7. Benefit Area

The benefit area was defined as the field boundary above the Medway Line, adjusted following the field survey. The Section 24(5) maps were used to identify the flood line. The western limit of the benefit area between Bawtry and Scrooby was taken as the railway line, except for a small area at Scrooby. The benefit area covers 311 ha of agricultural land (Figure 2).

Figure 4 : Longitudinal Section as Constructed (5)



The benefit area used in the first feasibility report (1, p. 47) covered 769 ha in the Bawtry to Mattersey section and was defined by the Idle and Ryton IDB boundary. While this boundary conforms fairly well with the identified benefit area to the north and east (see Figure 2) it extends well beyond it to the south and also includes the woods south of Scaftworth, which are excluded from this study. It is unclear from the map and definition given in the first feasibility report (1) how far the area of benefit was taken to extend to the south of the river, but benefit must have been assumed over a portion of the Idle and Ryton IDB area south towards Ranskill. This area is very flat and lies low, and some improvement in drainage may have become possible following the scheme, but the present study is restricted to the riparian lands previously affected by flooding, and the benefit area is defined accordingly.

8. Predicted Costs and Benefits

No separate appraisal was carried out for section 4 of the River Idle Improvement Scheme. The costs and benefits of section 4 need to be considered in the context of the entire scheme, including the construction of the West Stockwith Pumping Station. The entire scheme was estimated to cost £2.95 million and the benefits were assessed at £3.25 million (4). A contribution of £170,000 was made by the National Coal Board in respect of the mining subsidence in the vicinity of Bawtry. A more detailed description of the predicted costs and benefits of the River Idle scheme is contained in Appendix I to the report on sections 2 and 3.

It was estimated that improved profitability over the 769 ha of the Idle and Ryton IDB area which had been identified as benefiting from section 4 would be £100 per acre (£247 per ha), giving a benefit of £19,000 per annum. This estimate assumed that the land would be used for grazing.

9. The Scheme

Works on section 4 of the River Idle improvements were enacted between August 1981 and October 1982. The new bed level at Bawtry was 0.3 m lower than the design level due to other excavation on section 3 and it was decided to carry this extra depth of excavation up to Mattersey in view of a discovered need for greater freeboard for further work continuing upstream. In the event the bed and water levels at Mattersey have been lowered by about 1 m. The depth of water allowed for was 900 mm but so far water levels seem to be somewhat lower than this. Freeboard to immediately adjacent land in section 4 became a minimum of 1.25 m on the right bank and 1.52 m on the left bank and in most cases exceeds 1.60 m. The longitudinal section is shown in Figure 4.

Floodbanks were constructed to give 1 in 10 year protection. They were designed in consultation with farmers so that they could be constructed with steep or shallow slopes according to the intended land use.

The cost of work on section 4 was £795,000 (contract prices), out of a total of £2,394,000 for works between West Stockwith and Mattersey and £4,800,000 for the entire project, including the construction of West Stockwith Pumping Station (5).

10. Farm Survey

Ten farmers were interviewed during February 1983 who between them farmed 309 ha in the benefit area. Discussions were held with another farmer who had recently left the area and land use and drainage information was collected such that the survey covered 99% of the benefit area defined in section 7.

11. Agriculture in the Benefit Area

(a) Farm Type, Size and Tenure:

The farms surveyed are classified by size, type, tenure and management status in Tables 2-5 below.

Most farms with fields in the benefit area are classified as 'General Cropping' (6 out of 10 farms) but the two farms classified as 'Mainly Dairy' constituted the largest sector by area (41% of the benefit area, see Table 2). Six out of the 8 non-dairy farms have a beef enterprise of some type, so that only two farms are entirely arable.

Most farms are less than 200 ha in size (Table 3), accounting for 83% of the area. None of the farms is categorised as 'part-time' (less than 250 Standard Man Days) and about half fall within the range 250-999 SMD (5 farms, 43% of the area) with half in the range 1500-1999 SMD (4 farms, 53% of the area).

None of the farms in the benefit area is wholly owned, whereas 6 are wholly tenanted. Over half the farms are partnerships.

Table 2 : Farm Type (MAFF Classification)

Farm Type	No. of Farms	% of Surveyed Area
Mainly dairy	2	41
Mostly cereals	1	25
General cropping	6	33
Mainly vegetables	1	1
Data unavailable	1	1

Table 3 : Farm Size (area)

Farm Size (ha)	No. of Farms	% of Surveyed Area
50 - 100	4	39
100 - 200	3	44
200 - 300	1	9
300 - 500	2	7
Data unavailable	1	1

Table 4 : Farm Size (Standard Man Days)

Farm (SMD)	No. of Farms	% of Surveyed Area
250 - 499	2	29
500 - 999	3	14
1000 - 1499	0	-
1500 - 1999	4	53
2000 - 2499	1	3
Data unavailable	1	1

Table 5 : Management and Tenure

Management Status	% of Farm Owned						Total
	0	1-25	25-50	50-75	75-99	100	
Sole proprietor	3	0	0	1	0	0	4
Partnership	3	0	2	0	1	0	6
Other	-	-	-	-	-	-	
Total	6	0	2	1	1		10

Missing observations = 1

(b) Dairy Enterprises:

The two farms classified as Mainly Dairy have similar herd sizes (c. 160-170 dairy cows). One other farm has a smaller dairy enterprise. Only one farm supplied information for average annual milk yield, which was 5795 litres per cow. The average stocking rate was 2.26 L.U./ha (S.D. = 0.13)[1].

(c) Beef Enterprises:

A variety of systems are in use for beef rearing, so that the calculation of an average stocking rate has limited use, giving a large Standard Deviation (stocking rate is 1.83 L.U./ha; S.D. = 1.51). The systems used are specialist calf rearing (one farm), suckler herd (two farms), winter finishing (two farms) and overwintering with grass finishing (one farm).

(d) Arable Enterprises:

The main crops are barley and potatoes but winter wheat and sugar beet are also grown. One farm grows vegetables and some oil seed rape is grown. Yields are variable according to management and fertilizer use. Table 6 gives average yields, as reported by farmers in the survey. These figures may not be a reliable guide to current yields because of the recentness of the scheme. No yield data are available in many cases for crops grown since the scheme, and in these cases pre-scheme yield data have been used.

1 Weighted by area in benefit.

Table 6 : Average Crop Yields

Crop	Yield (t/ha)		
	Mean	Range	National Average †
Spring barley*	4.3	2.5 - 5.0	4.2
Potatoes	41.3	22.7 - 50.4	32.5
Winter wheat	4.0	2.5 - 5.5	5.5
Sugar beet	45.5	35.3 - 50.4	36.0

* Winter barley was also grown, but separate yield date is not available.

† Nix, J. (1981): Farm Management Pocketbook. Twelfth Edition (1982), Wye College (University of London).

12. Effects of the Scheme on Flooding and Land Drainage

Neither the road at Bawtry nor the washlands have flooded since the scheme was completed, although this has only been a matter of 18 months at the time of writing this report. Land drainage has so far been satisfactory throughout the scheme.

13. Agricultural Benefits of the Scheme

It is difficult to evaluate the benefits of the scheme because it was completed in 1982, so that only one year's post-scheme yield data are available, and even these figures may be affected by engineering work in progress during that farming year.

(a) Land Use Change:

The main change so far has been the ploughing up of about 100 ha of permanent grassland, as shown in Table 7 below. This land is now mostly used for crops. In the first year of the scheme land use has changed on 32% of the area.

Table 7 : Land Use Change (ha)

Pre-scheme Land Use \ 1983 Land Use	Permanent Grass	Temporary Grass	Grass/ Crop Rotation	Crops	No response	Total Pre-Scheme Land Use
Permanent Grass	94.7	17.4	10.5	72.7	-	195.3
Temporary Grass	-	-	-	-	-	0.0
Grass/crop rotation	-	-	15.0	-	-	15.0
Crops	-	-	-	101.5	-	101.5
No response	-	-	-	-	2.0	2.0
Total Post-Scheme Land Use	94.7	17.4	25.5	174.2	2.0	313.8

(b) Improved Productivity from Existing Land Uses:

From the single year's data two trends are apparent. Firstly, there is a shift within arable cropping to higher value crops. More potatoes and sugar beet are being grown, particularly on the peat, and winter wheat has replaced some of the barley. Secondly, the remaining grassland has largely been improved by reseeding either as temporary ley or as permanent pasture, and land which previously had been grazing of limited productivity now supplies silage as well as improved grazing.

(c) Field Drainage:

Before the scheme 33.6 ha had underdrainage. Since the scheme a further 150 ha (48% of the benefit area) have been drained (Figures 5 and 6). Drainage activity has been concentrated downstream of Stone Hill and the area drained corresponds very closely to that classified as Grade 4 under the MAFF Agricultural Land Classification (see Figure 1).

Most farmers at Stone Hill and upstream to Mattersey consider that their fields may not need underdrainage and are waiting to see whether the lower river level alone is enough to drain them. The peaty area on the north bank between Stone Hill and Mattersey, which was exploited even before the scheme for vegetables and potatoes, is likely to be more intensively farmed for these high value crops. The requirement for these crops is a relatively shallow but stable water table and it seems likely that the new river level will secure this without the need for field drainage. Some farmers expressed worries that the water table will be too low, resulting in an increased irrigation requirement; this cannot yet be evaluated, but such a need would partly offset the benefit of the scheme in preventing the kind of losses previously experienced on this land.

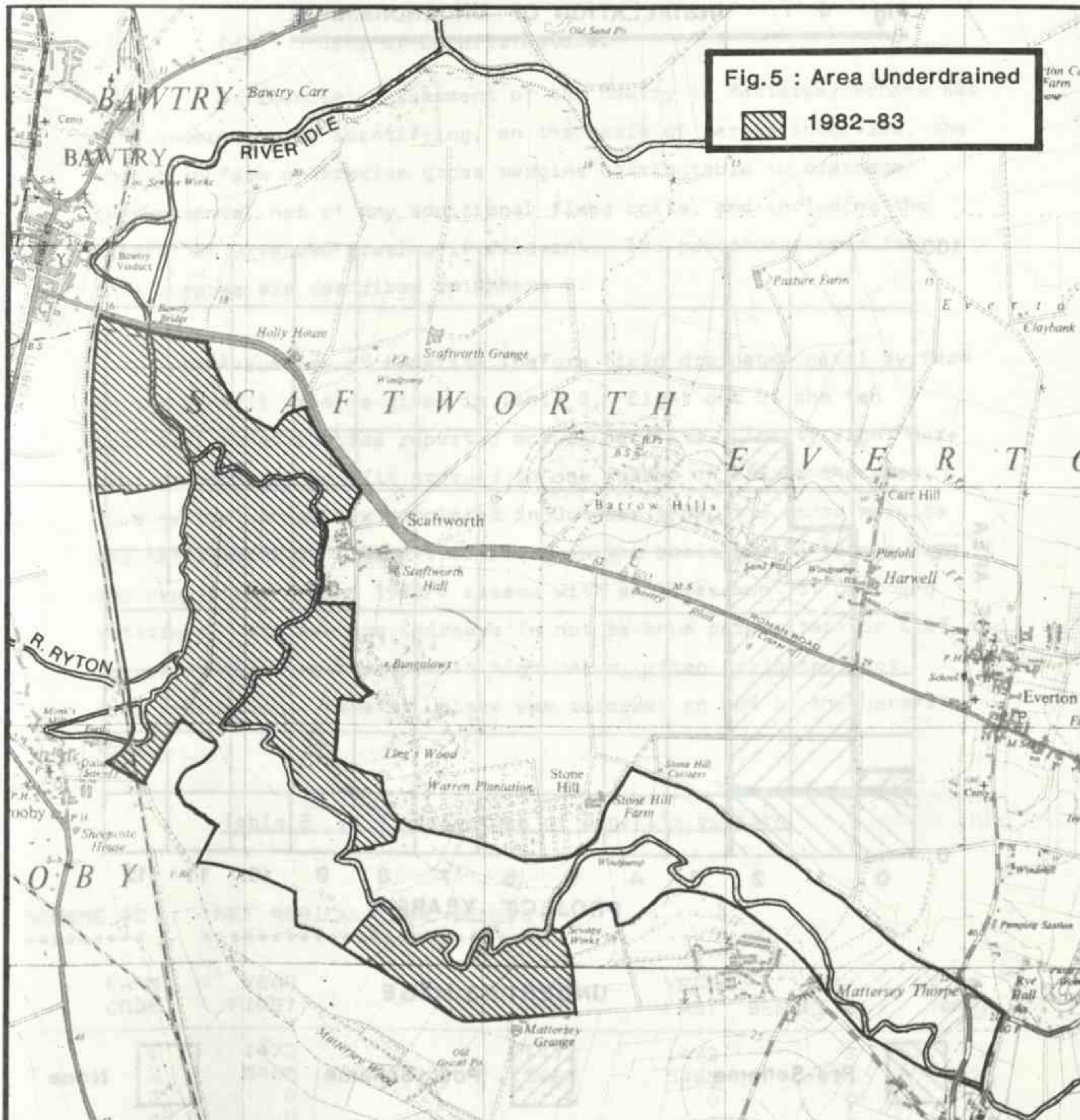
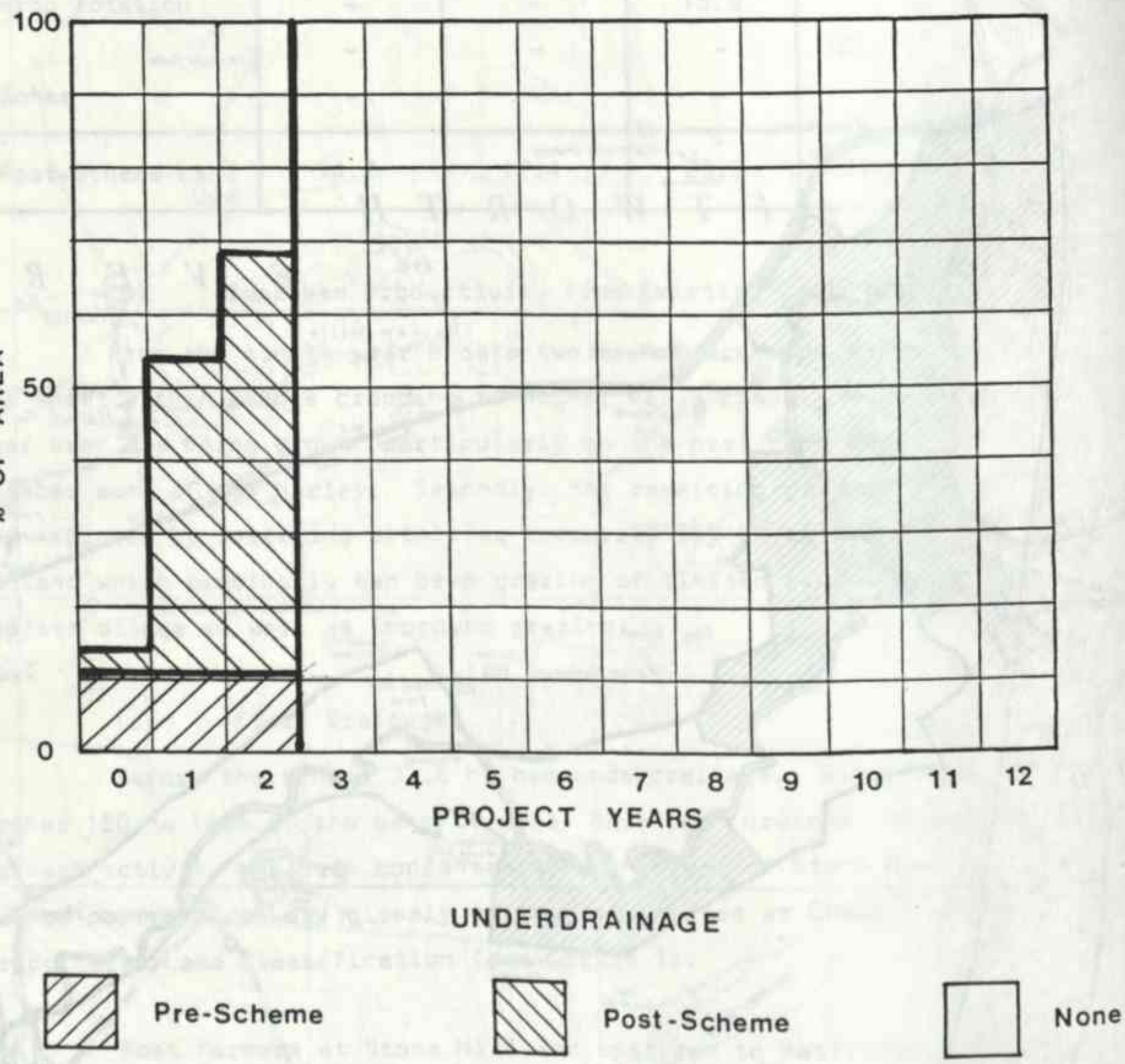


Fig.5 : Area Underdrained

1982–83

Fig 6 : INSTALLATION OF UNDERDRAINAGE



(d) Rate of Benefit Uptake;

A financial assessment of the Bawtry to Mattersey scheme has been undertaken by identifying, on the basis of farmer interview, the change in farm enterprise gross margins attributable to drainage improvements, net of any additional fixed costs, and including the benefit of extended grazing if relevant. The procedures used for this purpose are described in Annexe V.

A summary of benefits (before field drainage costs) by farm in the benefit area is given in Table 8. Eight out of the ten potential beneficiaries reported actual benefits. Thirty eight per-cent of reported benefit accrued to one farmer on 25% of the area. Because the scheme was completed in October 1982, the gross margins and net returns in Figure 7 combine, on the basis of the farm survey, the experience of the 1983/4 season with an assessment of proposed rotations. The average increase in net revenue per hectare is £167, largely reflecting the move to high value, often irrigated root crop production. Benefit uptake was recorded on 88% of the benefit area.

Table 8 : Distribution of Benefits by Farm

SCHEME 42 NET AGRICULTURAL BENEFIT

FARM CODE	YEAR FIRST	YEAR 2	YEAR LAST	% OF BENEFITS	% OF AREA
1	1472	1472	1472	3	4
2	5485	5485	5465	11	26
3	0	0	0	0	4
4	0	0	0	0	4
5	5359	5359	5359	10	4
6	2748	2748	2748	5	5
7	6056	6056	5919	11	10
8	16852	16852	19390	38	25
9	7514	7514	7514	15	16
10	3731	3731	3731	7	9
TOTAL			51623	100	309

Figure 8 expresses 1983/4 takeup as a percentage of scheme potential which is based on land capability and local farming practice. About 60% of the area post-scheme is in arable with the most intensive cropping involving potatoes, sugar beet, two cereals, and a field vegetable crop such as carrots. About 40% is in grass. The most intensive dairy systems are currently using about 375 kg N/ha which can be regarded as a realisable potential. Irrigation is being used, particularly for root crops.

On the basis of Figure 8, the first four years of the scheme's life is expected to account for 65% of potential gross margin.

14. Financial Analysis

A summary of the cash flow of the Bawtry to Mattersey scheme is contained in Table 9, in 1982 prices.

(a) Net Agricultural Benefits:

The net agricultural benefits attributable to the scheme are the extra net returns per hectare shown in Figure 7, and applied to the 311 ha of benefit. The 1984 uptake incorporates the new rotations already underway.

(b) Capital and Recurrent Costs:

The total capital cost of the four stages of the River Idle scheme was £5,367,000 in 1982 prices. On the basis of the share of total benefits predicted at the feasibility study stage, which would accrue to the Idle and Ryton IDB area (1255 hectares) a total cost of £813,939 is attributable to the latter. This equates to £649 per hectare for each hectare in benefit. The cost for the 311 hectares of agricultural land surveyed herein, is £201,839. The method used to apportion capital costs on the Idle scheme is described in section 14.1 of the River Idle: Idle Stop to Bawtry report.

Incremental recurrent costs have been assumed at 1½% of gross capital costs per year together with a share of the operating costs of the Stockwith pumps which approximate to £4.7 per hectare of benefit; £1,447 per year. Estimated recurrent costs equal £4,476.

FIGURE 7 : Degree and Rate of Financial Uptake

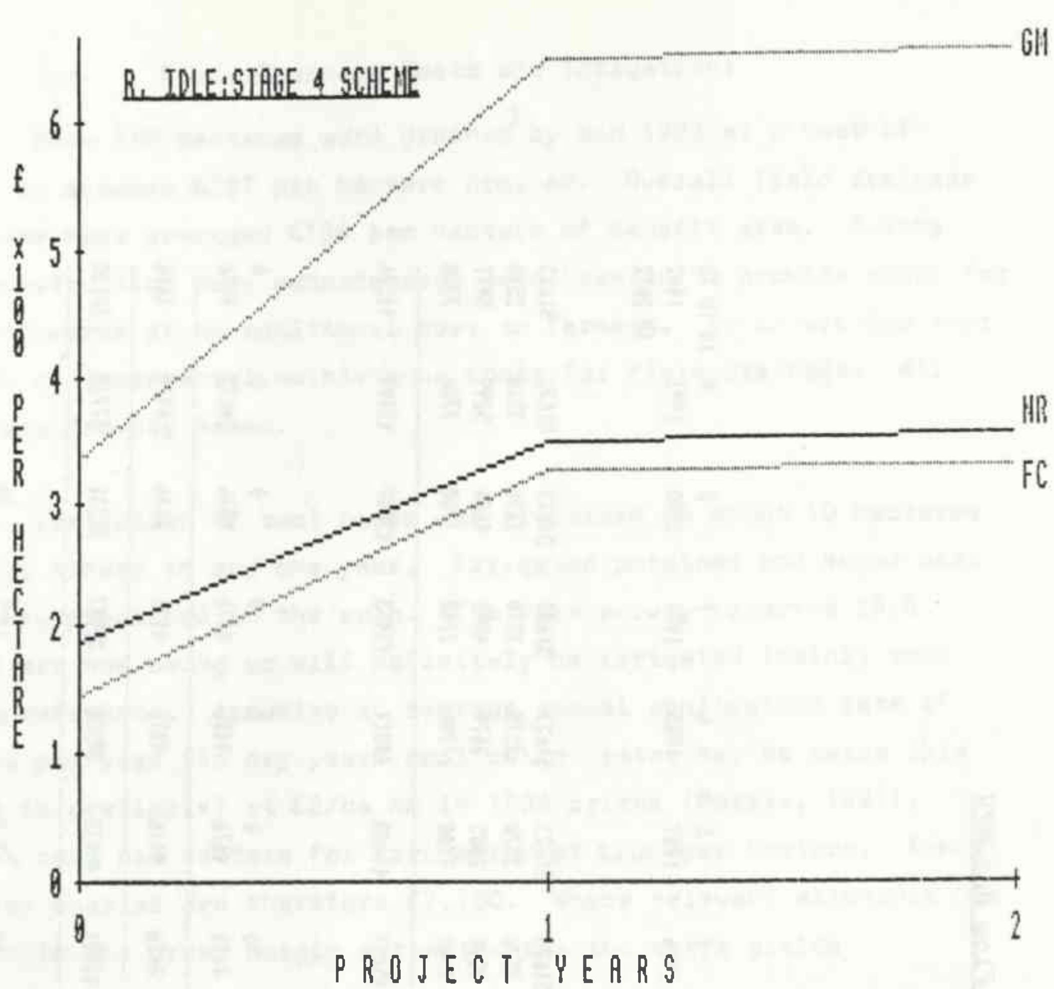


FIGURE 8 : Uptake as a Percentage of Potential

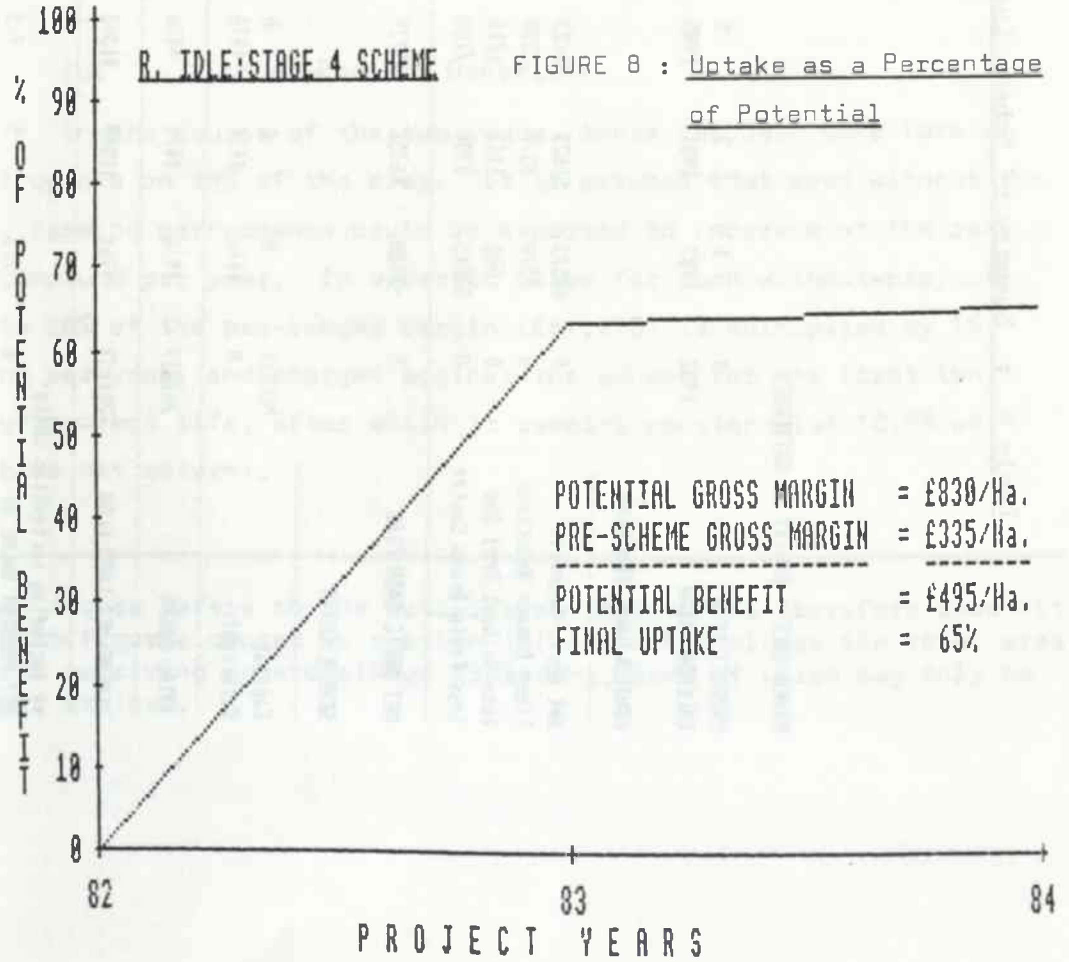


Table 9 : Summary of Scheme Cash Flow and NPV

RIVER IDLE : BAWTRY TO MATTERSEY

PROJECT YEAR	0	1	2	3	4	5	6	7	8	9	10 TO 30
CALENDAR YEAR	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992 TO 2012
AGRICULTURAL BENEFITS											
Net Agric Benefits	0	49523	51623	51623	51623	51623	51623	51623	51623	51623	51623
Flood Damage Reduction	0	3570	3570	3570	3570	3570	3570	3570	3570	3570	3570
less Without Proj Ben	0	566	1137	1714	2296	2885	3479	4080	4686	5299	5917
less Field Drain Cost**	0	58015	7700	7700	7700	7700	7700	7700	7700	7700	7700
NET AGRIC CASH FLOW	0	-5488	46356	45779	45197	44608	44014	43413	42807	42194	41576
SCHEME COSTS											
Capital	201839	0	0	0	0	0	0	0	0	0	0
Recurrent	0	4476	4476	4476	4476	4476	4476	4476	4476	4476	4476
TOTAL COSTS	201839	4476	4476	4476	4476	4476	4476	4476	4476	4476	4476
SCHEME NET CASH FLOW	-201839	-9964	41880	41303	40721	40132	39538	38937	38331	37718	37100

** including irrigation costs

NET PRESENT VALUE AT %	0	2.5	5	7.5	10	12.5	15	17.5	20

(c) Field Drainage Costs and Irrigation:

Some 110 hectares were drained[1] by mid 1983 at a cost of £58,015, an average £527 per hectare drained. Overall field drainage investments have averaged £186 per hectare of benefit area. During scheme construction many watercourses were lowered to provide spoil for embankment works at no additional cost to farmers. It is assumed that there are no incremental maintenance costs for field drainage. All systems are gravity based.

Irrigation of root crops was practiced on about 10 hectares before the scheme in any one year. Irrigated potatoes and sugar beet are commonly practiced in the area. The farm survey reported 38.5 hectares are now being or will definitely be irrigated (mainly root crops in rotation). Assuming an average annual application rate of 100 mm/ha per year (in dry years application rates may be twice this if water is available) at £2/ha mm in 1982 prices (Morris, 1983), implies a cost per hectare for irrigation at £200 per hectare. Annual irrigation charges are therefore £7,700. Where relevant allowance has been made in the gross margin estimates for the extra yields attributable to irrigation.

(d) Without-Project Benefits:

In the course of the two years, there has been some form of benefit uptake on 88% of the area. It is assumed that even without the scheme, farming performance could be expected to increase at the rate of 1% compound per year. In order to allow for such without-project benefits 88% of the pre-scheme margin (£64,270) is multiplied by 1% compound per year, and charged against the scheme for the first ten years of project life, after which it remains constant (at 10.5% of pre-scheme net return).

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1 This figure refers to the actual area drained and therefore does not agree with figures quoted in section 13(c) which includes the total area of fields receiving underdrainage treatment, some of which may only be partially drained.

(e) Flood Damage Reduction:

Pre-scheme flood damage information was obtained from farmers, but in the absence of hydrographical data, damage estimates are very tentative. Summer flooding on hay crops resulted in an average cost of £3,230 per year, and reported losses on cereals, potatoes and carrots with return periods of one in ten years added a further £3,760, which together with annual debris and fence repair costs at £900 gave a total pre-scheme cost of £7,890, equivalent to £25 lost per hectare per year.

There has been no flooding post-scheme. Bankfull design return periods are one in ten years.

Drawing on largely qualitative assessment, it is assumed that significant flooding on section 4 would result from a one in 15 year event, and that the seasonal distribution of such is likely to be 90% winter/spring, 10% summer.

About 147 hectares or 47% of the area were subject to pre-scheme flooding. Assuming such an area would be inundated in a one in 15 year event, then, depending on time of year, the actual losses will relate to losses in potential revenue less variable costs not yet committed.

In the event of a winter/spring flood (90% of one in 15 years), an estimated £200 per hectare is assumed for reseeding/ delayed production. In the event of a summer flood, the gross margin is used as a proxy for the value of a destroyed standing crop. Average annual cost of such an event over 147 hectares would be £2,600 per year, including debris and repair costs.

Major flood events resulting in complete inundation and loss are considered likely to occur once in 50 years, with a similar seasonal distribution which would result in an annual average loss of £76,000 plus say £10,000 clearance and repair costs, giving an annual cost of £1,720. Total post-scheme damage costs are tentatively estimated at £4,320, a net saving of £3,570 on pre-scheme flood costs. The sensitivity of the project to flood damage reduction benefits is considered in section

TABLE 10

River Idle : Bawtry to Mattersey - Sensitivity Analysis

Run No.	Agricultural Benefits Factor	Without Project Benefits Compounding Factor	Flood Damage Reduction Factor	Capital Works Cost Factor	NPV at 5% £	IRR %	Switching Value %*
1	1.0	1	1	1	325079	16.0	0.57
2	1.0	1.5	1	1	315540	15.6	0.58
3	1.0	0.5	1	1	334378	16.4	0.56
4	1.0	0	1	1	343444	16.7	0.55
5	1.0	1	1	2.7	0	5.0	0
6	1.0	1	0	1	272813	14.5	0.64

* The factors show the weights applied to the original estimates eg a factor of 1.5 for the without-project benefits indicates that the new value is 1.5 x 1% compound per year (the original value) ie 1.5% compound.

* Switching value : change in agricultural net benefits needed to make the project breakeven at 5% discount rate eg a 1.5 switch value shows an increase of 1.5 x the original estimated is required.

(f) Project Worthwhileness:

The scheme is presently two years old. However, discussions with farmers about the way they have already responded and their immediate intentions, means that a reasonable and possibly conservative estimate of uptake can be made for the project life.

At present and anticipated uptake levels the scheme gives a net present value of £325,079 at the 5% discount rate, and an internal rate of 16%.

(g) Sensitivity Analysis:

Table 10 shows the sensitivity of the scheme to selected benefit and cost parameters. The project could sustain a 43% reduction in estimated agricultural benefits before being prejudiced at the 5% discount rate.

At estimated levels of uptake, the scheme would cover capital costs by a factor of 2.7 times. Capital cost allocation was based on the expected benefits accruing to section 4 estimated in the River Idle Feasibility Study. Actual benefits accruing to section 4 would appear to be greater than expected with some justification for possibly apportioning a greater share of overhead costs to this section. Doing so would not appear to prejudice the scheme.

References

(1) Severn Trent Water Authority; Trent River Management Division (1974). River Idle: Improved Drainage of the Lower Reach. STWA, Nottingham.

(2) MAFF. Agricultural Land Classification of England and Wales. Sheet 103.

(3) Severn Trent Water Authority (1980) Land Drainage Survey, Section 24(5) Water Act 1973. Lower Trent Division and Nottinghamshire.

(4) Severn Trent Water Authority; Lower Trent Division (1975) River Idle Supplementary Report. STWA, Nottingham.

(5) M. Dodson, STWA, Senior Project Engineer, Nottingham. Personal Communication.

(6) J. Nix (1981) Farm Management Pocketbook, 12th edition. Wye College (University of London).

APPENDIX K

Derwent Division

River Tean : Stramshall Mill to Dove Confluence

SILSOE COLLEGE

STWA DERWENT DIVISION - RIVER TEAN SCHEME

Report on the background to, and development of the scheme and the nature and rate of uptake of agricultural benefits.

1. Physical Background

The River Tean rises just south of Wetley Rocks in North East Staffordshire and flows 21 km in a south easterly direction to meet the Dove at Doveridge. The catchment of 6,500 ha is generally agricultural in character, except for the textile towns of Cheadle and Upper Tean.

The reach under consideration runs 4.4 km from a point below the C110 road bridge near Stramshall Mill (SK 073 355), at an elevation of 90 m AOD(N), to the confluence with the Dove (SK 106 344) at an elevation of 73 m AOD(N). The upper reach is flanked on the left by Stramshall Hill which rises 30 m sharply from the river bank, such that there is no flood-plain on the north bank until the valley opens out towards Spath. The southern floodplain is between 100-250 m wide. In this upper reach the river channel meanders tightly and there are numerous cut-offs and ox-bows. The average gradient of the channel is 1 in 350.

Below the Ashbourne - Uttoxeter B5030 road bridge the Tean crosses the western floodplain of the Dove and although the valley gradient becomes less steep, the channel gradient steepens, due to the straightness of the channel, to about 1 in 250. Immediately below the road bridge the channel bifurcates with a secondary arm running north east and then east to meet the Dove approximately 1 km upstream of the confluence of the main channel. Here, the floodplain of the Tean, primarily restricted to between the two arms, becomes indistinguishable from that of the Dove.

2. Soils and Land Capability

No detailed soil survey has been carried out in this area but generally the reach runs through alluvial deposits, overlying Boulder Clay and Keuper Marl (Ref. 1). Field observation suggests that in the upper reach 15 cm of clay loam topsoil overlies a 15 cm transition zone into unstructured clay. In the Dove floodplain the top metre if silty and in the middle reach, a shallower layer of silty loam overlies gravel in some places and clay in others.

The Agricultural Land Classification (Ref. 5) shows the floodplain area (roughly equivalent to the benefit area) as grade 4, with grade 3 on the higher ground beyond.

3. Land Drainage History

In March 1967 5.94 km of the Tean, from the Dove confluence to upstream of Stramshall Mill, were classified as Main River and a pioneer scheme was designed for the full length to give improvement pending the preparation of a regrading scheme. The pioneer scheme consisted of the removal of fallen trees and trees in the banks, bush clearing, general trimming of the batters and removal of shoals. This was intended to reduce the roughness coefficient of the channel (Kutter's n) from 0.079 to 0.039 and hence increase the channel capacity (Ref. 1) (Manning's Formula suggests that such a reduction of the roughness coefficient by 50% will double the channel capacity at any given stage).

The pioneer scheme was thus intended to reduce normal water levels, prevent erosion of the bank, minimise shoaling and increase the bankfull capacity. An increase in the productivity of agricultural land was expected over a benefit area of 298 ha. The scheme was carried out in 1974 at a cost of £8,900 (1974 prices) under a grant aided scheme (LDW 28608) (Ref. 3).

4. Pre-Scheme Land Drainage Status

Prior to the pioneer works the channel had suffered from a general lack of maintenance. Obstructions to flow occurred due to fallen trees and branches which contributed towards the scouring and shoaling of the river, (a particular problem in the upper reach), and enhanced normal and flood water levels. The average freeboard was about 850 mm which was not sufficient to enable adjacent land to be properly drained. The washland was observed to be waterlogged for long periods in winter (Ref. 1). The results of the farm survey indicate that roughly 50% of the benefit area (see 7 below) was liable to flooding, of which 57% would flood a number of times each year (for a matter of a few days only) and 53% would flood once in every 2 to 5 years (again only for a few days).

Roughly 80% of the currently agricultural land had old underdrainage that pre-dated the scheme. Much of this dated from the last century and was unlikely to have been effective due to lack of maintenance and submergence of outfalls. However, nearly 70% of the benefit area was described as being 'Rarely' or 'Occasionally Wet'. The remainder was either 'Commonly' or 'Usually Wet'.

5. The Impact of Pre-Scheme Land Drainage Status on Land Utilization

The conditions described above appear to have a relatively minor impact upon land utilization. Land downstream of Spath was capable of, and in places under, arable rotations even before the scheme and flood damage was minimal. The land adjacent to the Dove was largely controlled by the frequency of flooding of the Dove rather than the Tean.

Upstream of Spath, pre-scheme conditions were worse and grassland productivity was constrained by poor drainage. Although the flooding would cause little damage, poor field drainage would restrict grazing seasons and limit access for nitrogen fertilizer application.

6. Scheme Design

In 1977 a regrading scheme was designed to reduce the frequency of flooding and improve land drainage over the entire length of main river (5940 m). This was to be achieved by regrading the existing channel, deepening beneath 3 road bridges and constructing a new outfall at the confluence with the Dove.

The previous confluence of the Tean and Dove was unsatisfactory as it joined in an upstream direction. Since 1960 Derbyshire County Council had been planning a new bridge for the A50 over the Dove just downstream of the old Dove Bridge (scheduled as an Ancient Monument and to be retained). This presented an opportunity to divert the Tean and create a new confluence below the 800 mm weir on the Dove. The Trent River Authority (as was) agreed to contribute towards the cost of the new road bridge and it was anticipated that the diversion would form part of the Pioneer Scheme. However, the new bridge was not built at the time of the Pioneer Scheme, and the diversion was left for the regrading scheme.

The regrading scheme was designed to:

(a) Reduce normal water levels and thus improve land drainage. A design freeboard of 1400 mm was taken from the MAFF publication 'Arterial Drainage and Agriculture' (Ref. 6).

(b) Minimise future shoaling and meandering.

(c) Increase bankfull capacity to take the 1 in 10 year flow (estimated at 16 cumecs).

(d) Reduce the risk of flooding of roads (Ref. 2).

In the lower reach, three channels are designated as Main River although one takes no flow from the main channel. The secondary channel would take roughly one third of the 1 in 10 year flow. The scheme designed the main channel to carry the full design flow although provision was made to allow some water to flow down the secondary channel to provide drinking water for cattle and additional protection in the event of more extreme flows.

In order to reduce scour, several steps were formed in the bed by constructing ramps at a slope of 1 in 10 protected with Reno mattresses.

7. Benefit Area

The benefit area is shown in Figure 1. An Agricultural Benefit Area of 222 ha was identified (Ref. 2) made up as follows:

Table 1 : Benefit Area
(Figures in brackets refer to the reduced benefit area.)

Source of Problem	Area (ha)	Agricultural Area (ha)
Tean only	107 (90)	103 (86)
Tean and Dove	122	119
Total	229 (212)	222 (205)

Source: STWA (1977)

This referred to a scheme covering the full length of Main River. However, the scheme was cut short at the upper end (see 9 below) and the benefit area was reduced to 205 ha (Ref. 3).

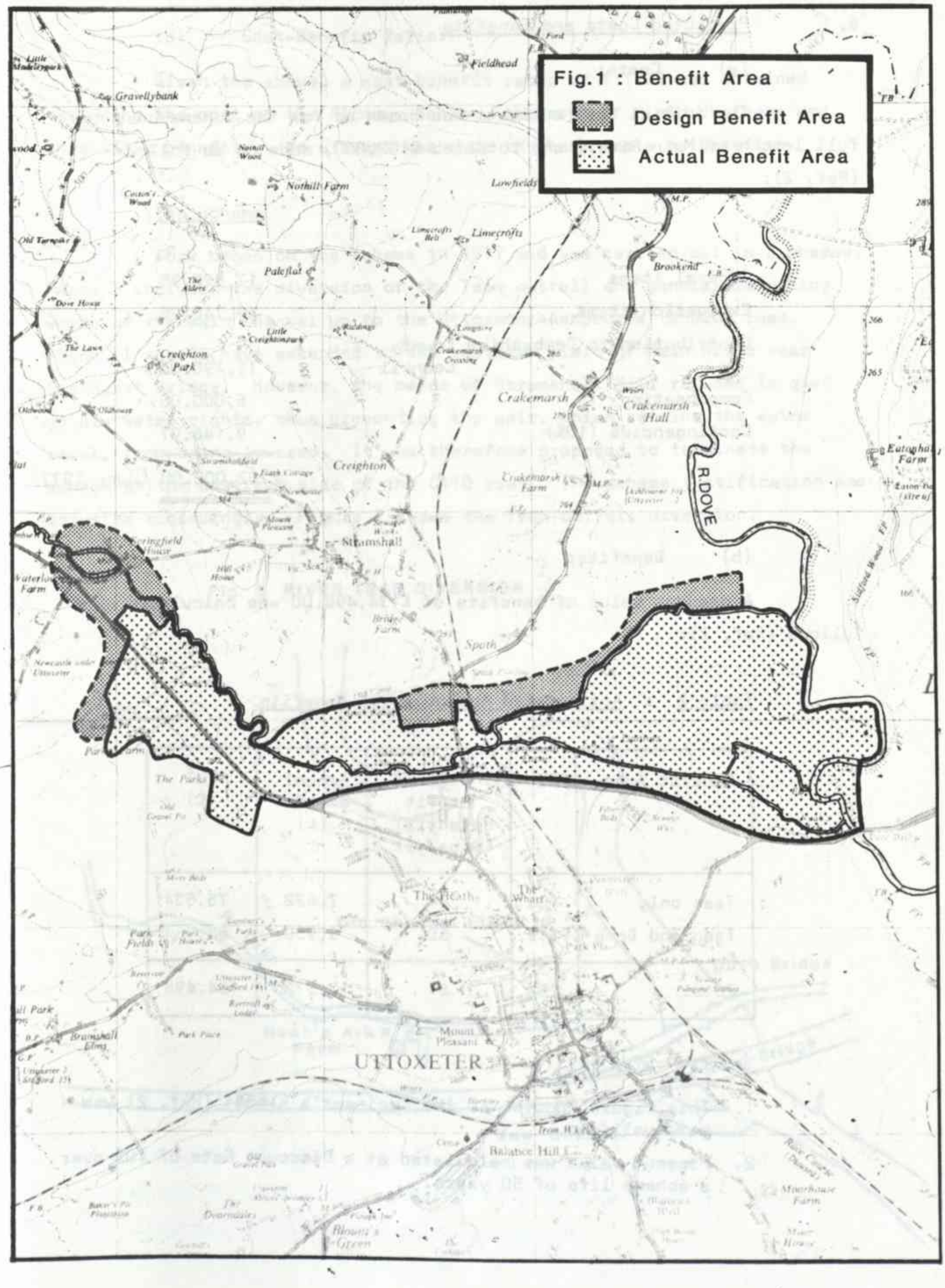


Fig.1 : Benefit Area
Design Benefit Area
Actual Benefit Area
R.DOVE
UTTOXETER
Crakemarsh
Creighton
Stramshall
Spath
Brookend
Limecrofts
Nothill Farm
Gravellybank
Fieldhead
Lowfields
Creighton Park
Paleflat
Crakemarsh Hall

8. Predicted Costs and Benefits

(a) Costs:

The initial cost estimate was drawn up for the scheme over the full length of Main River, and totalled £102,000, made up as follows (Ref. 2):

	£ p
General items	17,920.95
Excavation items	49,740.98
Contribution to Derbyshire County Council	19,190.00
Compensation	6,000.00
Contingencies (10%)	9,148.07
	£102,000.00 (June 1977)

(b) Benefits:

A present value of benefits of £134,498.00 was calculated as follows (Ref. 2):

Table 2 : Anticipated Agricultural Benefits

Benefit Area	Ha	Increased Profit Potential (£/ha/yr)[1]	Annual Benefit (£)	PV[2] (£)
Tean only	103	74	7,622	75,534
Tean and Dove	119	50	5,950	58,964
Total	222	61	13,572	134,498

Source: STWA (1977)

1. This figure, quoted in the Engineer's Report (Ref. 2) was not qualified.
2. Present value was calculated at a Discount Rate of 10% over a scheme life of 50 years.

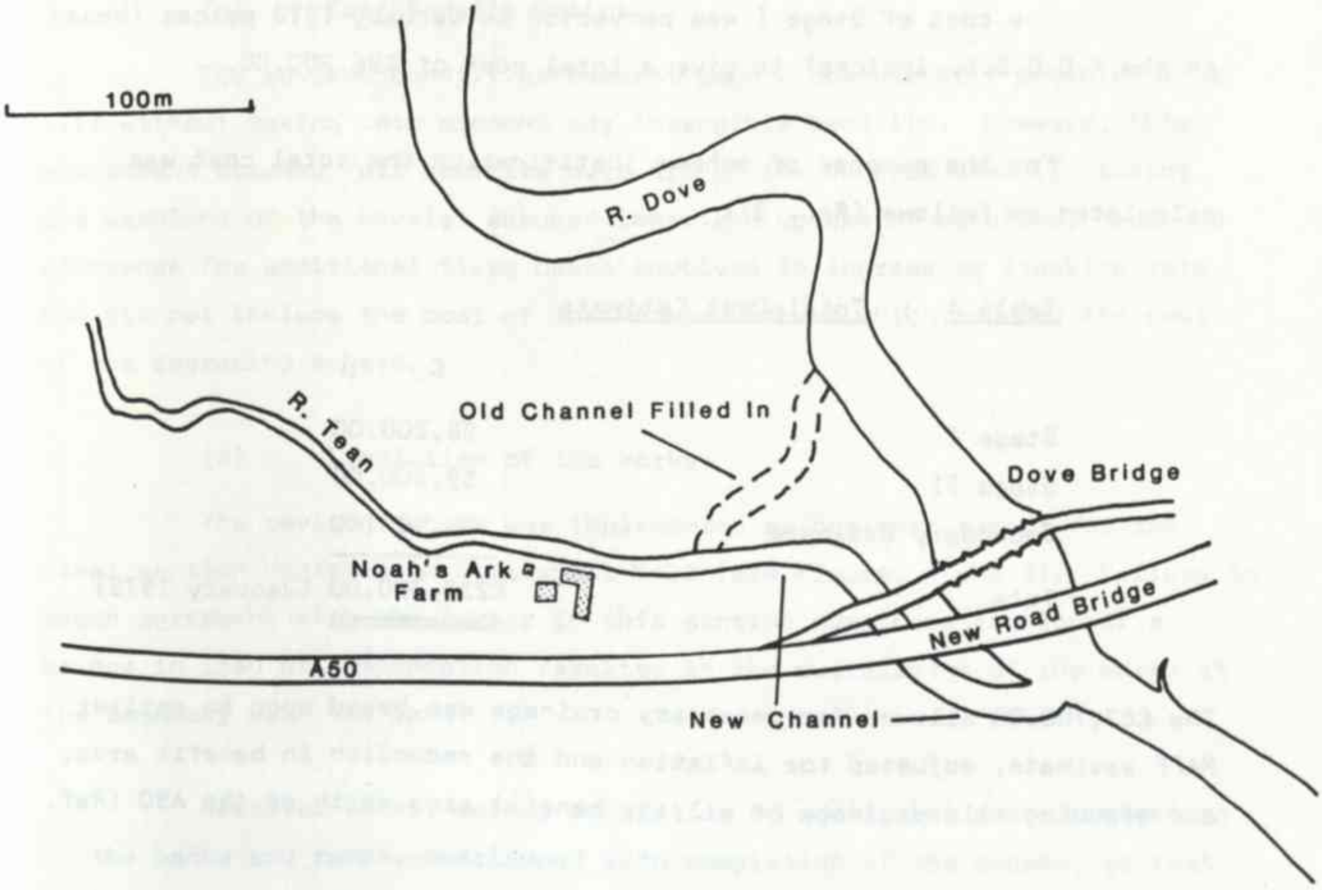
(c) Cost-Benefit Ratio:

Given the above, a cost-benefit ratio of 1:1.32 was obtained excluding the cost of the Pioneer Scheme, the cost of field drainage and intangible benefits. No attempt was made to phase costs or benefits.

9. The Scheme

Work began on the scheme in 1977 and was carried out in 2 phases. Phase I included the diversion of the Tean outfall and general regrading works of the main channel up to the Uttoxeter-Ashbourne (B5030) road. Phase II was to have extended to the upstream limit of Main River near Beamhurst Bridge. However, the owner of Stramshall Mill refused to give up his water rights, thus preventing the weir, which retains the water level, from being lowered. It was therefore proposed to terminate the scheme at the upstream side of the C110 road. The scheme justification was adjusted accordingly. Figure 2 shows the Tean outfall diversion.

Fig. 2 RIVER TEAN DIVERSION



(a) Revised Costs:

The revised cost estimate was made up as follows:

Table 3 : Revised Cost Estimate

Item	Cost (£)	
	Stage I	Stage II
Preliminary investigations	186.00	337.00
Engineering works	80,549.54	50,682.21
Land purchase and compensation	6,731.00	3,400.00
Contingencies (10%)	6,833.46	5,380.79
Total (£)	94,300.00	59,800.00

NB: Stage I costs are given in June 1977 prices and Stage II in January 1978 prices

The cost of Stage I was converted to January 1978 prices (based on the A.D.Q.S.S. indices) to give a total cost of £96,200.00.

For the purpose of scheme justification the total cost was calculated as follows (Ref. 3):

Table 4 : Total Cost Estimate

	£ p	
Stage I	96,200.00	
Stage II	59,800.00	
Secondary drainage	83,700.00	
Total	£239,700.00	(January 1978)

The £83,700.00 allowed for secondary drainage was based upon an earlier MAFF estimate, adjusted for inflation and the reduction in benefit area, and assuming tile drainage of all the benefit area north of the A50 (Ref. 4).

(b) Revised Benefits:

An agricultural benefit area of 205 ha was taken, but this was not divided according to location and it appears that equal benefits were assumed over the whole benefit area.

Prior to the scheme the whole area was used for grazing and the MAFF Senior Agricultural Advisory Officer estimated that the average stocking rate was 1.412 Livestock Units (LU) per hectare. It was assumed that following the scheme farmers would install tile drainage, buy in some winter feedstuffs and increase the stocking rate to 1.977 LU/ha (Ref. 4). The annual gross margin per livestock unit was estimated by the MAFF Officer to be £255.21 (January 1978 prices), giving an increase in gross margin of £144.20 per hectare ((1.977 - 1.412) x £255.21). Over 205 ha this is equal to an annual benefit of £29,561.00.

This figure was discounted at 10% over an anticipated life of 25 years to give a Present Value of £268,325.00.

(c) Cost-Benefit Ratio:

The revised benefit assessment gave a cost-benefit ratio of 1 to 1.12 without taking into account any intangible benefits. However, this assessment assumed full benefits over all of the benefit area (including the washland of the Dove); assumed immediate uptake of benefits; made no allowance for additional fixed costs involved in increasing stocking rate, and did not include the cost of the Pioneer Scheme which reduced the cost of the regrading scheme.

(d) Completion of the Works:

The revised scheme was implemented as designed except for the final section upstream to Stramshall Mill (see Figures 1 and 3). Failure to reach agreement with the farmer in this section over construction of a bridge in lieu of compensation resulted in the curtailment of the works at the boundary with his land.

Remedial works, mainly consisting of additional stone protection of the banks and ramps, overlapped with completion of the scheme, so that work was spread over 2 to 3 years, according to accessibility and availability of stone. These works became justifiable once the discount was changed to 5%.

Expenditure on Stage I was £6,451 over the budget of £94,300 approved in 1977, after taking account of inflation and subtracting £6,833 which had been allowed as a contingency. This extra cost was incurred as a result of additional works and delays; direct labour was the predominant component of over-budget costs. Information was not available at the time of writing to confirm the actual cost of Stage II, but for the purpose of analysis the estimated cost of £59,800 in 1978 prices has been used.

10. Farm Survey

Eight farmers were interviewed who farm 72% of the benefit area between them (141.2 ha). Information was collected concerning a farm occupying a further 9.7% of the benefit area (17.2 ha) which has recently been bought by the Ministry of Transport and whose previous owner has since died. This farm is currently not in agricultural use and will be retained by the Ministry during the construction of the new A50 Stoke-Derby road. A further 8 ha of farmland is not currently in agricultural use for the same reason, in addition to 3.6 ha which is non-agricultural (buildings, etc.) and 6.8 ha which is in pasture but not commercially farmed.

11. Agriculture in the Benefit Area

(a) Farm Type, Size and Tenure:

The farms surveyed are classified by size, type, tenure and management status in Tables 5-8 below.

Table 5 : Farm Type

Farm Type	No. of Farms	% of Surveyed Area
Specialist Dairy	6	38
Mostly Cattle	2	34
Data unavailable	1	9
Unsurveyed	-	19
Total		100

Table 6 : Farm Management and Tenure

Management Status	% of Farm Owned						Total
	0	1-25	25-50	50-75	75-99	100	
Sole proprietor					1	3	4
Partnership		1		1	1	2	5
Total	-	1	-	1	2	5	9

Table 7 : Farm Size (by Area)

Farm Size (ha)	No. of Farms	% of Benefit Area
10- 20	2	11.7
20- 30	1	9.0
30- 40	1	12.9
40- 50	3	20.7
50-100	2	26.9
No data	-	18.8
Total	9	100.0

Table 8 : Farm Size (by Standard Man Days)

Farm Size (SMD)	No. of Farms	% of Surveyed Area
100-174	1	12.9
175-249	1	3.5
250-499	1	8.2
500-999	4	27.3
Data unavailable	2	48.0

All farms have livestock systems, most being classified as Specialist Dairy (6 farms) and the others Mostly Cattle (2 farms). The Specialist Dairy farms currently occupy 38% of the benefit area and the Mostly Cattle farms occupy 34%. Nearly all the benefit area is still under grass and of the unsurveyed portions (28%), at least 19% is also used for grazing.

Most farms are small in area, four being less than 40 ha, although two were in the class 50 - 100 ha. Two farms are classified as "part-time", being less than 250 SMD, but the largest group is in the class 500 - 999 SMD (four farms).

Relatively high proportions of the farms are owned, five farms being wholly owned. Roughly half of the farms are in partnerships (five farms).

(b) Dairy Enterprises:

The average herd size is 47 dairy cows (S.D. = 11.5) and average stocking rate on Specialist Dairy farms is currently 2.17 Livestock Units per hectare of grass[1] (LU/ha), but this figure does not represent the stocking rate of dairy cows and followers alone, since all Specialist Dairy farms except one have some type of beef enterprise in addition to their dairy enterprise.

Only one farm was able to give milk yield data; annual milk yield was 5243 litres per cow. This farm was one of the most intensively stocked and managed, and this yield represents a likely maximum for the area, rather than an average.

(c) Beef Enterprises:

A variety of beef systems are used on the Specialist Dairy farms, including 18 month beef (2 farms) and 24 month beef (2 farms). The 2 farms classified as Mostly Cattle use mixed systems, varying their practice according to the market. The stocking rate on the farms classified as Mostly Cattle is 0.75 LU/ha of grass[1].

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1. Weighted by area in benefit.

12. The Effects of the Scheme on Flooding and Land Drainage

Of the area that was previously liable to flooding, 70% has been free from flooding since the completion of works and the flood frequency and duration have been reduced on a further 25%. Five percent remains with the same flood conditions (see Table 9).

Table 9 : Post-Scheme Flood Frequency

Flooding category	Area (ha)	% of benefit area
1. Did not flood pre-scheme	77.8	40
2. No flooding since scheme	65.1	33
3. Flooding reduced	23.9	12
4. Flooding unchanged	4.9	3
5. No response	23.8	12
Total	195.5	100

The scheme has had 3 main effects on land drainage. Firstly, it has provided an outfall for the installation of field drains where previously there was none; freeboard is now in the region of 1.3 m. Secondary, it has enabled the water level in tributary streams to be lowered, which in turn has improved land drainage in many fields in the upper part of the reach. Thirdly, it has provided a new outfall for old systems of underdrainage which had previously become ineffective. Old systems were reported in 125.2 ha, which is 64% of the benefit area. These are largely 19th Century installations, mostly consisting of a pair of horseshoe tiles, one inverted on the bottom with the other placed over it. It was observed that many of these drains are now running. They are placed at a depth of about 40 cm and a spacing of only 6 m. The subsoil in this area is unstructured clay and only such a close spacing, very rare in modern practice, would be expected to be effective. Many of these drains had no outfall before the scheme but in some fields which were reported as having good pre-scheme land drainage status old field drains of the type mentioned are present whose outfall had been taken some distance downstream (800 m in one case) in order to achieve sufficient fall. The pre-scheme land drainage of such fields contrasted sharply with adjacent fields whose systems led directly to the river, and which had poor pre-scheme land drainage. The revitalising of these old systems could be viewed as an automatic benefit of the river scheme.

13. <u>Agricultural Benefits of the Scheme</u>

(a) Increased Productivity:

There have been some increases in productivity from the grassland since the scheme was enacted. The benefit area can be conveniently divided into three sections (see Figure 3):

(i) the lower part of the reach near the confluence with the River Dove, upstream to the branching of the tertiary or intermediate channel from the Tean (Cross Section 28).

(ii) the middle part of the reach upstream to the vicinity of Spath (Cross Section 105),

(iii) the upper part of the reach upstream to the limit of the scheme.

In the lower part of the reach the stocking rate on the farm worst affected before the scheme has increased from 1.23 L.U./ha to 2.03 L.U./ha; this is a Specialist Dairy operation. This increase followed a pattern of grassland improvement which involved field drainage, increased fertilizer use, exploitation of a longer grazing season and a switch to a silage system of forage conservation. The top metre of soil in this area is silty so that it is fairly free draining and has a high load-bearing capacity. It is capable of carrying a high stocking density provided it is not subject to frequent inundation.

The middle part of the reach did not suffer from flooding to such a degree before the scheme. As well as enjoying greater freeboard than the other sections, the soil in this area is also free draining. In places, where a shallower silty layer overlies gravel, it has better natural drainage than the lower reach. As a consequence agriculture in this section had already developed to a level only recently attained in the downstream section. One farm in this section, classified as Specialist Dairy, already had a stocking rate of 3.7 L.U./ha in 1979, contemporaneous with the scheme.

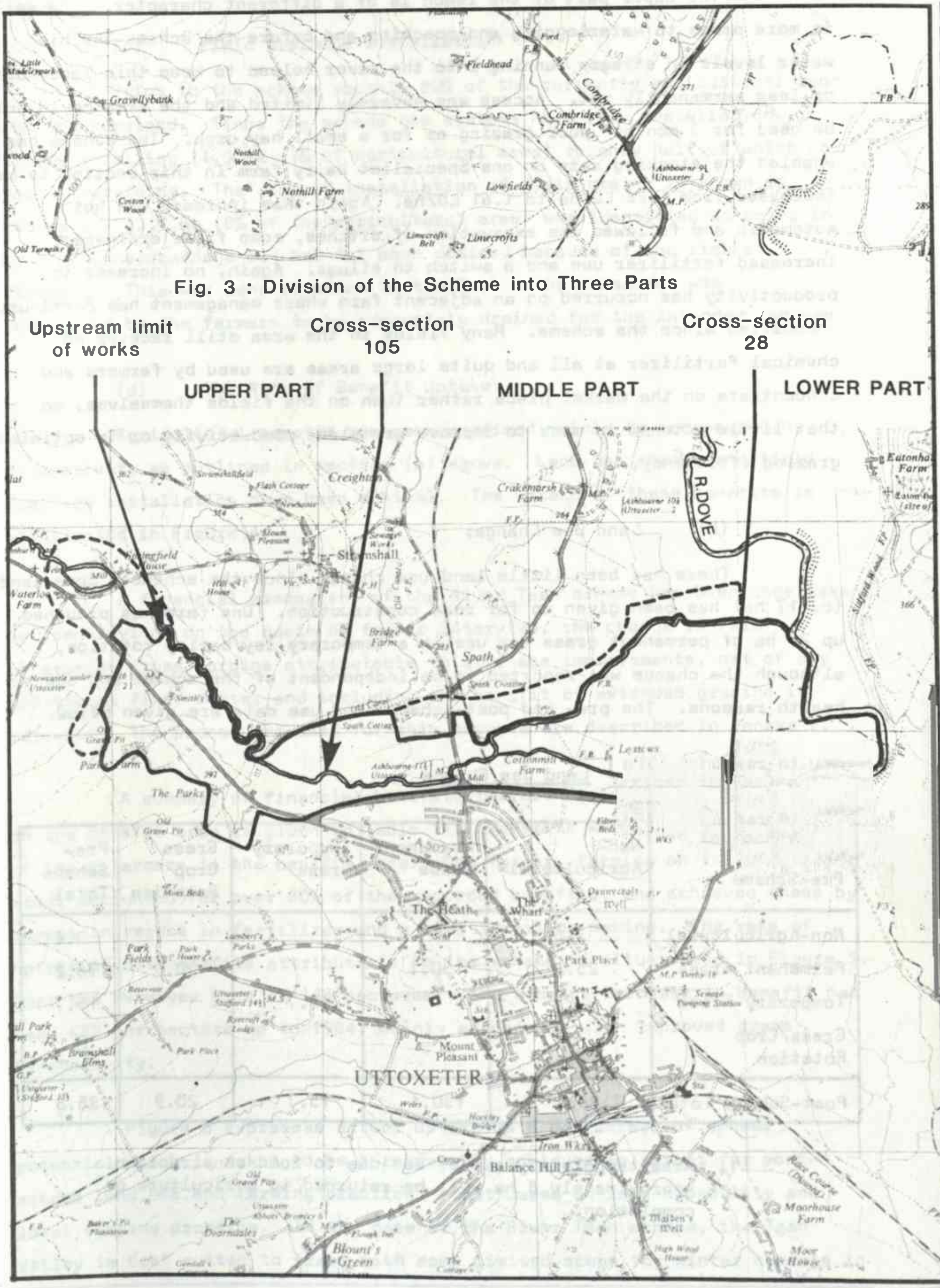

Fig. 3 : Division of the Scheme into Three Parts

The upper part of the reach is of a different character. The soil is more prone to waterlogging and poaching and before the scheme the high water levels in streams running into the river helped to keep this land more or less permanently wet. Access was severely limited and the area could only be used for 3 months' poor grazing or for a small hay crop. The scheme has enabled the stocking rate on one Specialist Dairy farm in this section to be increased from 1.26 LU/ha to 1.61 LU/ha. Again this increase was not automatic and followed the excavation of ditches, some field drainage, increased fertilizer use and a switch to silage. Again, no increase in productivity has occurred on an adjacent farm where management has continued unmodified since the scheme. Many fields in the area still receive no chemical fertilizer at all and quite large areas are used by farmers who concentrate on the market place rather than on the fields themselves, so that little attempt is made to improve grassland productivity or to optimise grazing efficiency.

(b) Land Use Change:

There has been little land use change since the scheme. Some land (c. 17 ha) has been given up for road construction. One farm has ploughed up 21 ha of permanent grass for use in a temporary ley/barley rotation, although the change was reported to be independent of the scheme and due to health reasons. The pre- and post-scheme land use data are given below.

Table 10 : Land Use Change

Post-Scheme / Pre-Scheme	Non-Agricultural	Permanent Grass	Temporary Grass	Grass/Crop Rotation	Pre-Scheme Total
Non-Agricultural	3.6				3.6
Permanent Grass	25.2 [1]	130.1		20.9	176.2
Tomporary Grass			15.7		15.7
Grass/Crop Rotation					0
Post-Scheme Total	28.8	130.1	15.7	20.9	195.5

1. Area temporarily out of use due to road construction. Approximately 8 ha will be returned to agriculture on completion.

(c) Field Drainage Installation:

Prior to the scheme roughly 80% of the currently agricultural land was underdrained. Since the scheme new systems have been installed on fields totalling 11.3 ha (7% of agricultural area) roughly half of which ha been re-draining. The rate of installation of field drains is shown in Figure 4. 13.7 ha (8% of the agricultural area) was identified as being in need of underdrainage but had not been drained because of the risk of flooding. This was land adjacent to the Dove. The remainder was considered by the farmers to be adequately drained for the intended landuse.

(d) The Role of Benefit Uptake:

Agricultural benefit has been confined mainly to increases in productivity as outlined in section (a) above. Land use change and field drainage installation have been minimal. The uptake of these benefits is illustrated in Figure 4.

A financial assessment of the River Tean scheme has been undertaken by identifying, on the basis of farmer interview, the change in farm enterprise gross margins attributable to drainage improvements, net of any additional fixed costs, and including the benefit of extended grazing if relevant. The procedures used for this purpose are described in Annexe V.

A summary of financial benefits (before field drainage) by farm in the benefit area is given in Table 11. Benefits were confined to 2 out of the 8 farmers in the benefit area. One farmer, farming on 18% of the area, accounted for over 80% of the recorded benefits, and achieved these by modest increases in fertilizer and a move to silage making. The rate of uptake of net benefits attributable to the scheme is illustrated in Figure 5. Over the surveyed area of 138 hectares[1], the average increase in benefit has been £22 per hectare up to 1984, mainly associated with improved grass productivity.

Figure 6 expresses actual uptake as a percentage of scheme potential which is taken to be a reasonably achieveable target for post-scheme land use and farming practice: that based on land capability and local farming practice. In the case of the River Tean scheme, the Tean Valley is best suited to grass with some limited scope for winter cereals in

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1. Ie. excluding land occupied for road construction and permanent pasture that is not farmed.

Fig 4 INSTALLATION OF UNDERDRAINAGE

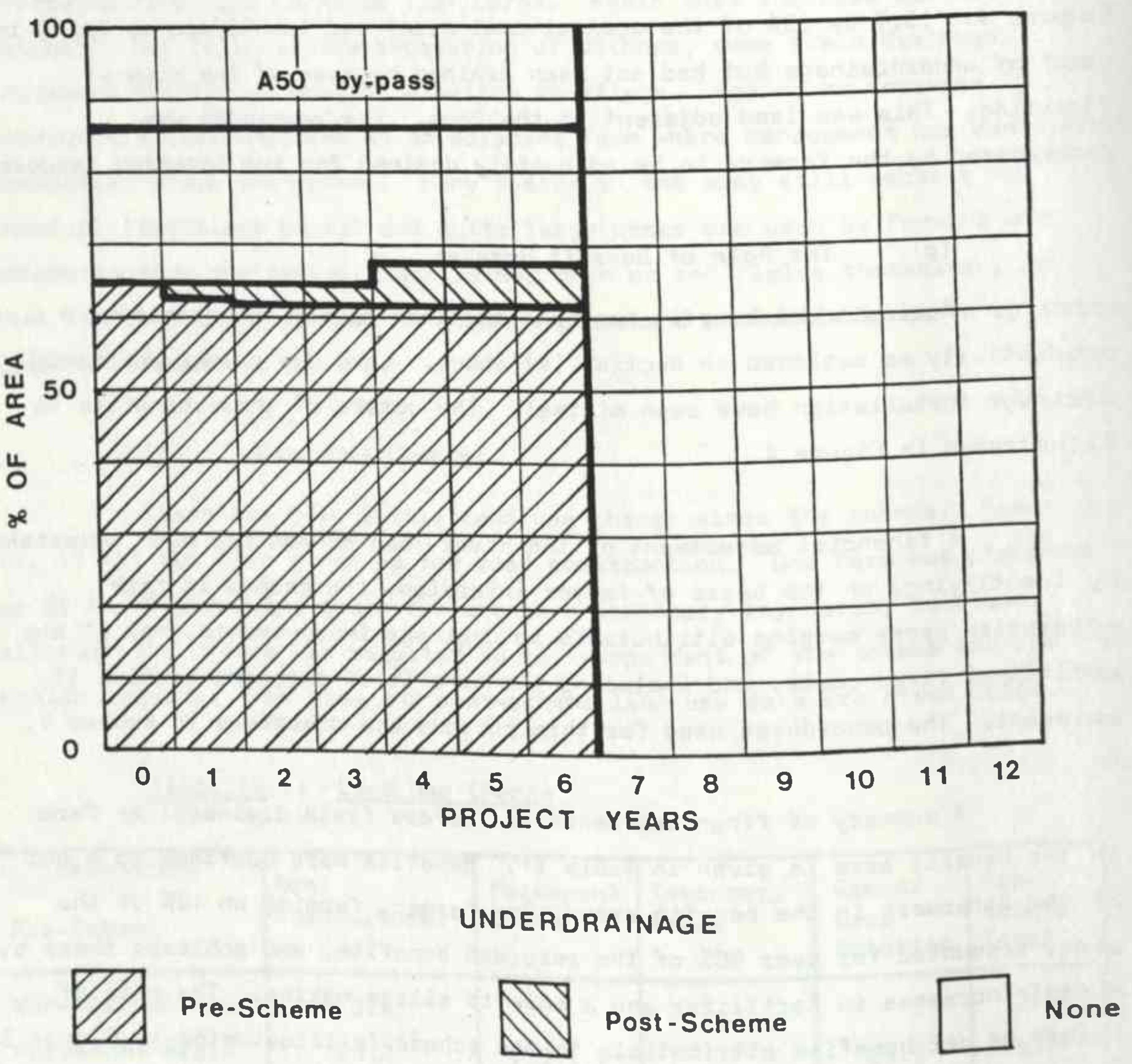


FIGURE 5 : Degree and Rate of Financial Uptake

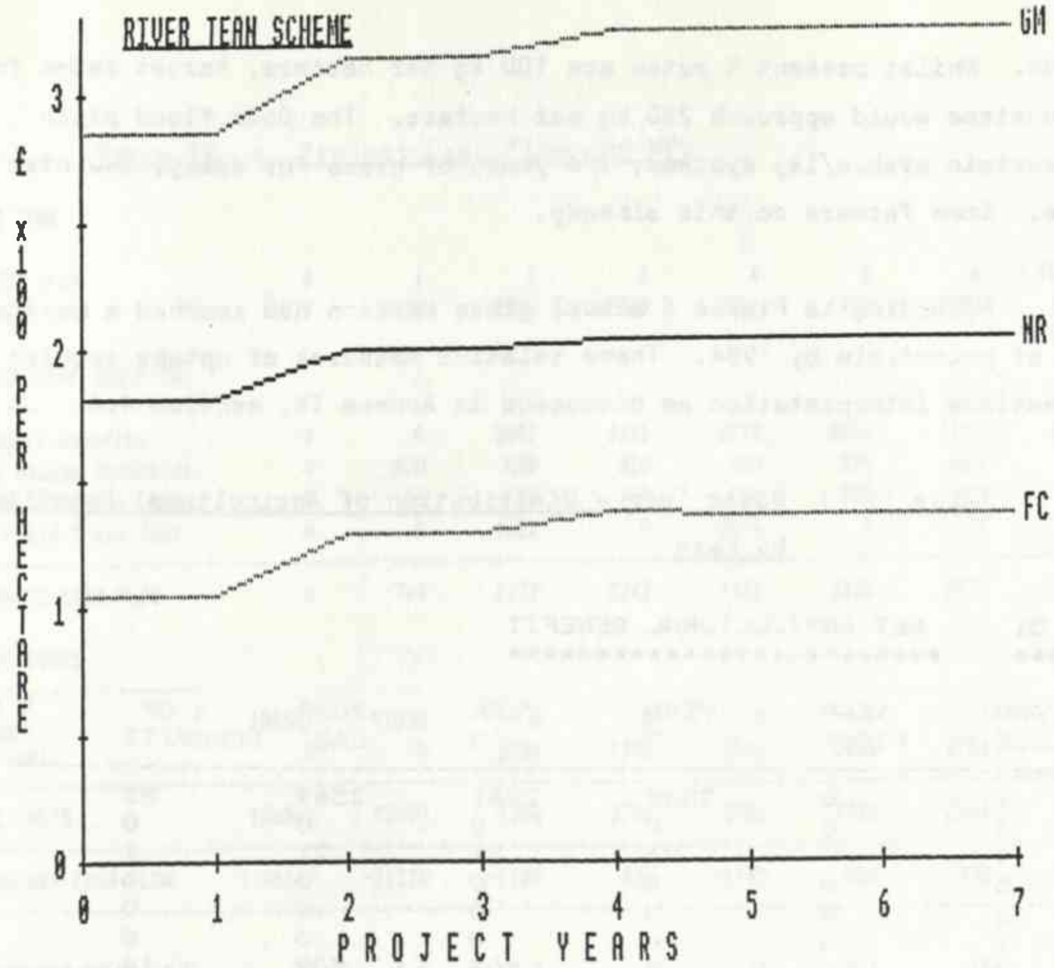
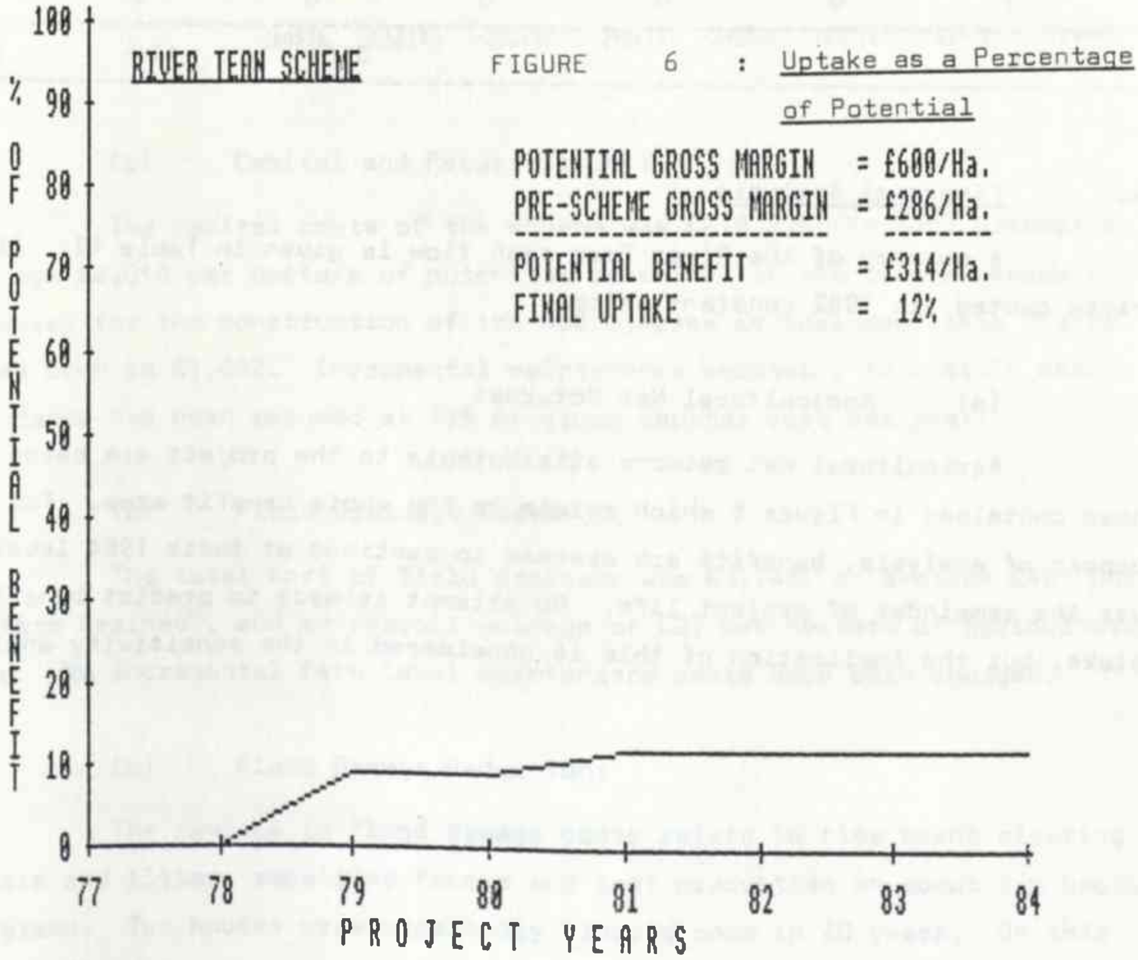


FIGURE 6 : Uptake as a Percentage of Potential



rotation. Whilst present N rates are 100 kg per hectare, target rates for dairy systems would approach 250 kg per hectare. The Dove flood plain would sustain arable/ley systems, 3/4 years of grass for dairy, 2 winter cereals. Some farmers do this already.

According to Figure 6 actual gross margins had reached a maximum of 12% of potentials by 1984. These relative measures of uptake require very cautious interpretation as discussed in Annexe IX, section 4.4.

Table 11 : River Tean - Distribution of Agricultural Benefits by Farm

SCHEME 51 NET AGRICULTURAL BENEFIT

FARM CODE	YEAR FIRST	YEAR 3	YEAR 5	YEAR LAST	% OF BENEFITS	% OF AREA
1	0	2569	2441	2569	83	18
3	0	0	0	0	0	5
4	0	21	21	21	1	5
5	0	0	0	0	0	9
6	0	0	0	0	0	11
7	0	0	0	0	0	18
8	0	0	509	509	16	5
9	0	0	0	0	0	29
TOTAL				3100	100	138

14. Financial Analysis

A summary of the River Tean cash flow is given in Table 12. All prices quoted are 1982 constant prices.

(a) Agricultural Net Returns:

Agricultural net returns attributable to the project are based on those contained in Figure 5 which relate to the whole benefit area. For the purpose of analysis, benefits are assumed to continue at their 1984 levels over the remainder of project life. No attempt is made to predict benefit uptake, but the implication of this is considered in the sensitivity analysis.

Table 12 : Project Cash Flow and NPV

RIVER TEAM

PROJECT YEAR	0	1	2	3	4	5	6	7 TO 30
CALENDAR YEAR	1977	1978	1979	1980	1981	1982	1983	1984 TO 2007
AGRICULTURAL BENEFITS								
Net Agric Benefits	0	0	2591	2591	2973	3101	3101	3101
Flood Damage Reduction	0	820	820	820	820	820	820	820
less Without Proj Ben	0	56	112	169	226	285	343	402
less Field Drain Cost	0	0	1622	0	2126	0	0	0
NET AGRIC CASH FLOW	0	764	1677	3242	1441	3636	3578	3519
SCHEME COSTS								
Capital	186567	92000	0	0	0	0	0	0
Recurrent	0	0	2786	2786	2786	2786	2786	2786
TOTAL COSTS	186567	92000	2786	2786	2786	2786	2786	2786
SCHEME NET CASH FLOW	-186567	-91236	-1109	456	-1345	850	792	733
NET PRESENT VALUE AT %	0	2.5	5	7.5	10	12.5	15	17.5
	-260576	-258240	-253692	-248110	-242101	-235981	-229920	-224004

(b) Capital and Recurrent Costs:

The capital costs of the scheme was £278,576 (in 1982 prices) an average £2,018 per hectare of potential benefit. If the land subsequently occupied for the construction of the A50 by-pass is included, this figure comes down to £1,452. Incremental maintenance necessary to sustain design standards has been assumed at 1½% of gross capital cost per year.

(c) Field Drainage Costs:

The total cost of field drainage was £3,748, an average £401 per hectare drained[2], and an overall average of £27 per hectare of agricultural land. No incremental farm level maintenance costs have been charged.

(d) Flood Damage Reduction:

The savings in flood damage costs relate to time spent clearing debris and litter, repairing fences and lost production on about 1.6 hectares of grass. Two houses were reportedly flooded once in 20 years. On this basis, flood damage reduction has been estimated at £820 per year.

(e) Without-Project Benefits:

A basic assumption of 1% compound per year is used to account for likely improvements in farming performance for the 'without-project' situation. Without-project benefits are charged for those areas where there has been some observed uptake attributable to the scheme. For the River Tean, uptake has occurred todate on 22.3% of the area. Without-project benefits are therefore taken as 1% compound per year of the pre-scheme net return (£25,016) multiplied by 22.3%, ie. £5,578 x 1% compound per year.

(f) Project Worthwhileness:

Assuming benefits continue at their 1984 level over a 30 year project life, the net present value of the scheme at the 5% discount rate would be -£253,692 in 1982 prices, implying a negative internal rate of return. The post-scheme construction of a new trunk road has frustrated potential agricultural benefits on 25.2 hectares, most of it being contained within one holding. If uptake on this land had been similar to that recorded on an adjacent farm, the net present value of the scheme would have been -£217,902 (negative IRR).

Using the derived uptake curve as a means of predicting uptake over remaining project life, and allowing for the fact that major scheme works were completed in 1978 (year 1), estimated benefits would peak in year 14 (13 + 1) at 2.59 times their 1983 (year 6) level. This level of improvement would generate a net present value at 5% of -£217,000, and result in a negative internal rate of return of -3.9%.

(g) Sensitivity Analysis:

Table 13 examines the sensitivity of the scheme to selected benefit and cost parameters. A 7 fold increase in net agricultural benefits would be needed to make the scheme break even at the 5% discount rate, or benefits over remaining scheme life would need to be 10 times their current estimated 1984 levels to break even. If current levels of uptake prevail, and ignoring maintenance costs, less than 20% of capital costs would be recovered at the 5% discount rate.

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2. Although fields covering 11.3 ha received underdrainage since the scheme only 9.35 ha were drained.

TABLE 13

River Tean : Sensitivity Analysis

Run No.	Agricultural Benefits Factor	Without Project Benefits Compounding Factor	Flood Damage Reduction Factor	Capital Works Cost Factor	NPV at 5% £	IRR %	Switching Value
1	1.0	1.0	1	1	-253692	-11.4	7.0
2	1.0	0	1	1	-248826	-ve	6.5
3	1.0	1.0	0	1	-265697	-ve	8.8
4[a]	1.0	1.0	1	1	-215430	-ve	5.5
5	1.0	1.0	1	0.2	0	5.0	0

* The factors show the weights applied to the original estimates eg a factor of 1.5 for the without-project benefits indicates that the new value is 1.5 x 1% compound per year (the original value) is 1.5% compound.

* Switching value : change in agricultural net benefits needed to make the project breakeven at 5% discount rate eg a 1.5 switch value shows an increase of 1.5 x the original estimated is required.

15. Problems Associated with the Scheme

(a) Bank Erosion:

The channel design has a steep longitudinal gradient and a narrow section, resulting in a high velocity of flow. Bank erosion was a problem before the scheme and continues to be so, particularly on bends, at entry points of tributaries, immediately downstream of stone-clad banks and around tree roots. Stone cladding, extensive though it is, seems to be ineffective in places, simply transferring erosion sites downstream. Erosion problems will be dealth with within the 5 years maintenance programme.

(b) Flow Velocity:

The flow velocity poses 2 problems for farmers. Firstly, watering holes are prone to both erosion and silting up. Secondly, the depth and speed of flow when the river level is high prevents cows from crossing the river, which they need to do for milking on at least one farm. It was necessary at the design stage to compromise between flow velocity, channel capacity and gradient to provide the necessary improvements to land drainage.

(c) The Irish Ford:

Although providing and improving crossing, logs often obstruct flow through this structure, raising water levels on the upstream side by 0.5 m. These need to be cleared at intervals to prevent loss of freeboard upstream.

(d) Stone Weirs:

These steps constructed with Reno mattresses have collapsed in places. Recently much larger block stone has been used. It was reported that some have been damaged by children playing.

(e) Wildlife:

In many places trees which were removed during the scheme have not yet been replaced. The bird population has not built up again and in particular a kingfisher nesting site has been lost. It is up to the farmers to agree to set aside land for planting.

16. Road Construction

The new A50 road (Stoke to Derby) is currently under construction and passes through the benefit area (Figure 1). Uncertainty as to the eventual siting of this road has been a disincentive to investment in agriculture in the upper part of the benefit area.

References

1. Trent River Board ( ). River Tean Pioneer Scheme - Engineering Report. Unpublished.

2. STWA Derwent Division (1977). River Tean Regrading Scheme. Engineering Report and Submission for Approval in Principle. Unpublished.

3. STWA Derwent Division (1978). Engineer's Report on the River Tean Regrading Scheme - Part II. Unpublished.

4. STWA (1976). Notes of meetings with MAFF held on 30th September 1976.

5. Ministry of Agriculture, Fisheries & Food (1972). Agricultural Land Classification (sheet 120).

6. ADAS (1974). Getting Down to Drainage No. 16 Arterial Drainage and Agriculture. MAFF.

APPENDIX L

Tame Division

River Sence : Temple Mill

SILSOE COLLEGE

STWA TAME DIVISION - RIVER SENCE, TEMPLE MILL SCHEME

Report on the background to and development of the scheme and the nature and rate of uptake of agricultural benefits.

1. Physical Background

The River Sence is a tributary of the River Anker in Leicestershire. It rises at Bardon Mill about 3 km east of Coalville and flows through undulating country in a south westerly direction for about 31 km to join the Anker north of Atherstone. The catchment of 17,330 ha is almost entirely agricultural except for part of the Urban District of Coalville. The present scheme relates to 1.5 km of the Sence in the vicinity of Temple Mill between GR SK35480344 and SK36360428.

2. Soils and Land Capability

The soils of the area are dominated by clay with layers of sand and gravel at a depth of about 1 metre (Ref. 1).

The National Soils Map (Ref. 7) classifies the soils adjacent to the river as Fladbury 2/Stixwould Series. This is a groundwater gley with a clay top soil and sandy subsoil. The drainage of this soil depends largely upon the relationship between the sandy layer and the river level. Beyond the floodplain the soils are surface water gleys of the Salop Series. This typical stagnogley has a slightly porous clay subsoil that holds up percolating drainage water leading to seasonal waterlogging.

The immediate floodplain was classified by MAFF as grade 4 with grade 3 land beyond (Ref. 2).

3. Land Drainage History

20 km of the Sence, from the Anker confluence to Heather were designated as Main River in 1965, although the owners of Temple Mill (the Crown Estates) retained the water rights. The Mill had not been in use for some time and the owners were preapred to relinquish the water rights subject to the river being diverted from the Mill. A Pioneer Scheme was carried out between 1966-68 on the full length of Main River at a total

cost of £6,722. It was anticipated that these works would give immediate benefit to an area of 4 ha upstream of Temple Mill (Ref. 3). The possibility of an improvement scheme in the vicinity of Temple Mill was discussed with the agents for the Crown Commissioners in 1968 and, following consultation, a scheme was designed in 1971.

4. Pre-Scheme Land Drainage Status

Prior to the scheme, water held up at the Mill gave rise to poor land drainage upstream. Riparian land was prone to frequent inundation. The farm survey (see section 8) indicated that fields totalling 55.1 ha upstream of Temple Mill were subject to flooding 2 to 3 times each year although water would only remain on the land for a matter of days. The high water levels (often above field level) at normal flow precluded efficient land drainage and even though all of the agricultural land had old underdrainage systems (often dating back to the last century) 9.7 ha were described as 'commonly wet' and 45.4 ha as 'usually' or 'permanently wet'.

5. The Impact of Pre-Scheme Land Drainage Status on Land Utilisation

The drainage conditions described above imposed severe constraints upon land utilisation and prior to the scheme all of the benefit area was under permanent grass. The Harris Bridge to Bilstone road was liable to flooding after heavy rain, especially in the vicinity of Temple Mill.

6. Scheme Design

The scheme involved the realignment of the channel, to avoid the Mill sluices and so remove the constriction to flow (Figure 1) and the regrading of 1404 m of Main River. The channel was designed for the run-off from the 1 in 5 year storm of 13.88 cumecs (compared to an estimated pre-scheme channel capacity of 13.31 cumecs). To allow a depth of flow of 1.39 m to be maintained a gradient of 1 in 500 was used and a trapezoidal channel cross-section with a 4.93 m bed width and $1:1\frac{1}{2}$ side slopes (Ref. 4).

At normal flow this design was intended to provide 1.54 m freeboard for field drainage.

The access bridge to Temple Mill was to be replaced.

7. **Benefit Area**

The Engineer's Report (Ref. 4) identified an agricultural benefit area of 109 ha. The field survey (see section 10) revealed a need to adjust the boundary as follows:

(i) To extend the upstream limit to field boundaries and to include all of the land previously subject to frequent flooding that has, as a result of the scheme, now been alleviated;

(ii) To exclude the area north of the Harris Bridge to Bilstone road which never suffered from any constraint imposed by the poor pre-scheme condition of the Sence; and

(iii) To limit the downstream benefit area at Temple Mill.

The adjusted benefit area measures 90 ha and is shown in Figure 2 below.

8. **Anticipated Costs and Benefits**

The original cost estimate was made up as follows:

	£	
Wages	5,800	
Plant	3,660	
Materials	1,800	
Land purchase and compensation	860	
S.E.T.	280	
	£12,400	(November, 1971)

This included contributions of £2,000 from the Crown Estates for additional works, and £500 from the County Council towards the cost of replacing the access bridge to Temple Mill.

The lowering of normal water levels was intended to improve the drainage over a Benefit Area of 109 ha (Figure 2) and it was understood, prior to commencement of works, that the Crown Estates would take full advantage of the opportunities presented and prepare a complete tile drainage scheme for the area.

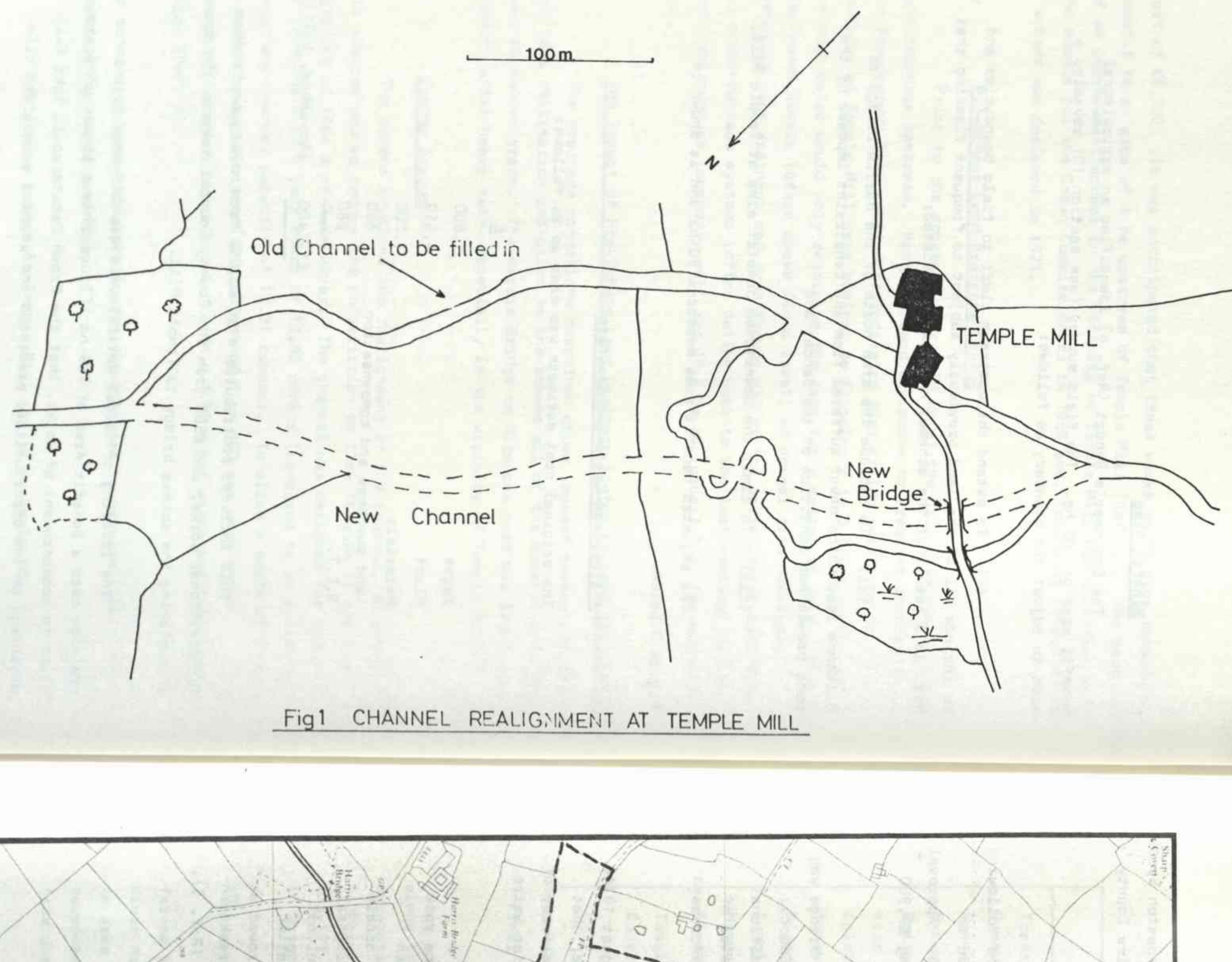


Fig1 CHANNEL REALIGNMENT AT TEMPLE MILL

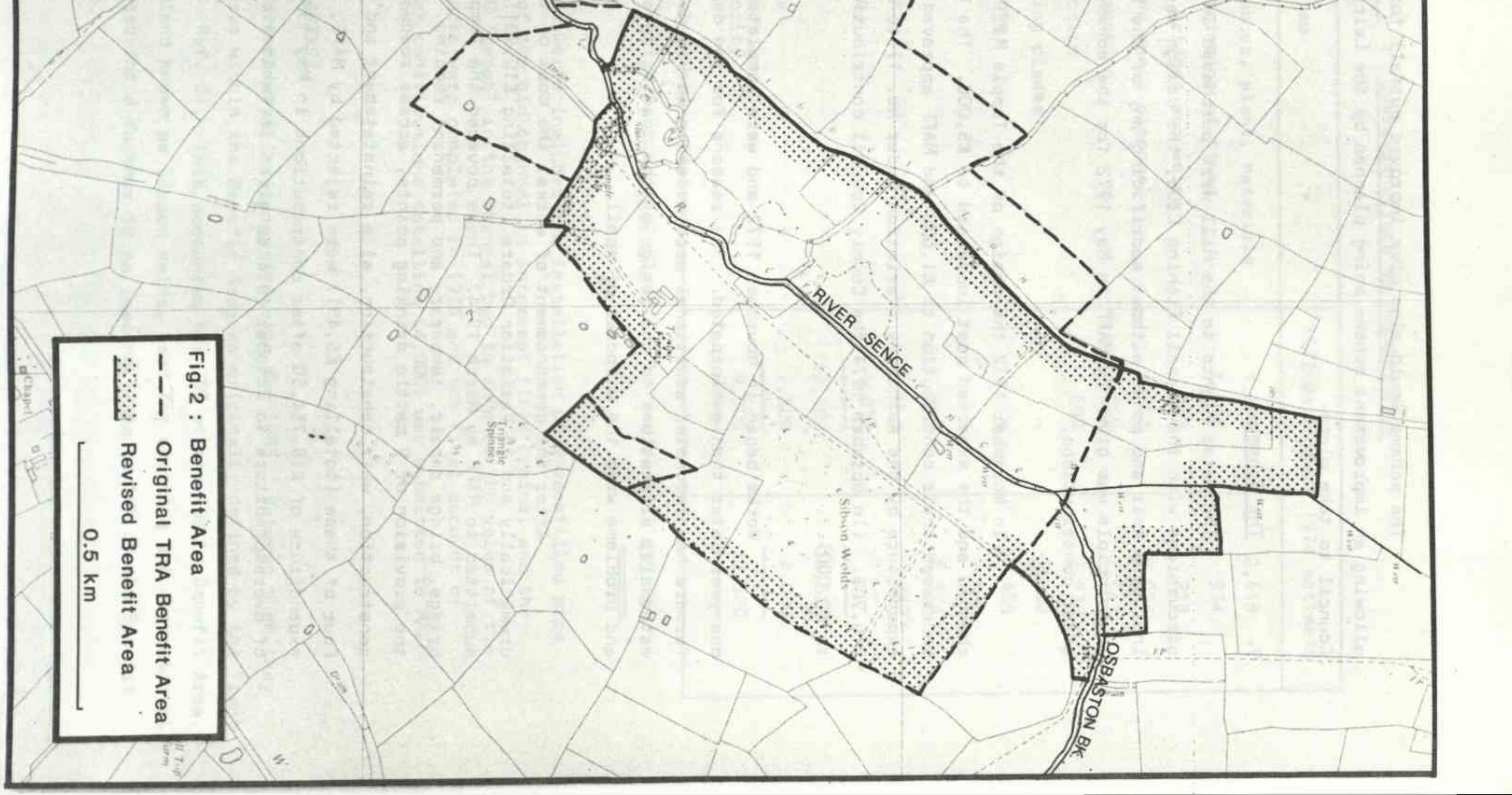


Fig.2 : Benefit Area

The scheme would also give improved outfall for the Osbaston Brook allowing an improvement scheme being planned by the Leicestershire County Council to take place.

9. The Scheme

The water rights to the Mill were purchased in 1971 and following discussions with the Gopsall Fishing Club, the design was revised to include a weir and ponds without sacrificing any of the benefits. Approval in principle was given by MAFF in May 1972 for the scheme costing £9,900 after contributions.

In November 1972 the design of the Temple Mill access bridge was changed and the expected cost increased to £5,000. The County Council increased their contribution to £1,000 and MAFF approved the additional expenditure by the Authority (Variation Order No. 1) to a new total of £10,900. (In October 1974 the County Council contribution was increased to £2,000).

Works began in November 1972 and were completed in August 1974, one year later than anticipated. The reasons for the delay were; that farmers had requested additional accommodation works; delayed delivery of materials; alterations to the design of the road bridge and gabion weirs and problems with the disposal of spoil.

After the commencement of works, the cost of the scheme rose dramatically and 13 Variation Orders (totalling £10,931) had been submitted to MAFF by March 1974. These covered the Temple Mill access bridge, bridge repair, temporary and permanent fencing, spoil disposal, the provision of 9 cattle drinking points, access roadway and culvert construction, weir construction, site reinstatement and compensation. Four of these (totalling £5,451) were rejected by MAFF, who approved an expenditure of £18,754.50 after contributions in May 1974. A breakdown of overexpenditure to October 1974 is given in Table 1 below. (Ref. 5).

Table 1 : Overexpenditure to October 1974

Item	1972 estimate	1974 estimate
Transport, labour, plant, materials	1,300	2,618
Removal and trimming of trees	1,120	974
Breaking out bridges and weirs	470	218
Excavation and spoil disposal	4,313	6,094
Bridge construction	3,065	7,547
Weir construction	600	2,936
Cattle drinking places	-	1,602
Access culverts	-	405
Piped ditch	-	500
Fencing	460	8,974
Miscellaneous	-	342
Contingencies	1,072	-
Total	12,400	36,520
Contributions	2,500	4,000
Cost to Authority	9,900	32,520

Final cost (1978) after contributions £33,121

Further works included the installation of a backfilled pipe along the path of the old channel to intercept field drains, and the excavation of 10 'deeps' in the channel bed to enhance the value of the fishery. All works were completed in 1978 and the final account of £33,121.11 (after contributions totalling £4,000) was submitted to MAFF in October 1982.

10. Farm Survey

Two farmers were interviewed during May 1983. Between them they farmed 90 hectares within the Benefit Area as originally defined by the Trent River Authority (Ref. 6). This accounted for 75% of the 109 ha Benefit Area. An area of woodland known as Sibson Wolds, used for sporting and recreational purposes accounted for a further 16 ha leaving 11 ha or 10% of the Benefit Area unsurveyed.

The revised benefit area, shown in Figure 2 measures 90 ha, of which the farm survey covered 74 ha, equal to 100% of the agricultural land (Sibson Wolds accounting for the remaining 18% of the revised benefit area).

One of the two farms in the benefit area changed hands after the scheme in 1979. The percentages of the farms in the benefit area are 7% and 31%.

11. Agriculture in the Benefit Area

(a) Farm Type, Size and Tenure:

Both farms with land in the benefit area are dairy farms but both also have significant areas of cereals. Both farms are in the size class 100-200 ha with Standard Man Day requirements between 1500 and 2000. A large proportion of the land in that part of Leicestershire belongs to the Crown and both farms are wholly tenanted from the Crown Estates.

(b) Dairy Enterprises:

The stocking rate is very similar on each farm and averages 2.2 Livestock Units per hectare of grass, although on one farm this is comprised of dairy cows only and on the other, half the herd is dairy cows, one quarter replacements and a quarter beef cattle. Milk yields per cow are high (over 6000 litres per annum).

(c) Beef Enterprises:

Only one farm keeps dairy bred cattle for beef and half of these are sold as finished cattle at 2 years of age and the rest at 12-18 months as stores.

(d) Arable Enterprises:

Both farms grow wheat and barley cereals in rotation with roughly 2 years of temporary grass for every 3 of cereals.

12. The Effects of the Scheme on Flooding and Land Drainage

Since the scheme the river has not flooded (ie. in 9 years to 1983) and a satisfactory outfall has been provided for field drainage. Average water levels have been lowered by about 0.6 m (Ref. 1).

It was anticipated in the Engineer's Report (Ref. 4) that an improvement scheme at Temple Mill would allow the Leicestershire County Council to carry out a regrading scheme on the Osbaston Brooks - a tributary of the Sence joining 1 km upstream of Temple Mill (also known as the Carlton Brook). At the time the Council were keen to carry out the works as soon as the Sence works were complete. However, no work has been carried out on the Osbaston Brook. Flooding has been alleviated near the confluence with the Sence due to the improved outfall and this has been included within the benefit area. Upstream however, the Osbaston Brook still causes problems.

13. The Agricultural Benefits of the Scheme

(a) Land Use Change:

The land use data are summarised in Table 2 below.

Table 2 : Land Use Change 1974-83 (hectares)

Pre-scheme \ Post-scheme	Permanent Grass	Grass/Crop Rotation	Woodland (Sibson Wold)	Total
Permanent Grass	8.5	64.4	-	72.9
Grass/Crop Rotation	-	-	-	-
Woodland	-	-	16.6	16.6
Total	8.5	64.4	16.6	89.5

The major change is the 64.4 ha (88% of the agricultural land in the Benefit Area) that has been ploughed and brought into an arable rotation. At present 19 ha of this is under temporary grass which is cut 3 times a year for silage. The rest is under wheat or barley yielding about 4 tonnes/ha. The anticipated rotation will be of 5 years with 2-3 years of grass and the remainder corn. Sibson Wolds, accounting for 19% of the Benefit Area, has remained woodland.

Figure 3 shows the rate of land use change. The first land was ploughed in the third year after the scheme but most has been ploughed in the last 4 years. This largely reflects the change of occupation of one farm covering 87% of the Benefit Area.

Fig 3 : LANDUSE CHANGE

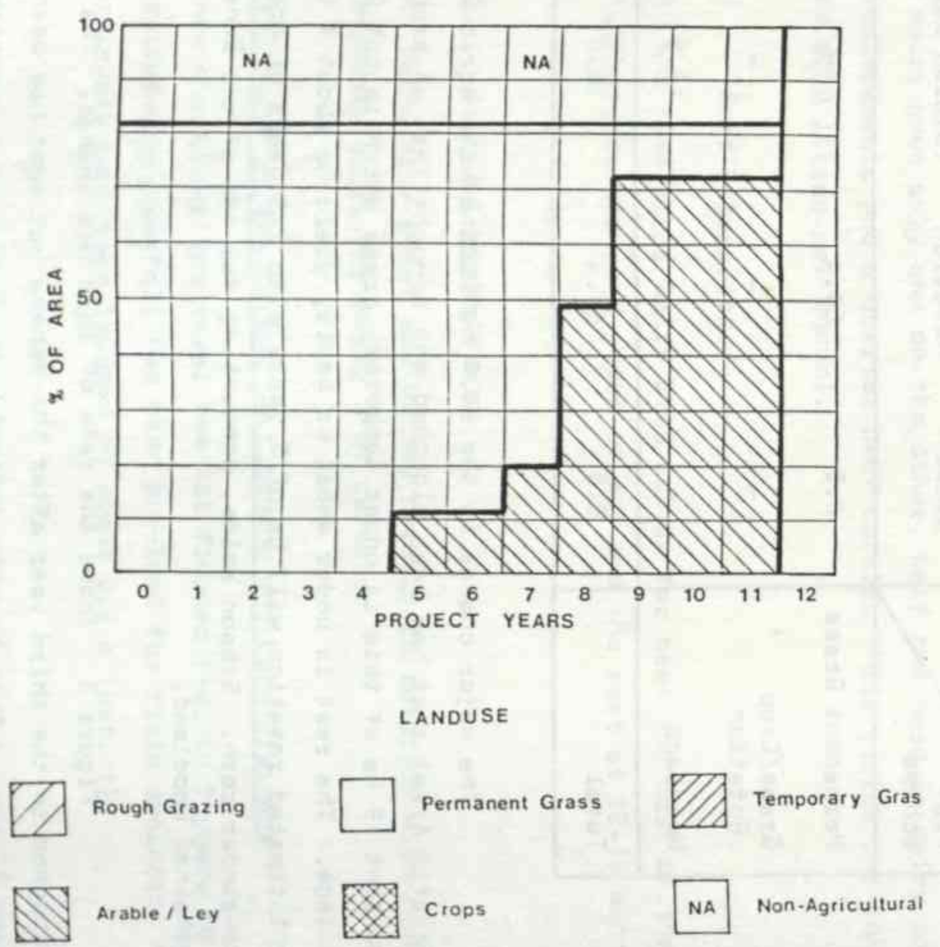


Fig 4 : INSTALLATION OF UNDERDRAINAGE

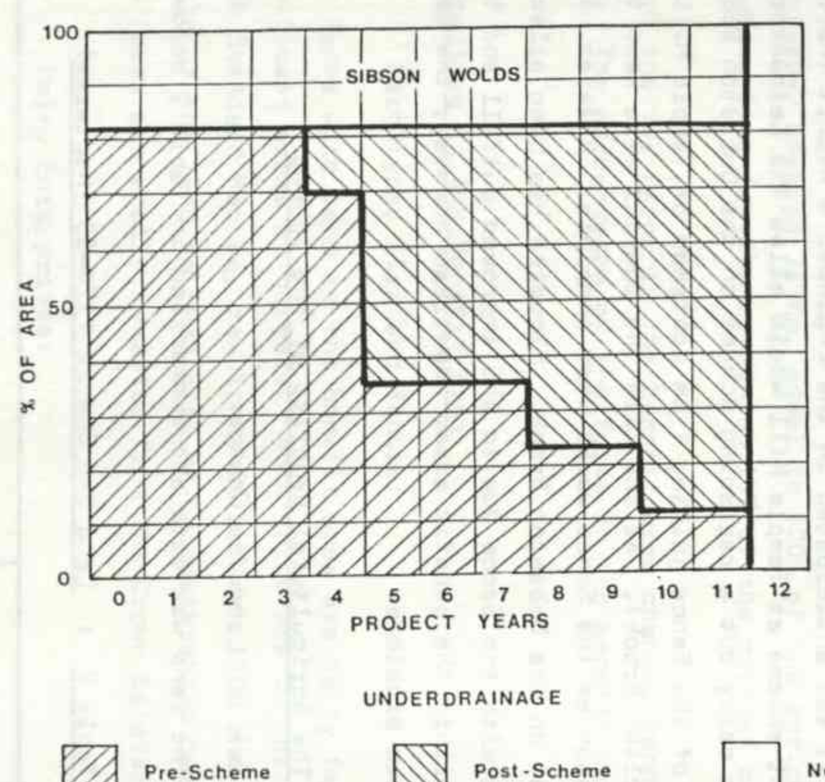


Table 3 : Field Drainage Installation

Date of Drainage	Area (ha)	Land Use		
		Pre-scheme	Post-scheme	Date of Change
1976	4	Permanent grass	Permanent grass	-
1976	6	Permanent grass	Rotation	1977
1977	3	Permanent grass	Rotation	1980
1977	1	Permanent grass	Rotation	1979
1977	7	Permanent grass	Rotation	1979
1977	13	Permanent grass	Rotation	1980
1977	7	Permanent grass	Rotation	1981
1980	10	Permanent grass	Rotation	1980
1982	6	Permanent grass	Rotation	1981
1982	3	Permanent grass	Rotation	1981
Date unknown	5	Permanent grass	Permanent grass	-

(b) Field Drainage Installation:

All underdrainage work has been carried out in association with the Crown Estates. It has been their policy to re-drain the entire Benefit Area to take full advantage of the river improvement scheme. The Estate has paid a contribution towards the cost of drainage after grant and it has been the finance policy of the Crown Commissioners that has determined how much of the land has been drained each year.

So far 63.9 ha (88% of the agricultural land in the Benefit Area) have been underdrained. The rate of installation is shown in Figure 4. None of this underdrainage would have been possible before the scheme. Nine hectares remain undrained, this is because the farmer is awaiting permission from the Crown Estates.

(c) Improved Production from Existing Land Uses:

Only 12% of the permanent grass in 1974 is still under grass. Most of this has been underdrained and conditions are markedly improved. The grazing season has extended by approximately three weeks at either end of the season and with increased nitrogen application, one farmer estimated that the land yields 3 times as much grass than before the scheme, allowing increased stocking densities.

Sibson Wolds is used for recreational purposes (mainly shooting) and cannot be considered agricultural.

(d) Rate of Benefit Uptake:

A financial assessment of the Temple Mill scheme has been undertaken by identifying, on the basis of farmer interview, the change in farm enterprise gross margins attributable to the drainage improvements, net of any additional fixed costs, and including the benefit of extended grazing if relevant. The procedures used for this purpose are described in Annex V.

A summary of benefits (before field drainage costs) by farm is given in table 4. The greatest benefit has been associated with a change in land use from permanent grass to arable/ley.

Both farmers in the benefit area recorded benefits, the order of which reflects their relative share of the benefit area.

The rate of uptake of financial net benefits attributable to the scheme is shown in Figure 4. Averaged over the benefit area of 73 hectares, net returns have increased by about £142 per hectare over the 12 year period.

Figure 5 expresses actual takeup as a percentage of scheme potential which is taken to be a reasonably achievable target for post-scheme land use and farming practice: that based on land capability and local farming practice. For the Temple Mill scheme, arable/ley rotations are possible throughout the benefit area: 2/3 years grass, 4 years winter cereals. Current grassland management with 350 kg N/ha and 3 cut silage systems represent realisable potential. Current cereal yields at 4 to 5 tonnes per hectare are below an expected potential of over 6.5 tonnes per hectare. According to Figure 5, actual gross margins reached 69 % of their potential by 1983/4. This relative measure of uptake requires cautious interpretation as discussed in Annexe IX section 4.4.

Table 4 : Distribution of benefits by Farm

NET AGRICULTURAL BENEFIT
****

FARM CODE	YEAR FIRST	YEAR 4	YEAR 9	YEAR LAST	% OF BENEFITS	% OF AREA
1	0	1773	6296	8037	78	87
2	131	131	2907	2300	22	13
TOTAL				10337	100	72

FIGURE 5 : Degree and Rate of Financial Uptake

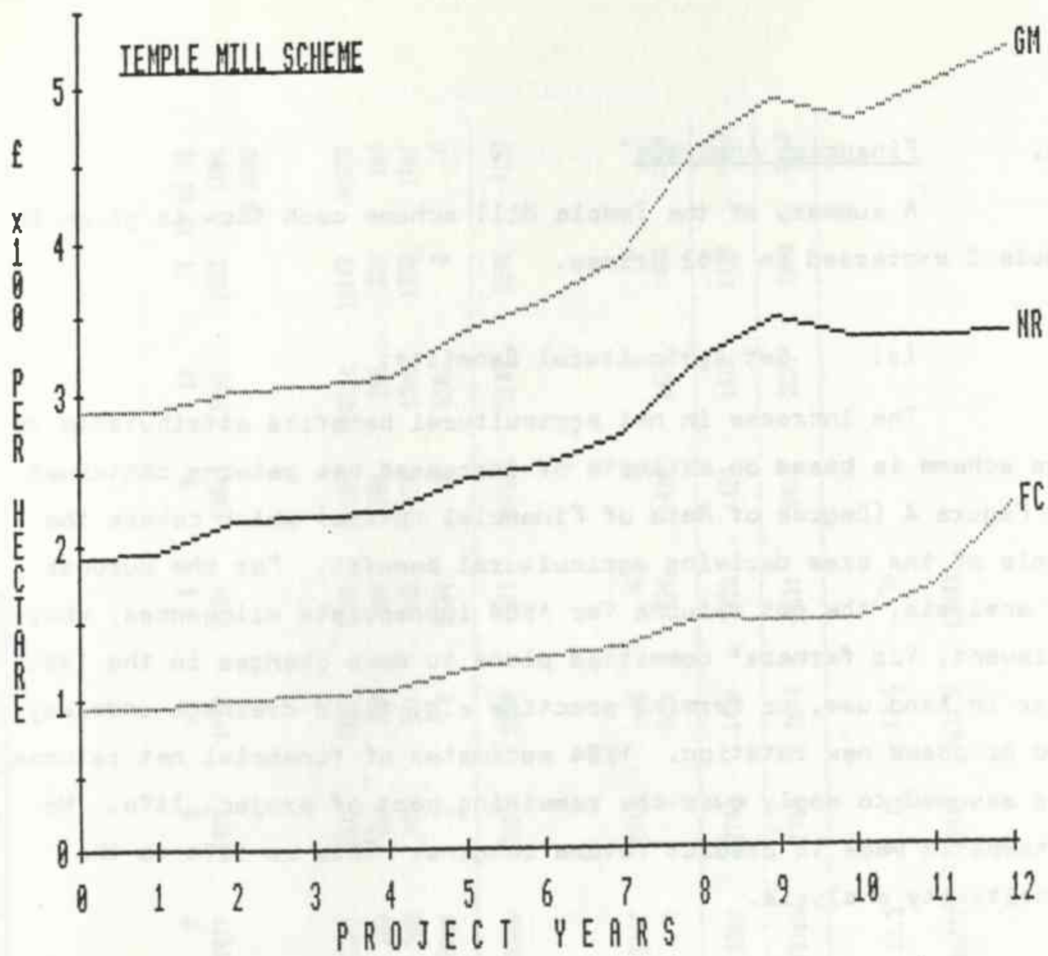
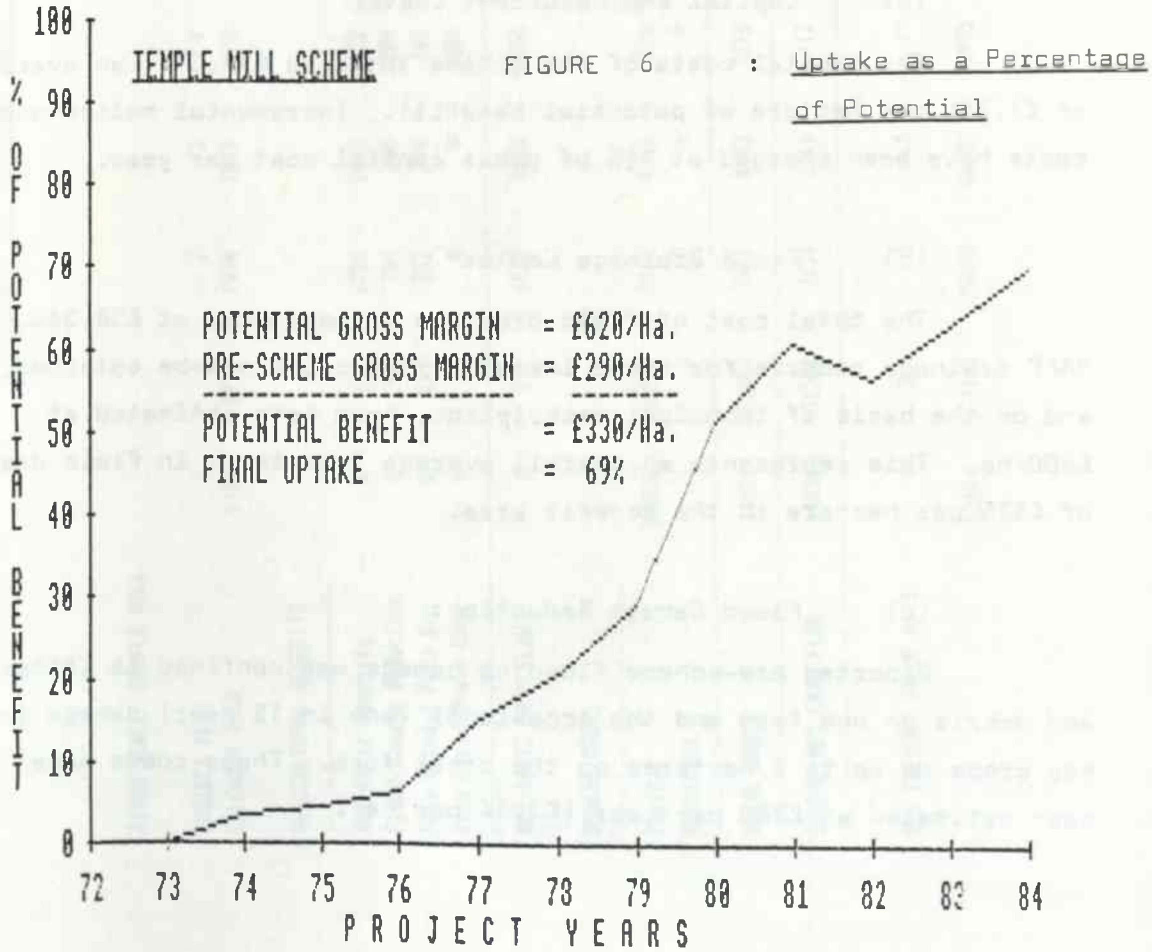


FIGURE 6 : Uptake as a Percentage of Potential



14. Financial Analysis

A summary of the Temple Mill scheme cash flow is given in Table 5 expressed in 1982 prices.

(a) Net Agricultural Benefits:

The increase in net agricultural benefits attributable to the scheme is based on estimate of increased net returns contained in Figure 4 (Degree of Rate of Financial Uptake) which covers the whole of the area deriving agricultural benefit. For the purpose of analysis, the net returns for 1984 incorporate allowances, where relevant, for farmers' committed plans to make changes in the 1985 year in land use, or farming practice e.g. field drainage underway and proposed new rotation. 1984 estimates of financial net returns are assumed to apply over the remaining part of project life. No attempt is made to predict future returns. This is left to the sensitivity analysis.

(b) Capital and Recurrent Costs:

The capital costs of the scheme totalled £94,611 (an average of £1,296 per hectare of potential benefit). Incremental maintenance costs have been charged at 1½% of gross capital cost per year.

(c) Field Drainage Costs:

The total cost of field drainage is estimated at £38,340. MAFF drainage records for these installations could not be obtained, and on the basis of technical description, have been estimated at £600/ha. This represents an overall average investment in field drains of £525 per hectare in the benefit area.

(d) Flood Damage Reduction:

Reported pre-scheme flooding damage was confined to litter and debris on one farm and the occasional (one in 15 year) damage to hay crops on up to 6 hectares on the other farm. These costs have been estimated at £280 per year (£3.84 per ha).

TABLE 5

Summary of Scheme Cash Flow and Net Present Value

RIVER SENCE TEMPLE MILL

PROJECT YEAR	0	1	2	3	4	5	6	7	8	9	10	11	12 TO 30
CALENDAR YEAR	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984 TO 2002
AGRICULTURAL BENEFITS													
Net Agric Benefits	0	132	1780	1905	2172	3622	4332	5841	9204	11156	10154	10142	10338
Flood Damage Reduction	0	280	280	280	280	280	280	280	280	280	280	280	280
less Without Proj Ben	0	115	232	349	468	588	709	831	955	1079	1205	1332	1461
less Field Drain Cost	0	0	0	0	5820	18180	0	0	8760	0	5580	0	0
NET AGRIC CASH FLOW	0	297	1828	1836	-3836	-14866	3903	5290	-231	10357	3649	9090	9157
SCHEME COSTS													
Capital	44826	31850	3962	4052	3876	3302	2743	0	0	0	0	0	0
Recurrent	0	0	0	0	0	0	0	1420	1420	1420	1420	1420	1420
TOTAL COSTS	44826	31850	3962	4052	3876	3302	2743	1420	1420	1420	1420	1420	1420
SCHEME NET CASH FLOW	-44826	-31553	-2134	-2216	-7712	-18168	1160	3870	-1651	8937	2229	7670	7737
NET PRESENT VALUE AT %	0	2.5	5	7.5	10	12.5	15	17.5	20				
	62609	3149	-29070	-46602	-55995	-60772	-62879	-63422	-63043				

(e) Without-Project Benefits:

A basic assumption of 1% compound per annum is used to account for likely improvements in farming performance which would have been achieved without the project. Without-project benefits are charged for those areas for which there has been some observed post-scheme uptake: 81.5% in this case. Without-project benefits are therefore taken as 1% compound of the pre-scheme net returns multiplied by 81.5%, ie. £11,520 x 1% compound.

(f) Project Worthwhileness:

Assuming benefits continue at their 1984 level over a 30 year project life, the net present value of the Temple Mill scheme at the 5% discount rate is -£29,070, with an internal rate of return of 2.7%. Whilst there is scope for improved performance particularly with respect to cereal yields, net agricultural benefits would need to increase by more than 25% over the remainder of project life for the project to break even at 5% discount rate.

Whilst the average extra benefit at full development has been substantial at more than £140 per hectare, the scheme's capital investment in river and field drainage has been about £1,820 per hectare of benefit.

The improvement of the River Sence at Temple Mill, however likely to offer potential benefits to the Osbaston Brook where farmers have for some time been pressurising the local authority to make improvements. Improvements to the latter would not be possible without the Temple Mill scheme. There would appear to be some justification to reducing the costs of the Temple Mill scheme charged against the latter in the event of improvements to the Osbaston Brook.

(g) Sensitivity Analysis:

Table 6 examines the sensitivity of the scheme to selected cost and benefit parameters, and the percentage increases in net agricultural benefits needed to break even at 5% discount rate. At present levels of uptake, capital costs would need to be 65% their actual level for the project to break even at 5% discount rate. This observation is made in the context of the potential provided for the Osbaston Brook improvement.

TABLE 6

River Sence : Temple Mill - Sensitivity Analysis

Run No.	Agricultural Benefits Factor	Without Project Benefits Compounding Factor	Flood Damage Reduction Factor	Capital Works Cost Factor	NPV at 5% £	IRR %	Switching Value
1	1.0	1	1	1	-29070	2.7	1.25
2	1.0	0.5	1	1	-21385	3.4	1.20
3	1.0	1.5	1	1	-37122	2.0	1.35
4	1.0	0	1	1	-14051	4.0	1.13
5	1.0	1	0	1	-33169	2.4	1.3
6	1.0	1	1	0.65	0	5.0	1.0

* The factors show the weights applied to the original estimates eg a factor of 1.5 for the without-project benefits indicates that the new value is 1.5 x 1% compound per year (the original value) ie 1.5% compound.

* Switching value : change in agricultural net benefits needed to make the project breakeven at 5% discount rate eg a 1.5 switch value shows an increase of 1.5 x the original estimated is required.

15. Discussion

When considering the benefits alone the scheme appears to have been very successful. The uptake of potential benefits has been both rapid and high in value (averaging £142/ha in 1982 prices). The infrastructural support of the Crown Agents, who promoted the scheme in the first place, has enabled almost all of the benefit area to be underdrained and as a result there has been extensive land use change.

However, the scheme exhibits a low Internal Rate of Return (2.7%) due to the unusually high cost of capital works per hectare of benefit (£1296/ha in 1982 prices). An element of the costs of this scheme could have been apportioned to provision of 'potential' for improvement of the Osbaston Brook. As this potential has not been taken up, in as much as the Osbaston Brook has not been improved, full costs must be charged to the Temple Mill scheme.

References

(1) J. Farnworth,
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(2) Ministry of Agriculture, Fisheries and Food (1972),
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(3) Trent River Authority (1966-68),
River Sence Pioneer Scheme. Scheme Files, unpublished.

(4) Trent River Authority (1972),
River Sence Improvement Scheme - Temple Mill. Engineering Report, unpublished.

(5) Trent River Authority/STWA (1971-1982),
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(6) Trent River Authority (1970),
River Sence Improvement Scheme - Temple Mill. Plan of areas of benefit. Drawing no. 2044/3/1.

(7) Soil Survey (1983),
National Soils Map at 1:250,000. Soil Survey, Harpenden.

APPENDIX M

Lower Severn Division

River Severn : Saxon's Lode to Mythe Hook

SILSOE COLLEGE

STWA LOWER SEVERN DIVISION - RIVER SEVERN:
SAXON'S LODE TO MYTHE HOOK

Report on the background to, and development of the Scheme and the nature and rate of uptake of agricultural benefits.

1. Physical Background

The scheme between Saxon's Lode and Mythe Hook was one of a series of schemes carried out on the River Severn between Worcester and Tewkesbury after 1962. The area affected is on the left bank of the Severn just upstream of Tewkesbury and lies within the counties of Hereford and Worcestershire and Gloucestershire.

In this reach the River Severn meanders through a floodplain approximately 1 km wide and over the years natural deposition from the river has built up considerable levees such that the land levels fall away from the river; the lowest points being in hollows abutting the higher ground of the bluffs.

The present scheme relates to an area of 250 ha bound to the north and west by the River Severn and to the east by higher ground. At the southern end of the area the Mythe Brook crosses the floodplain and joins the Severn forming the downstream boundary.

The area is drained by a number of internal ditches that flow in a south-easterly direction parallel to the Severn in the low ground behind the levees. Water is evacuated from the area by means of a channel cut through the levee to a 2.08 x 1.35 m flapped outfall on the Severn in the west, and the Ripple Brook that flows into the Mythe Brook in the south.

2. Soils and Land Capability

No detailed soil survey of the area has been carried out, however a comparison of the National Soils Map (Ref 1), the Agricultural Land Classification (Ref 2), a survey of a similar area downstream (Ref 3) and site observation suggests that the area can be divided into three facets as follows (see Figure 1).

(1) The Levees of the Severn:

Characterized by a red warp (alluvial) soil with a clayey texture. The land is higher than that behind thus flooding presents only a moderate limitation to land use. The land was classified as grade 3 and is suited to permanent grassland for grazing.

(2) The Low Ground Behind the Levees:

Characterized by typical alluvial gley soils on the Hollington association (possibly Compton series) which are deep and stoneless with a fine silty or clayey texture. This is the lowest lying land and flooding and wetness present limitations on land use with a high ground water table from November to April. The area was classified as grade 4 and is best suited to stock rearing on permanent grassland, although in this case an area of 9 ha is given over to Ozier beds.

(3) The Higher Ground Around Uckinghall:

This area is dominated by a typical brown earth of the Wick series. It is deep and well drained with a sandy loam texture; in places overlying gravel. The slopes are moderate although stoniness presents a minor limitation to land use. This area was classified as grade 2 and is suitable for cereals and horticultural crops. In the past Uckinghall was a locally important market gardening area, however today the land within the Benefit Area is largely under permanent grass.

3. Land Drainage History

In addition to the natural levees there is evidence of some historical involvement in floodbanking and internal drainage works although prior to the scheme there were numerous breaches in the banks, rendering them ineffective from flood protection point of view.

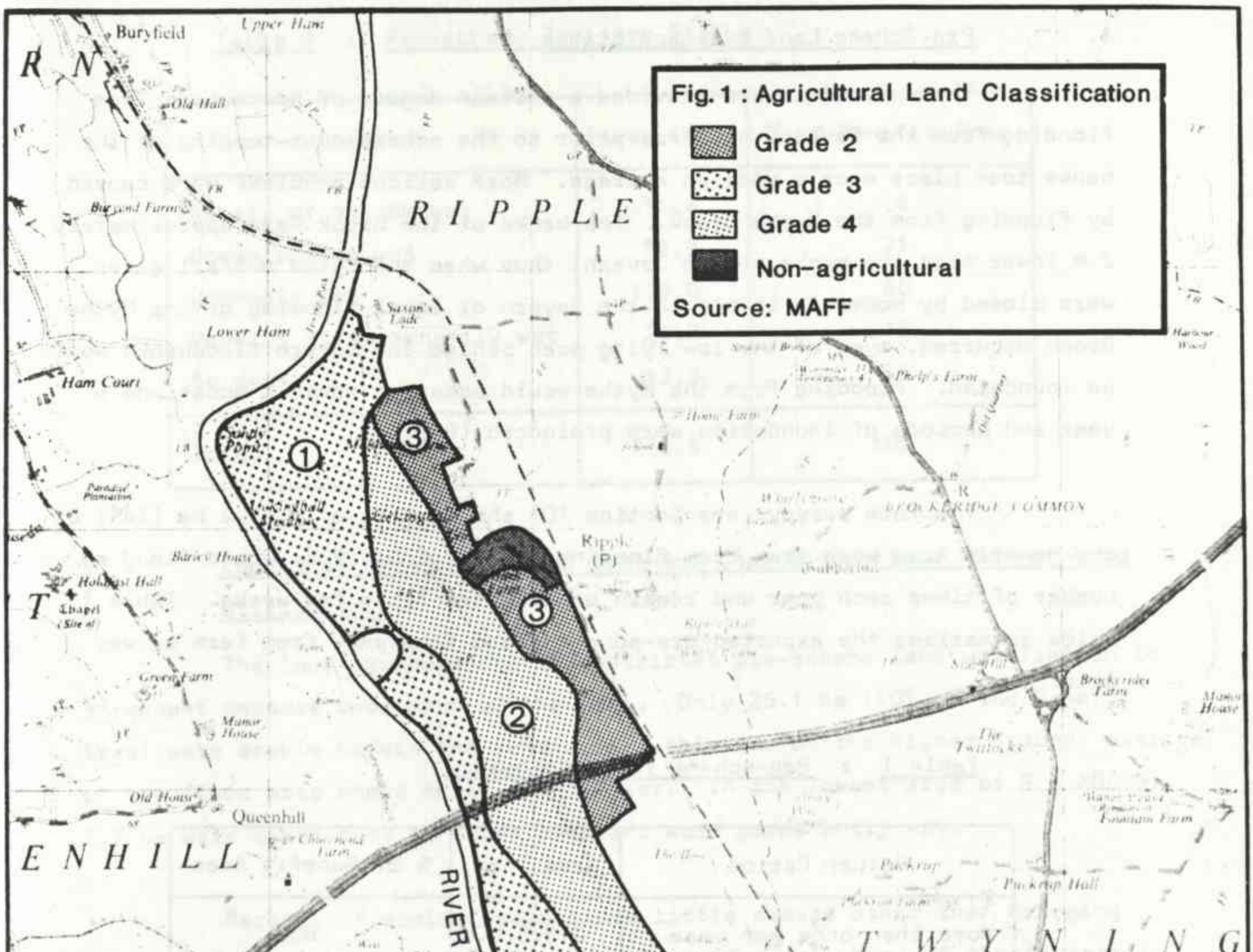
Fig. 1 : Agricultural Land Classification
Grade 2
Grade 3
Grade 4
Non-agricultural
Source: MAFF
RIPPLE
RIVER SEVERN
B U S H L E Y
T W Y N I N G
E N H I L L
Buryfield
Upper Ham
Lower Ham
Ham Court
Queenhill
Ripple
Twyning
Windmill Tump
Slades Green
Upper Green
The Mythe
Puckrup Hall

4. Pre-Scheme Land Drainage Status

The natural levees provided a certain degree of protection from flooding from the Severn, however, prior to the scheme over-topping of the banks took place once a year on average. More serious problems were caused by flooding from the Mythe Brook. The banks of the brook were approximately 2 m lower than the banks of the Severn, thus when the Mythe outfall gates were closed by moderate levels in the Severn or local flooding of the Mythe Brook occurred, much of the low lying area behind the Severn floodbanks would be inundated. Flooding from the Mythe would occur on several occasions a year and periods of inundation were prolonged (Ref. 4).

The farm survey (see Section 10) showed that only 35.2 ha (14%) of the Benefit Area were free from flooding and 187.6 ha (73%) would flood a number of times each year and remain under water for a few weeks. Table 1 below summarizes the expected pre-scheme flood frequency from farm survey data.

Table 1 : Pre-scheme flood frequency

Return Period	Area (ha)	% of Benefit Area
More than once per year	213.5	83
Once per year	4.9	2
Once in 2 to 5 years	-	0
Less than once in 5 years	3.2	1
Did not flood	35.2	14
Total	256.8	100

Only 50.1 ha of the area surveyed had underdrainage and all of these were old schemes with poor outfalls and often ineffective. Table 2 below summarizes the pre-scheme drainage status as estimated by the farmers.

Table 2 : Pre-scheme Drainage Status

Status	Area (ha)	% of Benefit Area
Rarely or seldom wet	11.4	4
Occasionally wet	52.9	21
Commonly wet	155.0	60
Usually or permanently wet	24.2	10
No data	13.3	5
Total	256.8	100

5. Impact of Pre-Scheme Land Drainage Status and Flood Risk on Land Utilization

The land drainage status restricted pre-scheme land utilization to permanent pasture over most of the area. Only 25.1 ha (10% of the Benefit Area) were arable before the scheme, and this was on the higher ground, outside of the flood area where soils are lighter. In the lowest area at 9 m AOD(N) 7.7 ha were given over to Ozier beds and were permanently wet.

Periodic flooding would cause little damage other than bringing litter and debris onto the land and damaging fences. Many of the farmers in the area actually welcomed the winter flooding as a source of 'natural fertilizer'. They felt that the silt brought by the flood was sufficient to 'freshen-up' the grassland and little or no artificial fertilizers were applied.

More serious problems were caused by summer flooding. Although this was a rare event, occurring twice in the last 25 years and last in 1969 (from farm survey), a flood in June would cause severe damage to the hay crop whether it was standing or baled and left in the field. Although some hay could be salvaged, most had to be written off, the consequences of which were exacerbated by the area's dependance upon hay as a major crop (see Section 11.5)

6. Scheme Design

A floodbanking scheme was designed to provide limited protection to the level of the five-year flood on the River Severn frontage. This was in accordance with other schemes between Tewkesbury and Worcester and allowed for flood storage on occasions of major flood.

The works consisted of (see Figure 2):

(a) Earth embankments (6.5 km) tying into high ground at Saxon's Lode and running the length of the Severn frontage (with the exclusion of a pool at Uckinghall ferry) to 'The Poplars', across the floodplain to the Mythe Brook near its confluence with the Ripple Brook then alongside the Mythe Brook to high ground near Bow Farm. The Severn floodbanks have a 2.5 m top width and 5:1 slopes, to allow for safe overtopping and mowing by farmers, producing an embankment 0.85 m high. The banks alongside the Mythe have a 2 m top width and 4:1 side slopes, being 2.5 m high.

(b) Replacement of the low level outfall situated on the line of the northern area outfall ditch.

(c) A new low level outfall discharging to the Mythe Brook at its confluence with the Ripple Brook.

(d) Dredging the Ripple Brook and three associated ditches to re-route the internal drainage of field OS.0040.

7. Benefit Area

The Engineer's Report identified a Benefit Area of 316 ha. However the field survey (see Section 10) suggested that a smaller area be used. The Benefit Area shown in Figure 3 was derived by taking the floodline as described by the farmers and extending to a Medway Line 2.5 m above. As detailed contour maps were used, this was felt to be a reliable estimate and conformed well with the results of the farm survey. The area around Bow Farm, although less than 2.5 m above the floodline, was excluded from the Benefit Area as it lies within the catchment of the Mythe Brook and was therefore unaffected by the scheme. The area outside the floodbanks, estimated at 12 ha, was excluded from the Agricultural Benefit Area, as was the village of Uckinghall. By this method an Agricultural Benefit Area of 257 ha was derived. (Figure 3).

8. Predicted Costs and Benefits

(a) Costs:

The initial cost estimate totalled £70,000 and was made up as follows:

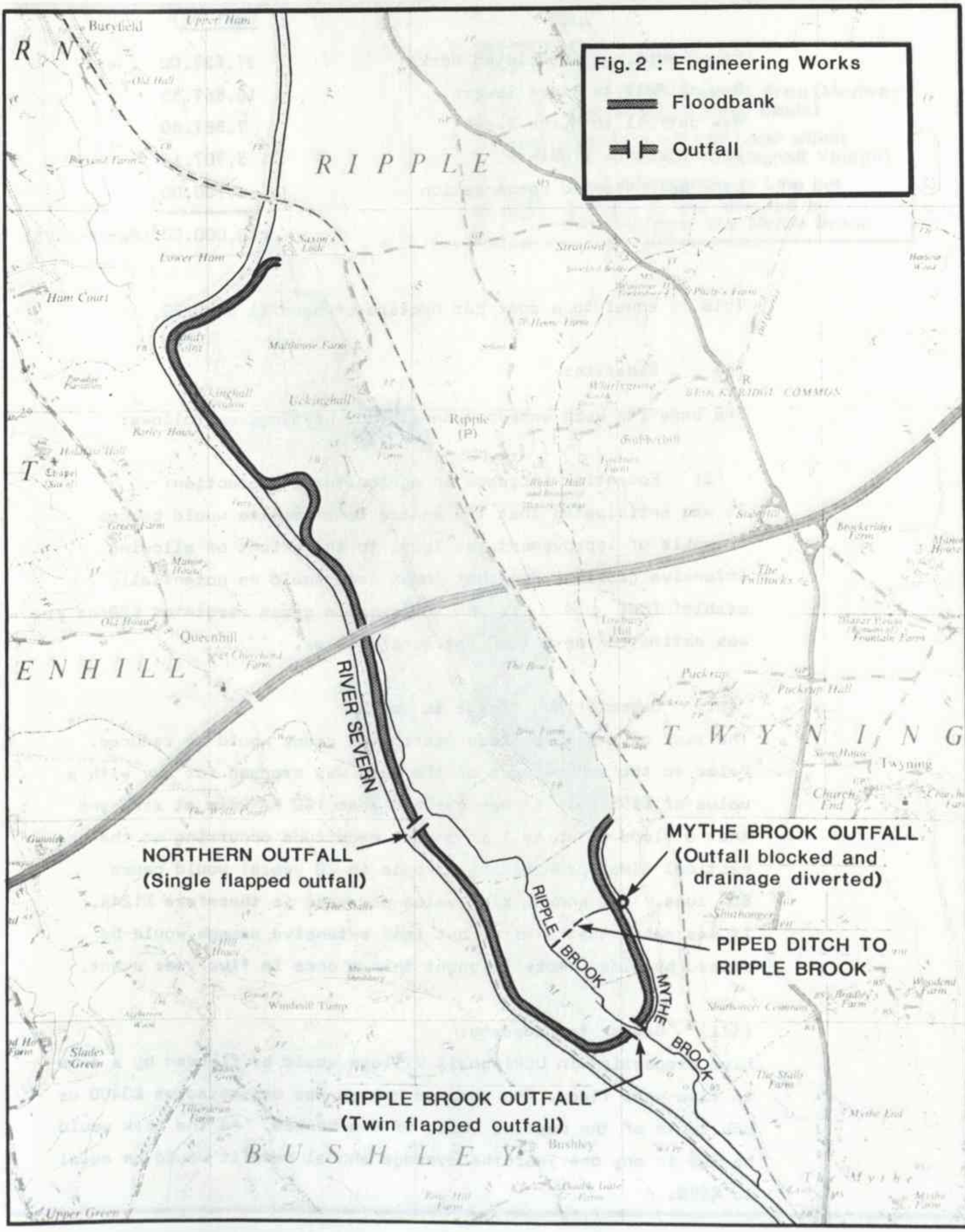
Fig. 2 : Engineering Works
Floodbank
Outfall
RIPPLE
RIVER SEVERN
NORTHERN OUTFALL
(Single flapped outfall)
MYTHE BROOK OUTFALL
(Outfall blocked and drainage diverted)
PIPED DITCH TO RIPPLE BROOK
RIPPLE BROOK
MYTHE BROOK
RIPPLE BROOK OUTFALL
(Twin flapped outfall)
TWYNING
BUSHLEY
ENHILL
Queenhill
Ripple (P)
Uckinghall
Twyning

Item	Cost (£)
Embankment and Associated Work	37,637.00
New outfall to River Severn	13,867.55
New outfall to Mythe Brook	7,887.80
Contingencies (10%)	5,907.15
Land purchase and compensation	4,700.00
	£70,000.00 (March 1975)

This is equal to a cost per hectare of benefit of £222.

(b) Benefits:

The benefits were assessed under four headings as follows:

(i) Potential increase in agricultural production:

It was anticipated that the entire Benefit Area would become 'capable of improvement, at least to the extent of allowing intensive grazing' and that 'most land would be potentially arable' (Ref 4). An increase in gross margin of £20/ha/yr was estimated for all of the Benefit Area.

(ii) Summer flood damage to crops:

The risk of a summer flood destroying crops would be reduced. Prior to the scheme most of the land was cropped for hay with a value of £195/ha. It was assumed that 160 ha were at risk and that a flood of up to 1 in 5 year magnitude occurring at the critical time (probability of once in 20 years) would cause 80% loss. The annual risk value per year is therefore £1248. It was noted that similar but less extensive damage would be caused by floods more frequent than a once in five year event.

(iii) Damage to property:

Five properties in Uckinghall Village would be flooded by a once in five year flood. The average damage was estimated at £3400 or one tenth of the capital value of the houses. As the risk would be 20% in any one year the average annual benefit would be equal to £680.

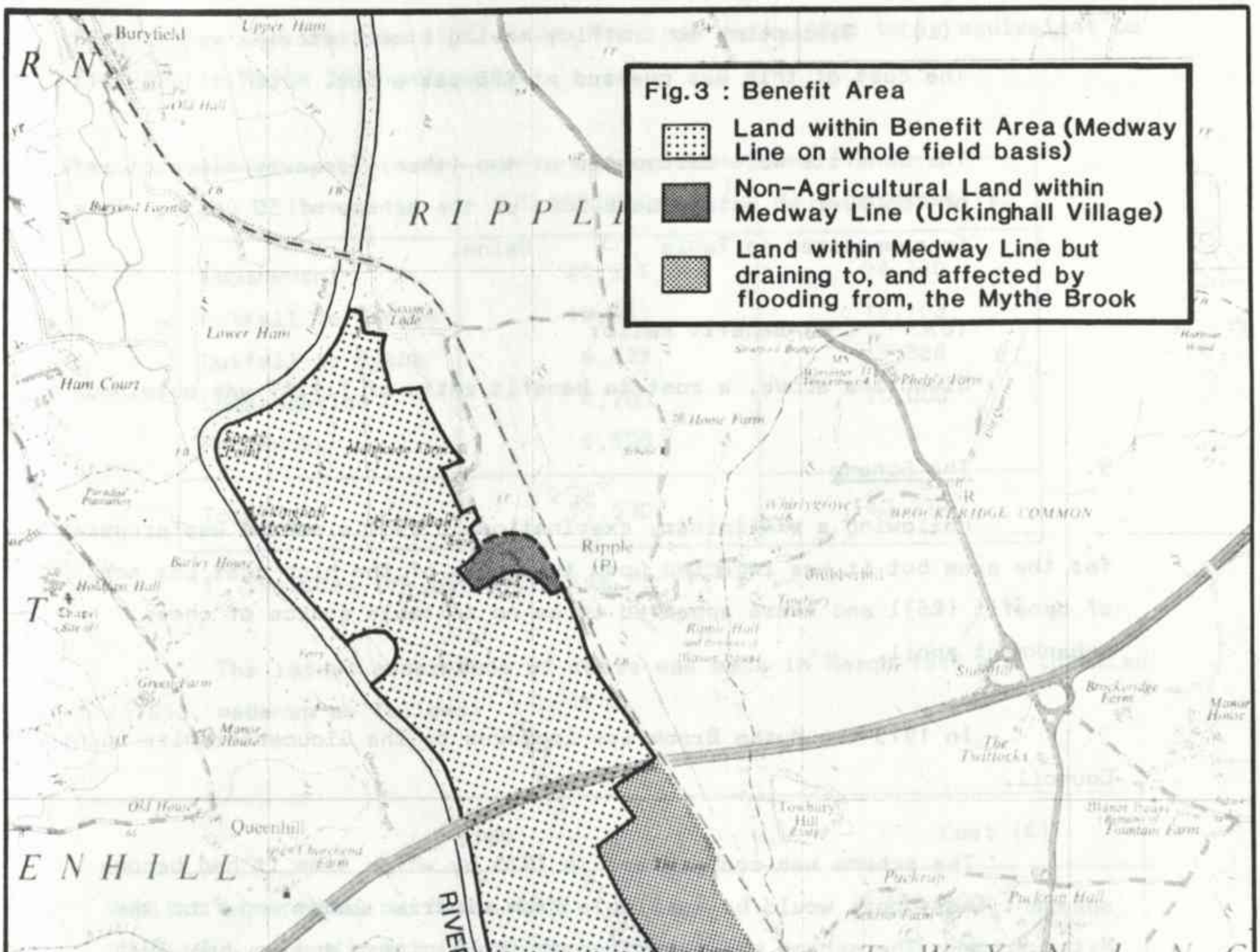
Fig.3 : Benefit Area
Land within Benefit Area (Medway Line on whole field basis)
Non-Agricultural Land within Medway Line (Uckinghall Village)
Land within Medway Line but draining to, and affected by flooding from, the Mythe Brook
RIVER SEVERN
Buryfield
Upper Ham
Lower Ham
Ham Court
Ripple
Queenhill
ENHILL
TWYNING
BUSHLEY
Bushley
Windmill Tump
Slades Green
The Twitlocks
Puckrup Hall
BROCKERIDGE COMMON

(iv) Disruption to traffic; moving stock, etc.:

The cost of this was guessed at £55 per annum.

The benefits were discounted at the (then) Treasury discount rate of 10% over an anticipated life of the scheme of 50 years. This is summarized in Table 3 below.

(c) Cost-Benefit Ratio:

Given the above, a cost to benefit ratio of 1:1.19 was obtained.

9. The Scheme

Following a preliminary examination in 1971 a scheme was prepared for the area but it was rejected upon the basis of the high cost per acre of benefit (£67) and there appeared to be no suitable source of cheap embankment spoil.

In 1973 the Mythe Brook was improved by the Gloucestershire County Council.

The scheme was reappraised in 1975 by which time it had become apparent that spoil would be available from riparian lands and from the Mythe Brook. The scheme was submitted to the Ministry and in July 1975 works commenced upon receipt of Ministry approval for the expenditure of £70,530.

Works progressed as per the original design. However there was a shortage of spoil in the upper part of the scheme and it was decided to enlarge the Brick Pit at Uckinghall Ferry. The owner of the land involved was not prepared to sell a small part and insisted on STWA purchasing the entire 11 acre block which they did in December 1977.

A further alteration was made to the original design when the proposed new outfalls were exchanged - the twin outfall being installed on the Ripple Brook and the single outfall onto the Severn - and some overexpenditure was incurred.

After allowing for overexpenditure and inflation the cost of the scheme was reassessed in February 1978 (see below) and the final cost estimated £140,339 after omitting the penstocks from the design. Using the

Cost of New Construction (CNC) index this was calculated to be equivalent to £101,956 in March 1975 prices.

Item	1975 estimate (£)[1]	1978 forecast (£)
Embankment	41,911	94,788
Outfall to Severn	10,847	16,163
Outfall to Mythe	6,472	19,388
Compensation	4,700	10,000
Penstocks	6,600	-
Total	70,530	140,339

1 includes 10% contingencies

The latest assessment of costs was made in March 1978 and totalled £146,653, made up as follows:

Item		Cost (£)
Capital expenditure to March 1978	113,800	
Committed expenditure to September 1978	19,060	
Works outstanding (fencing, seeding, etc.)	3,593	
Total Capital Expenditure		136,456
Compensation and land purchase to March 1978	19,200	
Compensation and land purchase to completion	2,000	
Less returns from sale of land[1]	-11,000	
Total Compensation and Land Purchase		10,200
Total Scheme Cost		£146,656

1 Todate the 4.45 ha purchased by STWA has not been resold. It has been let off for summer grazing or the hay has been sold each year. The scheme files cannot be closed until the sale is made.

On the basis of available information, the £136,456 has been apportioned over the 1975 to 1978 period and is equivalent to £276,820 in 1982 prices (using the PWWR index).

Table 3 : Summary of Benefits

Type of Benefit	Area Affected	Per Unit Benefit (£)	Total Annual Benefit (£)	Total Benefit (Discounted at 10% over 50 years (£))
Potential increase in agricultural production	315.7 ha	20/ha	6314	63,150
Reduction of summer flood damage to crops	160.0 ha	7.8/ha	1248	12,500
Reduction of damage to property	5 houses	136/house	680	6,800
Disruption to traffic	-	-	55	550
Total			8297	83,000 (March 1975)

Source: STWA, 1975

10. Farm Survey

Eight farmers were interviewed during June 1983 who between them farmed 243.5 ha within the Agricultural Benefit Area identified in Section 7. This accounts for 95% of the Agricultural Benefit Area. The occupiers of 13.3 ha (5%) were not interviewed. This area is largely gardens and paddocks behind houses in the village of Uckinghall and is not commercially farmed. All of the unsurveyed area is under permanent grass.

11. Agriculture in the Benefit Area

(a) Farm Type, Size and Tenure:

The data relating to farm type, size and tenure are summarized in Tables 4-7. Only one farm in the Benefit Area has a dairy herd; the others are mainly concerned with livestock rearing and fattening. There are two mixed farms that grow sugar beet and/or cereals on lighter ground outside the Benefit Area. Two of the farms were not classified according to the standard classification as they were only part-time business.

The average farm size is 70 hectares. One smallholding has only 10 hectares but all the others are within the range 40-120 ha. In terms of Standard Man Days three of the farms are classified as part-time smallholdings, being of less than 250 SMD. The mean is 267 SMD and most lie in the range 250-600 SMD.

Most of the farmers are owner-occupiers and all own at least a quarter of their land. Most of the land within the Benefit Areas is owner-occupied. There are two areas of common land within the Benefit Area (see Figure 4); Uckinghall Meadow (28 ha) is owned by four farmers and farmed by two, and part of Shuthonger Common (27 ha) is owned and farmed by two others. The 'common' status dictates the number of cattle that may be grazed and forbids ploughing of the land. Shuthonger Common has traditionally been cut for hay and then grazed after Lammas Day (historically the day when separate user rights ended and common grazing began).

The percentage of the farms surveyed that is within the Benefit Area varies from 6% to 100%. The mean is 48%.

Table 4 : Farm Type

Farm Type	No. of Farms	% of Benefit Area
Mainly dairy	1	11
Mostly cattle	1	11
Cattle & sheep	2	14
Mixed	2	51
No data[1]		13
Total		100

1 See Section 10 (a)

Table 5 : Farm Size (Hectares)

Farm Size (ha)	No. of Farms	% of Benefit Area
10- 20	1	4
20- 40	0	0
40- 50	1	9
50-100	4	39
100-200	2	43
No data		5
Total		100

Mean = 70.0 St. Dev = 35.3 (8 valid cases)

Table 6 : Farm Size (Standard Man Days)

Farm Size (SMD)	No. of Farms	% of Benefit Area
99	2	13
100-174	0	0
175-249	1	10
250-499	4	62
500-999	1	10
No data		5
Total		100

Mean = 267.4 St. Dev = 178.3 (8 valid cases)

Table 7 : Management and Tenure

Management Status	% of Farm Owned						Total
	0	1-25	25-50	50-75	75-99	100	
Sole Proprietor	-	-	1	-	2	4	7
Partnership	-	-	-	-	1	-	1
Total	-	-	1	-	3	4	8

(b) Dairy Enterprises:

Only one farmer accounting for 11% of the Benefit Area keeps a dairy herd. Less than half of the farm lies within the Benefit Area and most of this land is used for grass conservation and aftermath grazing. The average farm stocking rate is 1.84 Livestock Units per hectare of grass.

(c) Beef Enterprises:

One farm, accounting for 11% of the Benefit Area is classified as Livestock Rearing and Fattening ; Mostly cattle, but two others accounting for a further 14%, are classified as Cattle and Sheep. In all, six of the farms surveyed keep cattle for beef and herd size ranges from 10 to 115 head. There is no preference of system in the area; some finish stores, one has a suckler herd and others have mixed systems. In most cases the grassland is conserved as hay and the aftermath grazed. The single 'Mostly Cattle' farm has a very low stocking rate due to the large area given over to hay for sale. (0.43 Lu/ha)

(d) Sheep Enterprises:

Two of the farms, accounting for 14% of the Benefit Area keep sheep flocks of 200-250 ewes in addition to cattle. Both fatten lambs off grass. The average stocking rate for Livestock Rearing and Fattening:Cattle and Sheep farms is 0.93 Livestock Units per hectare of grass.

(e) Hay Enterprises:

Five of the farms, accounting for 71% of the Benefit Area cut hay for sale off the farm, and for three of them this is their sole agricultural activity within the Benefit Area. One is exclusively a hay merchant who buys hay from other farmers in the area. Yield averages 5-6.25 ton of baled hay per hectare.

(f) Arable Enterprises:

The dairy and mixed farms and the two unclassified farms grow some arable crops. In general winter wheat and spring barley are grown on the lighter Wick soils on higher ground outside of the Benefit Area. One farm also grows sugar beet. Only 10% of the land within the Benefit Area is today under arable use and that is on the edge of the area near Uckinghall.

12. The Effect of the Scheme on Flooding and Land Drainage

Following the scheme flooding has been alleviated on 194.9 ha (76% of the Benefit Area) and 35.2 ha (14%) were always flood free. There have been no major floods from the Severn since the scheme but minor flooding has been caused by backing up of internal drainage water when the flapped outfalls have been closed.

Two of the farmers interviewed have noticed a deterioration in the drainage status of their land following the scheme. Although flooding has been alleviated they believe that water levels in the internal ditches are now higher for longer and low patches in their fields are lying wet. The general neglect of the ditches may have exacerbated this problem.

On the part of Shuthonger Common within the Benefit Area flooding has increased following the scheme.

As part of the scheme the shallow ditch crossing the field was blocked at its junction with the Mythe Brook and its flow reversed so that it would drain via a pipe, 8" below the surface, to the Ripple Brook (see Figure 2).

It is apparent that the system has been unsuccessful and the duration of flooding within field 0040 has increased. In 1982/3 it was under water from 24th November to 21st February and again from 26th April to 7th June. Each time, when at its worst, 12 hectares were inundated. As the area occupies a large hollow, even after the flood level in the Mythe Brook has subsided the meadow cannot drain. In May/June 1983 water remained on the land for 40 days after the Mythe had subsided. Land levels at the centre of the field are only 1.35 m above the invert level at the Ripple Brook outfall which is 1 km away by channel. The occupier estimated his loss of hay to be worth £4,500 (3,000 bales from 12 ha).

Since the farm survey an old drain has been uncovered, draining into the Mythe Brook. This has been cleaned and flapped and the occupier has now dropped his claim for compensation (Ref. 7)

13. The Agricultural Benefits of the Scheme

(a) Land Use Change:

The land use data are summarized in Table 8 below.

Table 8 : Land Use Change 1975-83 (hectares)

Pre-scheme \ Post-scheme	Permanent grass	Grass/crop rotation	Crops	Woodland or unused	Total
Permanent grass	185.9	4.9	31.2	-	222.0
Grass/crop rotation	-	6.1	-	-	6.1
Crops	-	-	19.0	-	19.0
Woodland or unused	-	-	-	9.7	9.7
Total	185.9	11.0	50.2	9.7	256.8

Most of the area has remained under permanent grassland. 36.1 ha (16% of the grassland) has been ploughed and is under cereals or in a rotation. 25.1 ha of this had not taken place at the time of the survey but was due for drainage in the summer of 1983, followed by ploughing and seeding with barley for at least two years. After that it may be resown with grass. The other 11 ha were ploughed at various times since the scheme and the change to arable was effected without field drainage. About 5 ha of this is due to be resown with grass in the near future.

(b) Field Drainage Installation:

At the time of the farm survey none of the Benefit Area had been underdrained following the scheme. One farmer had planned a scheme for the summer of 1983 for 25.1 ha and the pipes were already on site. The remaining 231.7 ha (or 90% of the Benefit Area) are without effective field drainage and only 14.6 ha of this was considered to be naturally free draining (on the lighter soils). The reasons why the remaining 84% of the Benefit Area has not been drained are summarized below.

Table 9 : Reasons for Not Draining

Reason	Area (ha)	% of Benefit Area
Insufficient outfall	111.7	43
Requires cooperation with neighbours to improve ditches	48.4	19
Not worth the money	9.3	4
Floods too often[1]	26.7	10
Ozier beds	7.7	3
Land for sale by STWA	3.6	1
No data	9.7	4
Total	217.1	84

1 See 12 above.

(c) Improved Production from Existing Land Use:

Largely because of problems of deteriorating field drainage (see Section 12) few of the farmers have perceived any improvement in the productivity of their land. The reduced occurrence of winter flooding has extended grazing seasons by up to four months in some areas and sheep can now graze all year. One farmer noted that he can now get on the land to fertilize earlier in spring.

(d) The Rate of Benefit Uptake:

A financial assessment of the Ripple scheme has been undertaken by identifying, on the basis of farmer interview, the change in farm enterprise gross margins attributable to drainage improvements, net of any additional fixed costs, and including the benefit of extended grazing if relevant. The procedures used for this purpose are described in Annexe V.

A summary of benefits (before field drainage costs) by farm in the benefit area is given in Table 10. Six out of eight farmers reported benefits. One farmer reported disbenefits due to deteriorating drainage conditions that required additional fertiliser to maintain yields. One farmer accounted for over 50% of total benefits.

The rate of uptake of financial net returns attributable to the scheme is shown in Figure 4. Over the 243.5 hectare agricultural benefit area, the average increase in net return todate has been £22 per hectare, an average of £44 per hectare for those areas where some measure of benefit was recorded.

Figure 5 expresses actual takeup as a percentage of scheme potential which is taken to be a reasonably achieveable target for post-scheme land use, and based largely on land capability and local farming practice. On 90% of the benefit areas, the silty clays are best suited to permanent grassland with target fertilizer application at about 150 kg N/ha for dairy and followers. Under present conditions stocking rates are constrained by poaching liability. The remaining sandy loams of the higher ground are suited to most arable crops. Yields of wheat and sugar beet in excess of 7 tonnes and 50 tonnes per hectare respectively have been obtained on these areas.

According to Figure 5, actual gross margins reached 10% potential by 1983/84. This relative measure of uptake requires careful interpretation as discussed in Annexe IX section 4.4.

14. FINANCIAL ANALYSIS

A summary of the cash flow of the Ripple scheme is contained in Table 11, expressed in 1982 prices.

(a) Net Agricultural Benefits:

The net agricultural benefits attributable to the scheme are the extra net returns per hectare shown in Figure 4, applied to the whole agricultural benefit area of 243.5 hectares. Uptake is assumed to remain at 1984 levels for the remainder of project life. The sensitivity of the scheme to this assumption is considered in 14.g.

FIGURE 4 : Degree and Rate of Financial Uptake

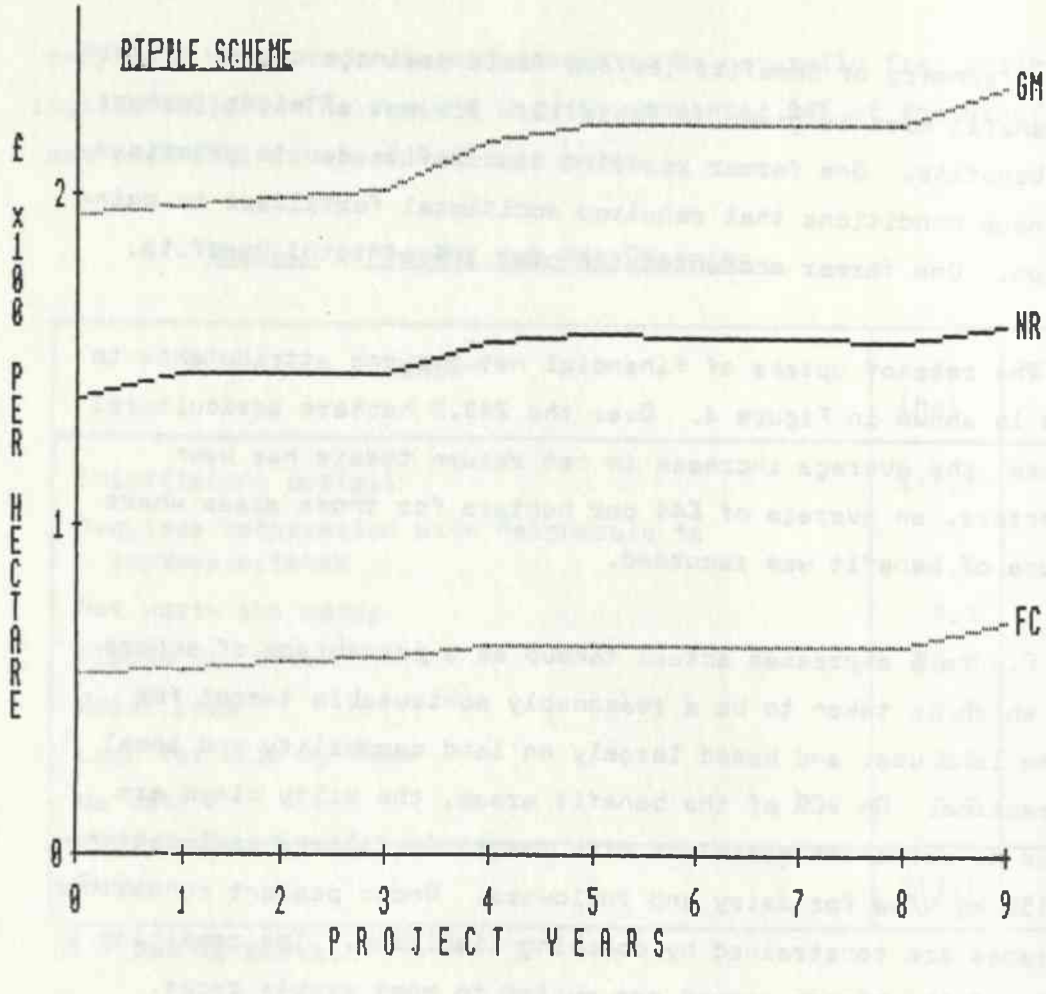

FIGURE 5 : Uptake as a Percentage of Potential

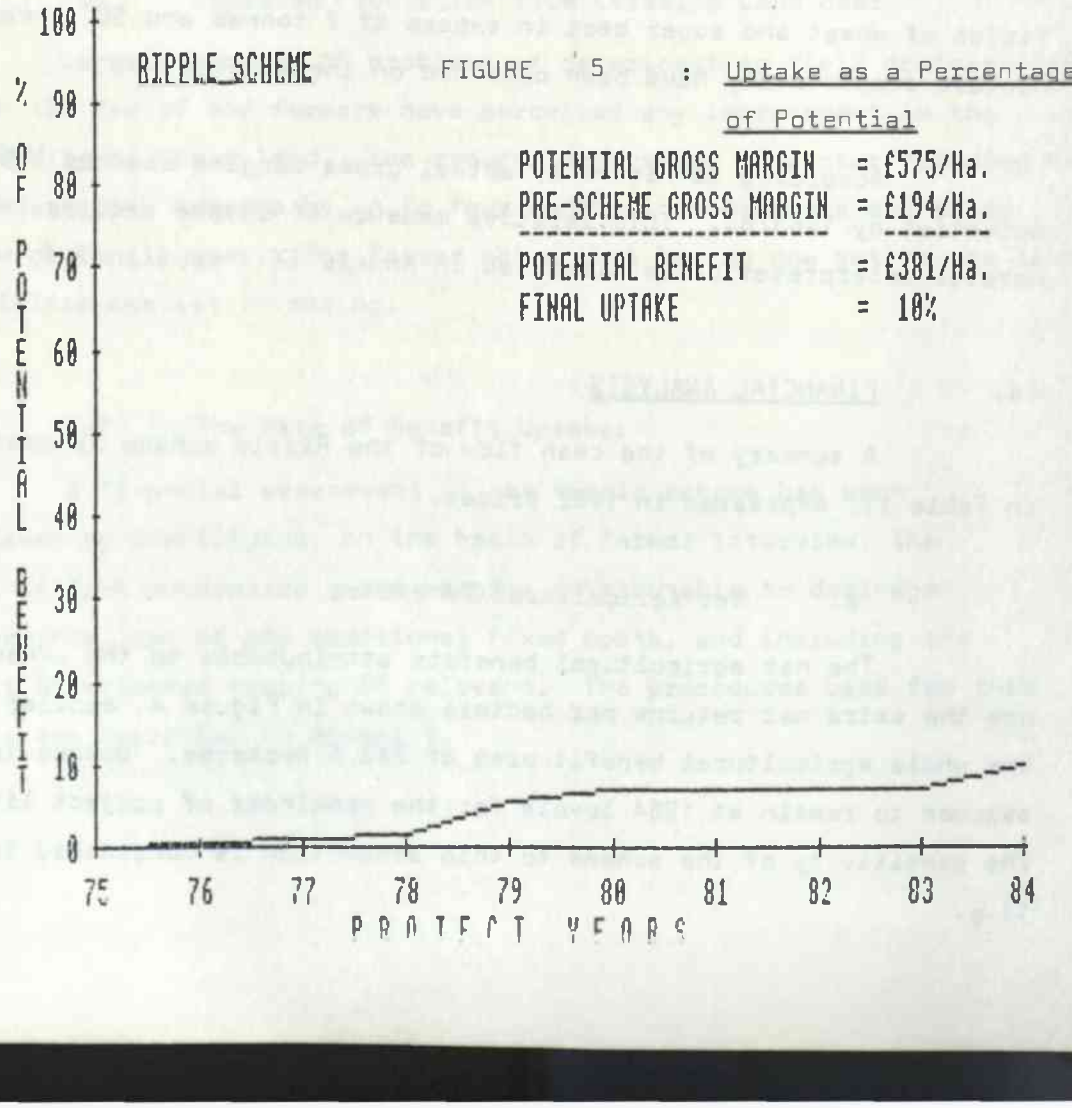

Table 10 : Distribution of Benefits by Farm

SCHEME 71 NET AGRICULTURAL BENEFIT

FARM CODE	YEAR FIRST	YEAR 3	YEAR 7	YEAR LAST	% OF BENEFITS	% OF AREA
1	657	723	857	857	16	10
2	155	155	1201	277	5	4
3	0	0	0	0	0	9
4	-7	-13	-39	-52	-1	1
5	-237	-473	1020	548	10	33
6	574	574	574	574	11	18
7	284	284	284	284	5	11
8	332	434	639	2813	53	13
TOTAL				5302	100	243

(b) Capital and Recurrent Cost:

The capital cost of the scheme averaged £1,137 per hectare of agricultural benefit. Incremental costs have been assumed at 1½% of gross capital costs per year.

(c) Field Drainage Costs:

The total cost of field drainage installations was £13,640 in 1982 prices, an average of £543 per hectare drained, and equivalent to an overall average expenditure of £56 per hectare in the benefit area. No incremental field drainage maintenance costs have been assumed.

(d) Without-Project Benefits:

It is assumed that without-project improvements in the financial performance of farming would be equivalent to an annual increase of 1% compound of pre-scheme net revenues. This has been levied on those areas for which some post-scheme benefit uptake has been ascertained in the case of the Ripple, the without-project returns are charged at 1% compound of 38.9% of the pre-scheme returns, ie. £34,576 × .389 × 1% compound.

Table 11 : Summary of Scheme Costs and NPV

RIVER SEVERN RIPPLE										
PROJECT YEAR	0	1	2	3	4	5	6	7	8	9 TO 30
CALENDAR YEAR	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984 TO 2005
AGRICULTURAL BENEFITS										
Net Agric Benefits	0	1760	1688	1614	4067	4780	4538	4295	4053	5303
Flood Damage Reduction	0	4905	4905	4905	4905	4905	4905	4905	4905	4905
less Without Proj Ben	0	135	270	408	546	686	827	970	1114	1260
less Field Drain Cost	0	0	0	0	0	0	0	0	13640	0
NET AGRIC CASH FLOW	0	6531	6323	6111	8426	8999	8616	8230	-5796	8948
SCHEME COSTS										
Capital	65566	125430	34706	47950	0	0	0	0	0	0
Recurrent	0	0	0	0	4152	4152	4152	4152	4152	4152
TOTAL COSTS	65566	125430	34706	47950	4152	4152	4152	4152	4152	4152
SCHEME NET CASH FLOW	-65566	-118900	-28383	-41839	4274	4847	4464	4078	-9948	4796
NET PRESENT VALUE AT %	0	2.5	5	7.5	10	12.5	15	17.5	20	
	-141463	-169921	-182050	-185591	-184566	-181122	-176431	-171147	-165640	

(e) Flood Damage Reduction:

Pre-scheme, according to farmers, summer floods occurring at an estimated one in 15 year return period destroy the hay crop on 110 hectares, resulting in an equivalent annual cost of £2,750. All farmers except one, reported the need to repair fences, and clean up debris which involved about £760 per year before the scheme, although a number still required to undertake such tasks in the event of post-scheme winter flooding. Due to internal drainage problems 12 hectares of hay were lost in 1982/3 at an estimated cost of £4,500. The cause has been remedied under the scheme's maintenance schedule. This event however is equivalent to an average £150 per year cost over the scheme's life. The overall estimated reduction in agricultural flood damage costs is put at £3,360. An additional £1,545 of urban flood alleviation benefits was identified at initial scheme proposal making a total saving of £4,905 per year. This figure is consistant with the pre-scheme estimate (See 8.b).

(f) Project Worthwhileness:

Assuming benefits continue at their 1984 levels over a project life of 30 years, the net present value of the Ripple scheme at the 5% discount rate is -£182,050, resulting in a negative internal rate of return of -3.9%. Agricultural benefits would need to be 3.75 times higher to break even at the 5% discount rate, or 4.5 higher than present levels over the remainder of project life.

Using the statistically derived aggregate uptake came to predict uptake over remaining project life, benefits would peak in year 13 at 1.46 times their observed year (1983) level, resulting in a net present value of -£167,500 and a negative internal rate of return of -1.9%.

(g) Sensitivity Analysis:

Table 12 examines the sensitivity of the scheme to changes in cost and benefit parameters. At present levels of performance, the scheme is not likely to recover any significant part of capital costs at the 5% discount rate.

TABLE 12

River Severn : Saxon's Lode to Mythe Hook - Sensitivity Analysis

Run No.	Agricultural Benefits Factor	Without Project Benefits Compounding Factor	Flood Damage Reduction Factor	Capital Works Cost Factor	NPV at 5% £	IRR %	Switching Value*
1	1.0	1	1	1	-182050	-3.9	3.75
2	1.0	0	1	1	-167765	-ve	3.5
3	1.0	1	0	1	-253861	-ve	4.7
4	1.0	1	1	0	-5835	4.0	1.1
5[a]	1.0	1	1	1	-132032	-ve	3.0

The factors show the weights applied to the original estimates eg a factor of 1.5 for the without-project benefits indicates that the new value is 1.5 x 1% compound per year (the original value) ie 1.5% compound.

* Switching value : change in agricultural net benefits needed to make the project breakeven at 5% discount rate eg a 1.5 switch value shows an increase of 1.5 x the original estimated is required.

a. excluding maintenance costs

15. Environmental Aspects

There are three sites within the Benefit Area that were recognised by the Nature Conservancy Council as being of conservation importance (Ref. 6) (see Figure 6).

(a) Uckinghall Meadow (28 ha):

This is a registered common with four commoners and was described by NCC (op cit) as a 'large ham meadow with a rich flora'. Today it is farmed by two local farmers who cut the hay and then graze it. Prior to the scheme little fertilizer was used, as it was felt that the floods provided enough 'natural' fertilizer. Today nitrogen is applied at a rate of 55-88 kg/ha, either as 'straights' or compound.

(b) Meadow OS 9452 (6 ha):

This was described by NCC (op cit) as an 'unimproved meadow with a rich flora'. It was cropped for hay and then grazed in the traditional manner with no nitrogen fertilizer applied. In recent years it has been ploughed and it is now under continuous winter wheat.

(c) Ripple Lake and the Knapps (10 ha):

An old clay pit and willow wood occupying the lowest part of the Benefit Area. At one time cropped for oziers it is now managed by a syndicate for shooting.

16. Discussion

The main effect of the scheme has been to eliminate, or at least substantially reduce the risk of flooding from the River Severn and the Mythe Brook and hence reduce the damage caused by floods and allow animals to be grazed for longer in autumn. The farmers have appreciated these automatic benefits. The improvement potential presented by the scheme was limited by the condition of the internal drainage system. The new outfall structures have prevented back flooding at times when the Severn or Mythe are high but have made no difference to the outfall facility for field drainage nor the frequency of occurrence of minor floods.

Only one farmer has been able to install underdrainage since the scheme. This is at the lower end of the Ripple Brook near the confluence with the Mythe Brook where the outfall facility is slightly deeper than elsewhere. Shallow (0.75 m) closely spaced (7 m) drains had to be used because of the restrictions on the outfall. In the main there is insufficient outfall for underdrainage, and many farmers see that the only way to improve the land would be by improving the arterial ditches and installing a pump on the Ripple Brook at its outfall. Although this is technically feasible it would require the cooperation of all the farmers of the area which under present conditions is unlikely.

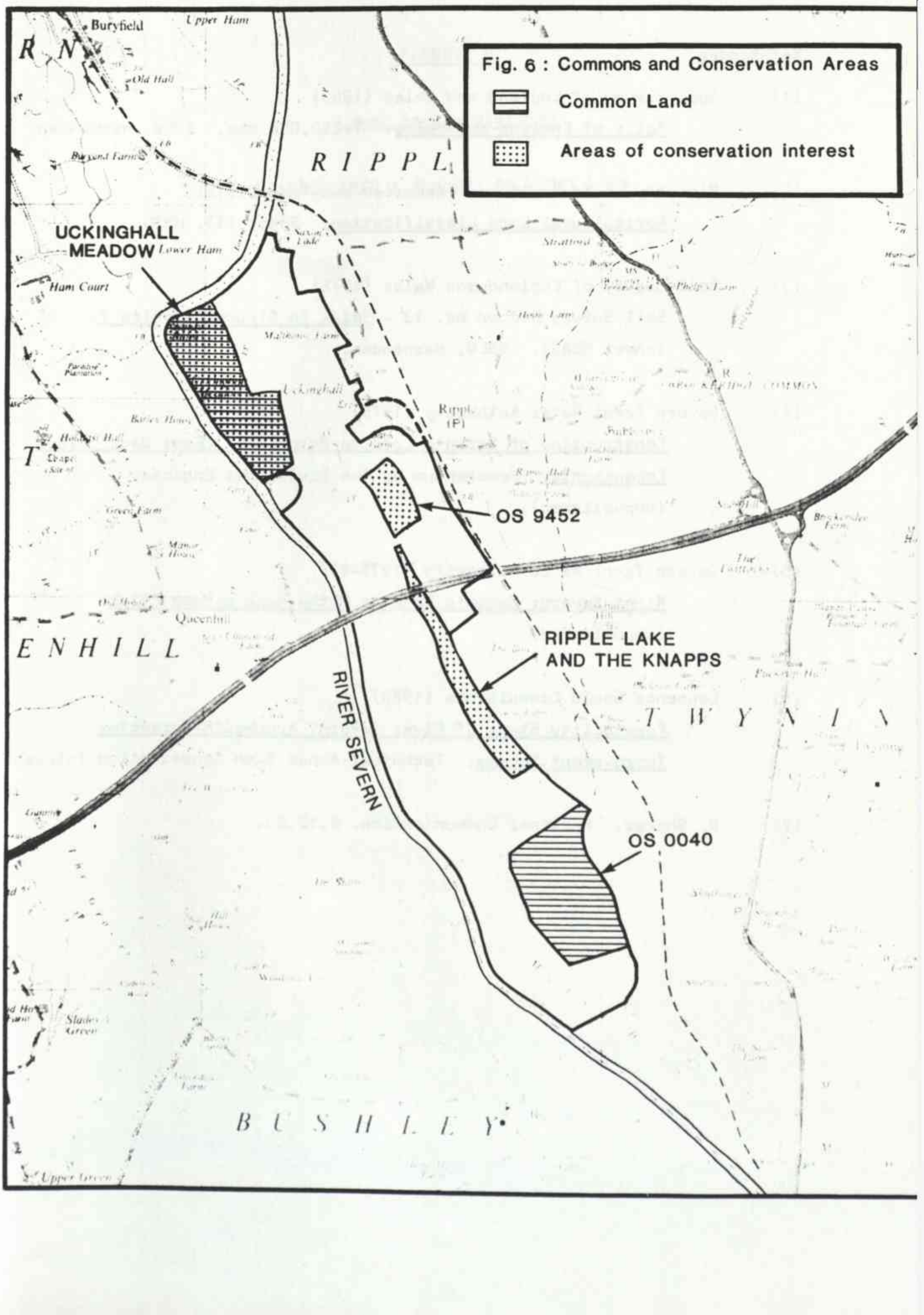
Fig. 6 : Commons and Conservation Areas
Common Land
Areas of conservation interest
UCKINGHALL MEADOW
OS 9452
RIPPLE LAKE AND THE KNAPPS
OS 0040
RIVER SEVERN
RIPPL
ENHILL
TWYNIN
BUSHLEY
Buryfield
Upper Ham
Old Hall
Lower Ham
Ham Court
Uckinghall
Ripple (P)
Queenhill
Slades Green
Upper Green

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Soils of England and Wales. 1:250,000 map. SSEW, Harpenden.

(2) Ministry of Agriculture, Fisheries and Food (1972)
Agricultural Land Classification, Sheet 143, HMSO

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(4) Severn Trent Water Authority (1975)
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(5) Severn Trent Water Authority (1975-83)
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APPENDIX N

Lower Severn Division

River Severn : Bushley to Upper Lode

SILSOE COLLEGE

STWA LOWER SEVERN DIVISION - RIVER SEVERN:
BUSHLEY TO UPPER LODE

Report on the background to, and development of the scheme and the nature and rate of uptake of agricultural benefits.

1. Physical Background

The Bushley scheme was one of a series of similar schemes that were carried out between 1962-75 on the reach of the River Severn between Worcester and Tewkesbury. The area affected is on the right bank of the Severn in the County of Hereford and Worcestershire, near Tewkesbury (Glos.). In this reach, the River Severn meanders through a floodplain approximately 1 km wide and over the years natural deposition from the river has built up considerable levees such that the land levels slope away from the river; the lowest points being in hollows abutting the higher ground of the bluffs.

The present scheme relates to a discrete area of 135 ha bound on three sides by a loop of the river that ties into higher ground at up- and down-stream ends. The whole area lies at an elevation of less than 15 m AOD(N).

2. Soils and Land Capability

There is no detailed soil survey of the area but the National Soils Map (Ref. 1) classifies the soil as being a typical alluvial gley of the Hollington association. A comparison with similar floodplain areas south of Tewkesbury (Ref. 2) and the Agricultural Land Classification (Ref. 3) suggest the area may be divided into three facets as follows (see Figure 1):

(1) Levees of the Severn:

Characterized by a gleyed brown warp (alluvial) soil of the Tewkesbury series (silty phase) with a silty clay loam texture. When the Severn floods water runs from the banks at about 10.75 m AOD(N) towards the lower ground behind thus flooding is a moderate limitation on land use. Classified as grade 3, high watertable, surface wetness and cultivation difficulties also present moderate limitations. Best suited to permanent grass for grazing prior to the scheme.

(2) Low ground behind the levees extending to the edge of the floodplain:

Characterized by Compton series soils with a silty clay or clay texture. The land was poorly drained due to a high groundwater table from November to April and has a slowly permeable profile. Short term seasonal flooding posed a moderate limitation to use and high watertable, surface wetness and cultivation difficulties were severe such that the land was classified as grade 4. The lowest parts are at about 9.0 m AOD(N). Best suited to permanent grass for hay and summer grazing prior to the scheme.

(3) Higher ground at the edge of the floodplain:

Characterized by stagnogleyic argillic brown earths of the Worcester series with silty clay or silty clay loam texture. They are moderately well drained. Such soils have moderate surface wetness and cultivation difficulties and are classified as grade 3; being suitable for an arable rotation. The land rises at a gradient of about 1 in 30 from the low ground to the road that forms the boundary of the area.

3. Land Drainage History

It is evident that prior to the present scheme there were minor floodbanks along the right hand bank of the Severn throughout the reach from Bushley to Upper Lode tying in to high ground at either end. However, upstream of Mythe Bridge the floodbank was indistinguishable from the top of the river bank, and in 1955 it was noted (Ref. 4) that the floodbank downstream of Mythe Bridge was breached in four places. At this time the floodbanks and the wooden flapped outfalls, which were in a poor state of repair, belonged to the Forthampton Estates although the land behind had been sold off some years previously. It was therefore unlikely that the Estate would attend to the upkeep of the banks and gates.

In 1956 the floodbanks were taken over by the Severn River Board and improvements were made to the floodbanks and outfall structures at a cost of £550. A new outfall was constructed at the upstream end and breaches in the banks were repaired. No further works were carried out during the 1960's.

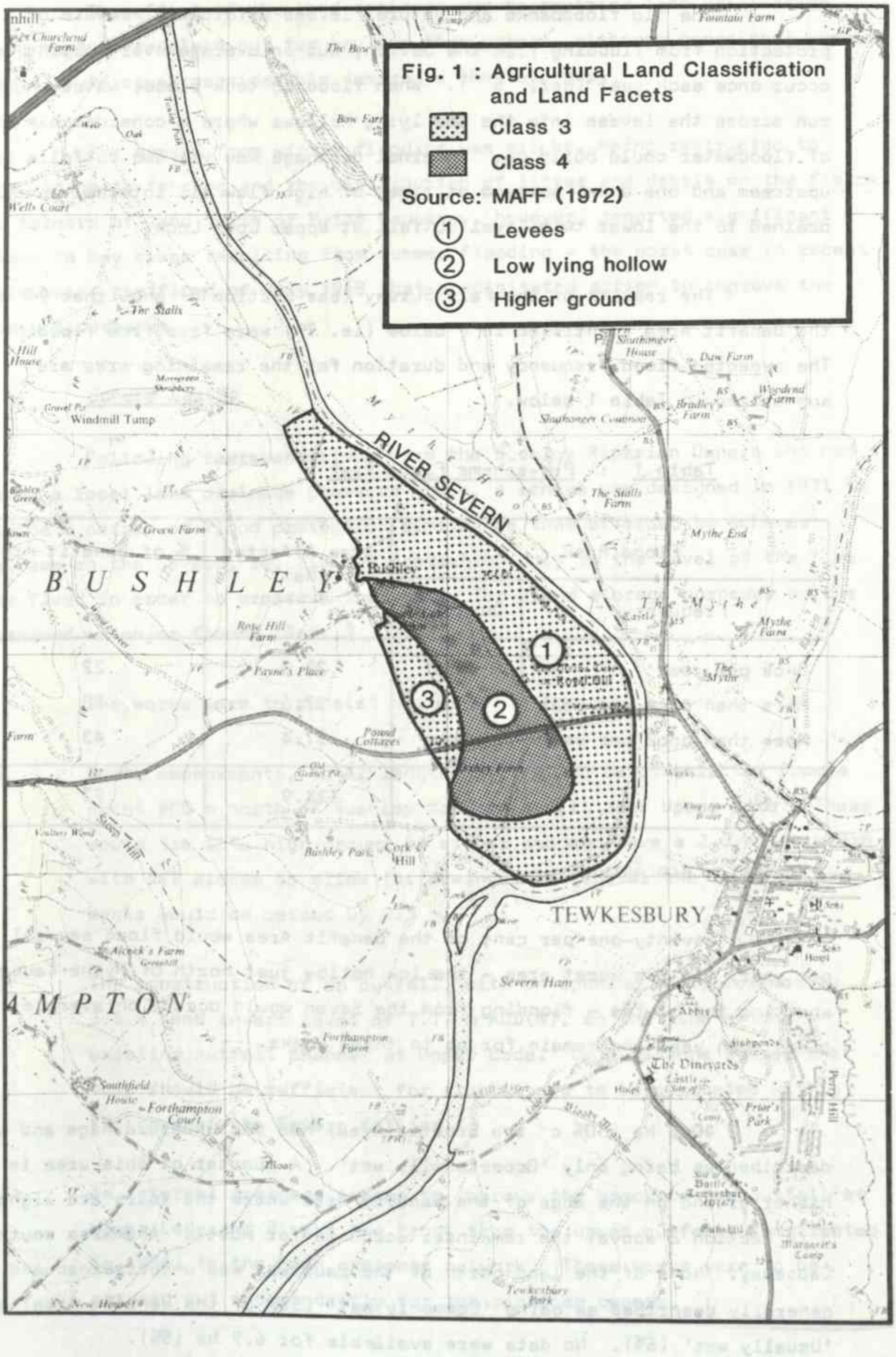


Fig. 1 : Agricultural Land Classification and Land Facets

4. Pre-Scheme Land Drainage Status

The old floodbanks and natural levees afforded a measure of protection from flooding from the Severn, but on average over-topping would occur once each year (Ref. 5). When flooding took place, water would run across the levees into the low lying hollows where a considerable depth of floodwater could build up. Internal drainage was via two outfalls one upstream and one down, however at times of high flow all internal water drained to the lower twin-level outfall at Upper Lode Lock.

The results of the Farm Survey (see Section 10) show that 9·7 ha of the Benefit Area identified in 7 below (ie. 7%) were free from flooding. The expected flood frequency and duration for the remaining area are summarized in Table 1 below.

Table 1 : Pre-scheme Flood Risk

Flood Risk		Area Affected (ha)	% of Benefit Area
Frequency	Duration		
Once per year	Days	29.9	22
More than once per year	Days	37.6	28
More than once per year	Weeks	57.4	43
Total		124.9	93

Source: Farm Survey

Seventy-one per cent of the Benefit Area would flood several times per year. In the worst area - the low hollow just north of Mythe Causeway abutting the bluffs - flooding from the Seven would occur, on average, three times each year and remain for up to three weeks.

40.8 ha (30% of the Benefit Area) had old underdrainage and was described as being only 'Occasionally wet'. A quarter of this area is on the higher ground on the edge of the Benefit Area where the soils are lighter (area 3 in Section 2 above) the remainder accounts for most of the area south of Mythe Causeway. None of the land north of the Causeway was underdrained and it was generally described as being 'Commonly wet' (58% of the Benefit Area) or 'Usually wet' (6%). No data were available for 6.9 ha (5%).

5. The Impact of Pre-Scheme Drainage Status on Land Utilization

The effect of the land drainage was to restrict land utilization to permanent grassland cut for hay and then grazed, although occasional summer floods would cause considerable damage to the hay crop.

The damage from winter flooding was slight, being restricted to some damage to fencing and the distribution of litter and debris on the fields. All farmers of land north of Mythe Causeway, however, reported significant damage to hay crops resulting from summer flooding - the worst case in recent years being the flood of July 1968 that precipitated action to improve the Severn floodbanks.

6. Scheme Design

Following representations from the Bushley Riparian Owners who had formed a local land drainage pressure group, a scheme was designed in 1971 to provide a degree of flood protection similar to that afforded by schemes upstream on the Severn, ie. limited protection only to the level of the five year flood in order to preserve the valley for flood storage purposes on the occasions of major floods (Ref. 5).

The works were to consist of:

(a) Earth embankments, total length 3.62 km, to be constructed from a point 800 m north of Bushley to Cork's Hill near Upper Lode. These would tie into high ground at either end and have a 2.5 m top width with 5:1 slopes to allow for mowing. In general the level of the banks would be raised by 0.5 m.

(b) The construction of an outfall, with an opening of approximately 3.5 m^2 and invert level of 7.17 m AOD(N), on the line of the existing outfall channel at Upper Lode. Calculations showed that this should be sufficient for floodwaters to be evacuated within 15 hours of the Severn falling.

(c) An internal drainage scheme to improve the brook to the outfall at Upper Lode and divert the brook from the upper outfall (constructed in 1956) to the main drainage network. These works were to be carried out independently for the riparian owners.

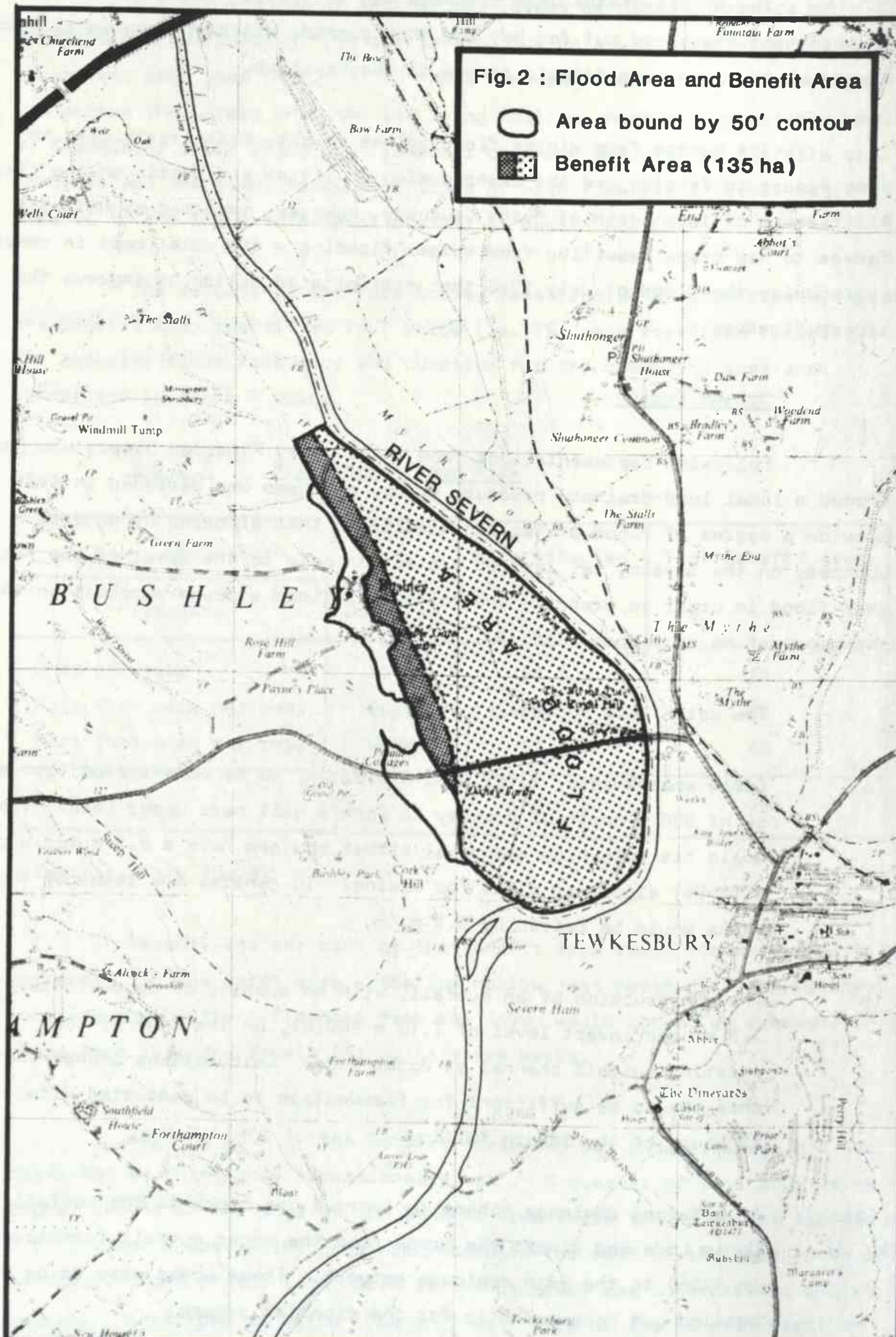


Fig. 2 : Flood Area and Benefit Area

7. Benefit Area

The flood area was estimated at 142 ha and a benefit area of 167 ha was identified in the Engineer's Report (ref. 5), bound by the river and the 15.25 m (10') contour (Figure 2). For the purposes of the farm survey (see 9) the village of Bushley was excluded as was the area between the floodbank and the river (with an average berm of 26 m this amounts to 8 ha), giving an agricultural benefit area of 135 ha.

8. Predicted Costs and Benefits

(a) Costs:
The original cost estimate of £19,000 was made up as follows (excluding internal drainage works):

Table 2 : Cost Estimate (January 1971)

Item	Cost (£)
Embankment works	11,745
Outfall structure	5,403
Contingencies (10%)	1,852
	19,000

(b) Benefits:
The Engineer's Report contained no assessment of benefits, however it was anticipated that considerable areas of grassland would be converted to arable after the scheme as had happened in similar schemes upstream (Ref. 5). The cost per unit area of benefit was admitted to be high, but it was believed that the scheme would allow a much more intensive utilization of the highly fertile land behind the floodbanks leading to greatly increased productivity (ibid).

9. The Scheme

MAFF approval in principle was granted in April 1971 upon the condition that the farmers agree to the new ditching scheme and formal approval was given in October 1971. Works by the Authority were completed by August 1974 but grant was withheld pending completion of the internal drainage works which were held up due to difficulties with one particular farmer.

The final statement of account dated November 1977 amounted to £20,733, an over expenditure of £1,733 after additional works totalling £2,831 and savings totalling £1,098. This over expenditure was approved by MAFF.

Since 1977, the upstream outfall has been re-opened because of the internal flooding problems caused by the excess water.

10. Farm Survey

Seven farmers were interviewed during June 1983 who between them farmed 134.6 ha within the Benefit Area. This accounts for 100% of the agricultural land within the Benefit Area identified in Section 6 above. None of the farms have changed ownership since the scheme but in three cases the management has changed. This has generally been from father to son, but in one case a neighbouring farmer, also with land in the Benefit Area, has entered into a partnership and taken over the management of the farm.

11. Agriculture in the Benefit Area

(a) Farm Type, Size and Tenure:

The data relating to farm type, size and tenure are summarized in Tables 3-6 below. The largest proportion of the Benefit Area belongs to a 'Mainly Cereals' farm and accounts for 41% of the area. A mainly dairy farm accounts for a further 23%. There are three Livestock rearing and fattening: Mostly cattle farms but between them they account for 24% of the Benefit Area. There is one Mixed farm accounting for 6%. It was not possible to classify one farm - accounting for the remaining 6% of the area - according to the standard classification as all the farm is under grass for hay and the farm is only a part-time business.

Three of the farms, covering 13% of the Benefit Area are less than 30 ha in size and have Standard Man Day requirements of less than 250. These are therefore classified as part-time businesses. The remaining 87% of the Benefit Area is occupied by four farms ranging from 40-230 hectares in size with SMD requirements ranging from 250-1700. The mean farm size is 81.7 ha and 473 SMD although in each case the standard deviation is at least as high as the mean.

Five of the 7 farms are wholly owned and are farmed by sole proprietors or family partnerships. The remaining 2 farms (accounting for 64% of the Benefit Area) are largely tenanted although in each case 15-20% of the total farmland is owned.

The percentage of each farm within the Benefit Area ranges from 9 to 49% with a mean of 27% (St. Dev. 16%).

Table 3 : Farm Type

Farm Type	No. of Farms	% of Benefit Area
Mainly Dairy	1	23
Mostly Cattle	3	24
Mostly Cereals	1	41
Mixed	1	6
No Data	1	6
Total	7	100

Table 4 : Farm Size (hectares)

Size Group (ha)	No. of Farms	% of Benefit Area
10- 20	1	5
20- 30	2	8
30- 40	-	-
40- 50	1	17
50-100	1	6
100-200	1	23
200-300	1	41
Total	7	100

Mean = 81.7 ha St. Dev. = 80 ha

Table 5 : Farm Size (Standard Man Days)

Size Group (SMD)	No. of Farms	% of Benefit Area
99	2	11
100- 174	1	1
175- 249	-	-
250- 499	2	24
500- 999	1	41
1000-1499	-	-
1500-1999	1	23
Total	7	100

Mean = 473 SMD St. Dev. = 574 SMD

Table 6 : Management and Tenure

Management Status	% of Farm Owned						Total
	0	1-25	25-50	50-75	75-99	100	
Sole proprietor	-	-	-	-	-	3	3
Partnership	-	2	-	-	-	2	4
Total	-	2	-	-	-	5	7

(b) Dairy Enterprises:

One farm, accounting for 23% of the Benefit Area, has a dairy herd but only 19% of the farm land lies within the Benefit Area and this is not used for dairy stock. Two other farms in the Benefit Area used to have dairy herds at the time of the scheme but left dairying under MAFF schemes. In one case this was only possible because of the scheme. The average stocking rate on dairy farms is 236 LU/ha[1].

(c) Beef Enterprises:

Five of the farms keep cattle for beef production and herd size ranges from 10 to 130 head. One farm fattens month old calves and one has a suckler herd. The others fatten store cattle and finish them on grass or winter rations. The average stocking rate on 'Livestock rearing and fattening: Mostly cattle' farms is 2.01 Livestock Units per hectare of grass[1]..

(d) Sheep Enterprises:

Two of the farms graze sheep. One has a 600 ewe flock that is fed on aftermath grazing, the other lets the new leys off for 3 months to a neighbour who has sheep prior to turning out his own cattle.

(e) Arable Enterprises:

Four farms have arable enterprises within the Benefit Area (a fifth has arable land elsewhere on the farm). One of the four is classified as 'Mostly cereals' and another as 'Mixed'. In some cases winter wheat is grown continuously and in others a rotation of wheat, barley and grass is followed. Yields average 5-7 t/ha of winter wheat.

1 Weighted by area in benefit.

12. The Effect of the Scheme on Flooding and Land Drainage

9.7 ha or 7% of the Benefit Area were free from flood risk before the scheme. Of the remaining area the frequency of flooding has been reduced on 119.6 ha (89%) of the Benefit Area . The area has only flooded once from the River Severn since the scheme and this was in the winter of 1981/82. The calculated return period of this flood was about 1 in 8 years and in excess of the design return period (Ref. 6). The entire Benefit Area was inundated apart from the higher land adjacent to the river and some winter sown cereals were lost.

In the lowest part of the Benefit Area on a block of 5.3 ha (4% of the Benefit Area) the expected frequency and duration of flooding has increased. The source of the floodwater is the internal brook flowing to the outfall at Upper Lode. When the level of the Severn is high the outfall flap is shut and internal drainage water backs-up in the brook and spills over into the hollow - lying only 2 m above the invert level at Upper Lode - just north of Mythe Causeway. This can flood up to 8 times per year. The reason for the increase in flood frequency is unclear but the farmer concerned believes that the river levels in the Severn are higher for longer than they used to be. A small area adjacent to the brook has been dug as a pond and turned over to conservation.

13. The Agricultural Benefits of the Scheme

(a) Land-Use Change:

The pre- and post- scheme land use data are summarized in Table 7 below.

Table 7 : Land Use Change 1972-83 (hectares)

Pre-scheme \ Post-scheme	Permanent grass	Grass/Crop rotation	Continuous crops	Pre-Scheme Total
Permanent grass	39.6	33.5	55.4	128.5
Grass/crop rotation	-	6.1	-	6.1
Post-Scheme Total	39.6	39.6	55.4	134.6

Prior to the scheme 95% of the Benefit Area was under permanent grass used for the grazing of dairy or beef cattle and sheep. One field, equal to 5% of the Benefit Area was in a spring barley/grass ley rotation. This was on the silty clay loam soil of the levees adjacent to the river.

The major change since the scheme has been the ploughing of 70% of the permanent pasture and its subsequent arable use. Two thirds of this is now under continuous winter cereals and one third in a rotation of winter cereals and grass ley. In some parts a break crop of beans or oil seed rape is included in the rotation. In general the change of land use has been associated with drainage, however 14 ha have changed from permanent grass to continuous cereals on undrained land.

With the exception of 8.1 ha in an arable rotation the area south of the Mythe Causeway has remained under permanent grass and this accounts for nearly all of the permanent grass within the Benefit Area. The rate of change of land use is shown in Figure 3.

(b) Field Drainage Installation:

Table 8 : Drainage Installation and Land Use Change

Date of Drainage	Area (ha)	Land Use		
		Pre-scheme	Post-scheme	Date of change
1972	8	P. Grass	Cont. Cereals	1974
1972	2	P. Grass	P. Grass	-
1974	21	P. Grass	Cont. Cereals	1975
1974	5	P. Grass	Cont. Cereals	1975
1976	3	P. Grass	Rotation	1982
1976	5	P. Grass	Rotation	1982
1979	3	P. Grass	Rotation	1972
1979	6	Rotation	Rotation	-
1979	4	P. Grass	Rotation	1979
1979	2	P. Grass	Rotation	1979
1979	7	P. Grass	Cont. Cereals	1977

Fig 3 : LANDUSE CHANGE

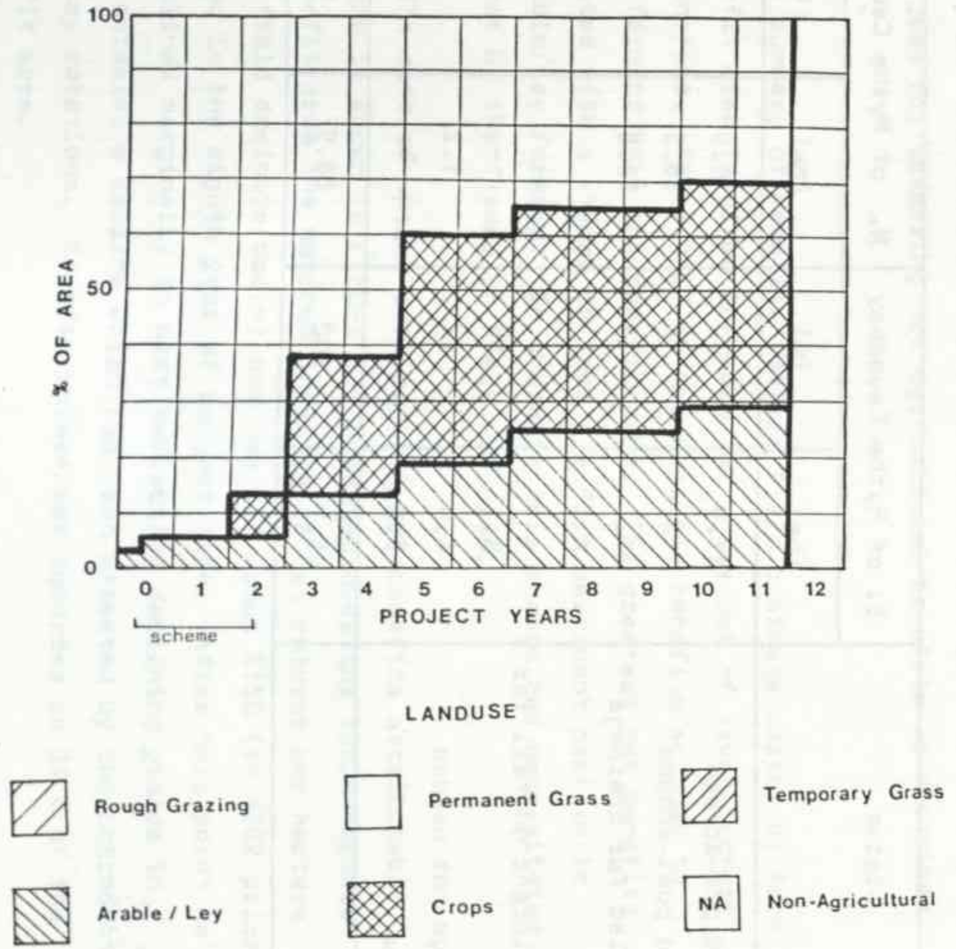
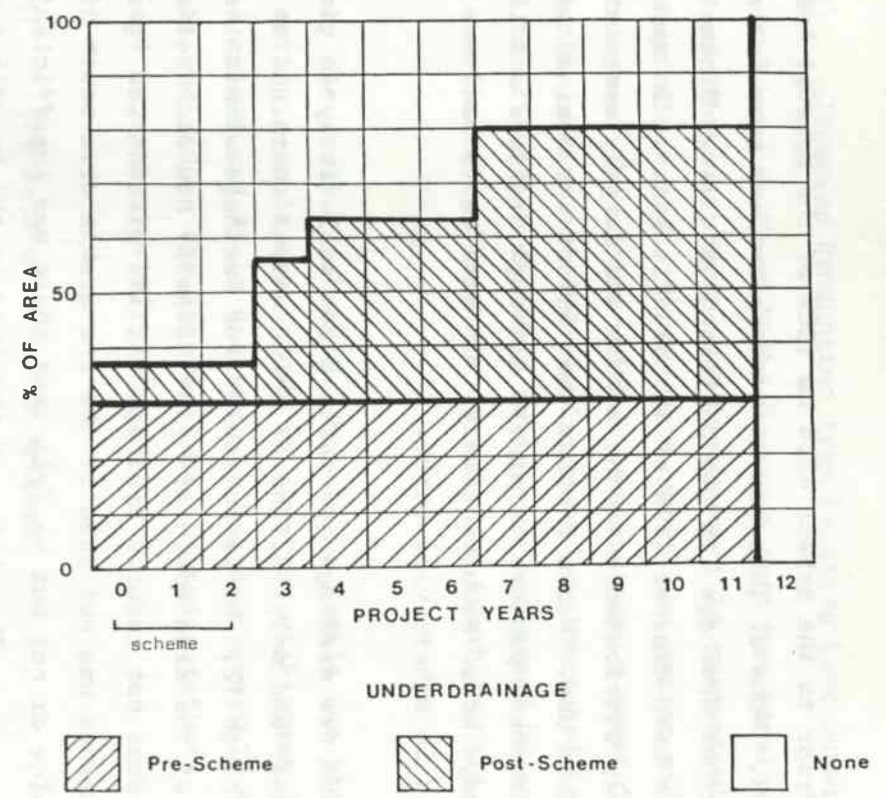


Fig 4 : INSTALLATION OF UNDERDRAINAGE



Prior to the scheme 40.8 ha (30% of the Benefit Area) already had field drains. None of this has been redrained and none is judged to be in need of further drainage for its preferred land use. Since the scheme 66.3 ha have been drained (49% of the Benefit Area). In each case this has been entirely attributable to the scheme and largely associated with a change of land use. Table 8 shows that 88% of the drained land has changed use from permanent pasture to arable although drainage and land use change did not always occur simultaneously. In some cases land use change preceded drainage and in others vice versa.

The new drainage has taken place exclusively in the area north of Mythe Causeway and only 13.7 ha of this remains undrained at the time of the survey (although 12.5 ha is scheduled for drainage within the next year or so). Most of the area south of Mythe Causeway had old drains prior to the scheme and does not require drainage for its present use (grassland). The farmer concerned was not sure if the one arable area south of the Causeway had old drains or not but he felt that there was insufficient outfall for new underdrainage. The status of the land in the Benefit Area with respect to underdrainage is summarized in Table 9.

Table 9 : Underdrainage Status, 1983

Status	S. of Mythe Causeway		N. of Mythe Causeway		Total	
	(ha)	(%)	(ha)	(%)	(ha)	(%)
Drained pre-scheme	31.9	70	8.9	10	40.8	30
Drained post-scheme	-	-	66.3	75	66.3	49
Scheduled for drainage	-	-	12.5	14	12.5	9
Insufficient outfall for drains	8.1	18	-	-	8.1	6
Drainage not needed	4.9	11	1.2	1	6.1	6
No Data	0.8	1	-	-	0.8	1
Total	45.7	100	88.9	100	134.6	100

(c) Improved Production from Existing Land Uses:

On the area south of Mythe Causeway that has remained under permanent grass, there has been some improvement in productivity, due to the reduction of flood risk. Management has become easier and sheep can be grazed throughout the winter without keeping such a careful watch on the river levels. Where nitrogen application has increased (eg. in one case from 0 to 125 kg/ha) stocking rates have increased by an estimated 30% (farmer's estimate). Elsewhere no tangible benefits have been perceived.

Only one small block of 6.1 ha was in arable use prior to the scheme when spring cereals were grown in rotation with grass leys. Following the scheme and field drainage it has been possible to switch to winter cereals and reduce the length of ley in the rotation. Yields of corn have risen by approximately 50%.

(d) The Rate of Benefit Uptake:

A financial assessment of net agricultural benefits to the Bushley scheme has been made by comparing pre-scheme and post-scheme enterprise gross margins, adjusting, where relevant, for changes in fixed costs, and the value of any extension to the grazing season. The method used for assessing net agricultural benefits is described in Annexe V.

A summary of benefits (before field drainage costs) by farm in the benefit area is given in Table 10. Five out of seven farmers reported benefits. About half of the scheme's benefits accrued to one farmer farming half the benefit area. The greatest net benefits are associated with a change in land use from permanent pasture to arable, arable/ley farming. In the main this change has necessitated an investment by the farmer in field drainage.

The rate of uptake of financial net benefits attributable to the scheme is shown in Figure 5. Averaged over the 125.4 hectare Bushley benefit area the maximum increase in net returns per hectare (excluding field drainage costs) per year of about £150 (in 1982 prices) was achieved in the eighth year of project life. After this point net returns declined marginally in part reflecting declining yields in continuous cereals, a decline which has been arrested by the introduction of arable/ley rotations. Benefit uptake was recorded on 94.8 of the total benefit area.

Table 10 : The Distribution of Benefits by Farm

SCHEME 22 — NET AGRICULTURAL BENEFIT

FARM CODE	YEAR FIRST	YEAR 4	YEAR 9	YEAR LAST	% OF BENEFITS	% OF AREA
1	176	412	883	883	5	9
2	0	0	224	312	2	7
3	0	0	0	0	0	6
4	1574	5302	8040	7613	46	50
5	65	65	76	76	0	1
6	1766	2732	5205	5732	34	21
7	357	834	2062	2062	12	6
TOTAL				16680	100	112

FIGURE 5 : Degree and Rate of Financial Uptake

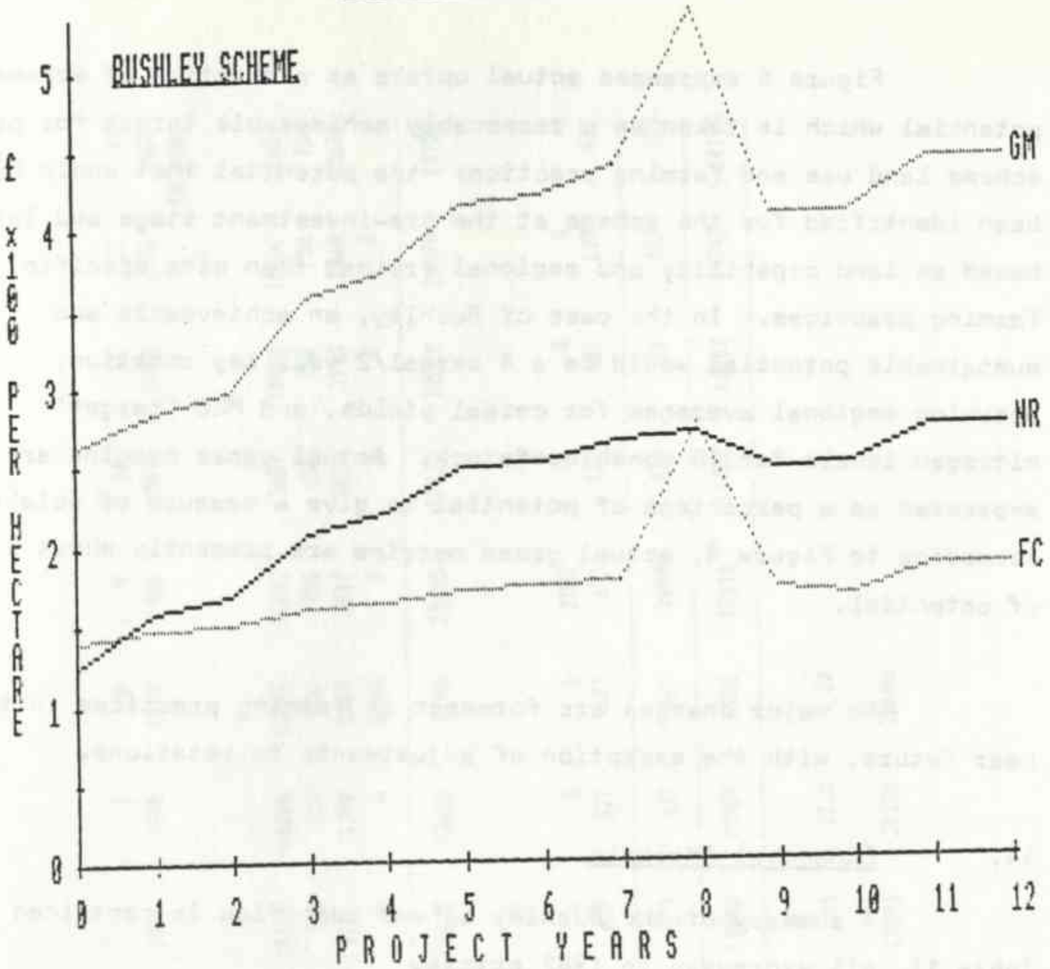


FIGURE 6 : Uptake as a Percentage of Potential

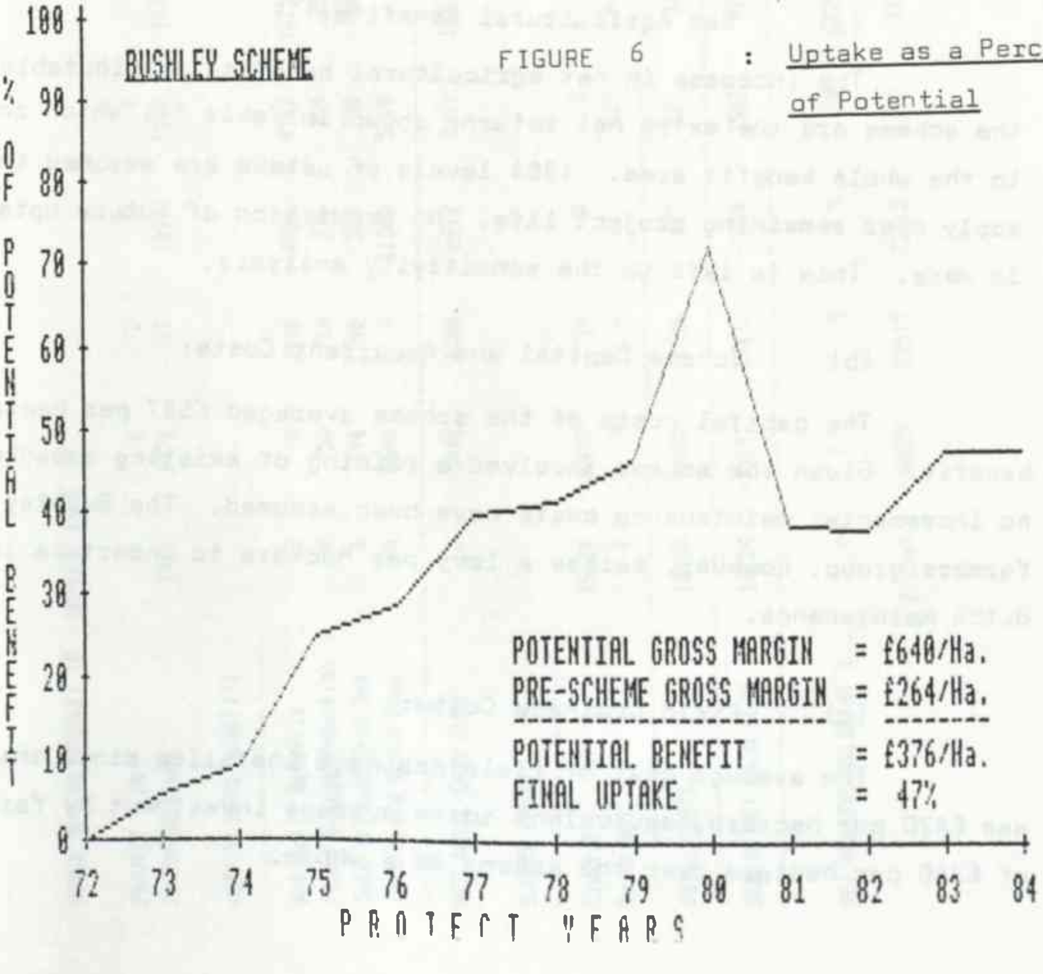


Figure 6 expresses actual uptake as a function of scheme potential which is taken as a reasonably achieveable target for post-scheme land use and farming practice: the potential that would have been identified for the scheme at the pre-investment stage and largely based on land capability and regional (rather than site specific) farming practices. In the case of Bushley, an achieveable and sustainable potential would be a 4 cereal/2 year ley rotation, assuming regional averages for cereal yields, and MLC 'target' nitrogen levels for 18 month beefstock. Actual gross margins are expressed as a percentage of potential to give a measure of uptake. According to Figure 6, actual gross margins are presently about 47% of potential.

No major changes are foreseen in farming practices in the near future, with the exception of adjustments to rotations.

14. <u>Financial Analysis</u>

A summary of the Bushley scheme cash flow is contained in Table 11, all expressed in 1982 prices.

(a) Net Agricultural Benefits:

The increase in net agricultural benefits attributable to the scheme are the extra net returns shown in Table 11, which relate to the whole benefit area. 1984 levels of uptake are assumed to apply over remaining project life. No prediction of future uptake is made. This is left to the sensitivity analysis.

(b) Scheme Capital and Recurrent Costs:

The capital costs of the scheme averaged £567 per hectare of benefit. Given the scheme involved a raising of existing embankments, no incremental maintenance costs have been assumed. The Bushley farmers group, however, raises a levy per hectare to undertake internal ditch maintenance.

(c) Field Drainage Costs:

The average cost of field drainage installed since the scheme was £420 per hectare, equivalent to an average investment by farmers of £240 per hectare over the scheme as a whole.

Table 11 : Summary of Scheme Cash Flow and NPV

RIVER SEVERN BUSHLEY TO UPPER LODE

PROJECT YEAR	0	1	2	3	4	5	6	7	8	9	10	11	12	13
CALENDAR YEAR	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984 TO 2001
AGRICULTURAL BENEFITS														
Net Agric Benefits	0	0	3940	4926	9347	10757	14118	14265	15805	16492	13689	14002	16680	16680
Flood Damage Reduction	0	750	750	750	750	750	750	750	750	750	750	750	750	750
less Without Proj Ben	0	194	390	588	788	989	1193	1399	1607	1817	2029	2243	2460	2678
less Field Drain Cost	0	5600	0	11500	5100	0	0	0	8200	0	0	0	0	0
NET AGRIC CASH FLOW	0	-5044	4300	-6412	4209	10518	13675	13616	6748	15425	12410	12509	14970	14752
SCHEME COSTS														
Capital	18924	30497	21726	0	0	0	0	0	0	2182	0	0	0	0
Recurrent	0	0	0	627	627	627	627	627	627	627	627	627	627	627
TOTAL COSTS	18924	30497	21726	627	627	627	627	627	627	2809	627	627	627	627
SCHEME NET CASH FLOW	-18924	-35541	-17426	-7039	3582	9891	13048	12989	6121	12616	11783	11882	14343	14125
NET PRESENT VALUE AT %	0	2.5	5	7.5	10	12.5	15	17.5	20					
	271569	148529	77513	35162	9172	-7156	-17593	-24330	-28680					

(d) Flood Damage Reduction:

Flood damage reduction is assumed at an average value of £750. This allows for the reduction of summer flooding events which previously damaged the hay crop. Whilst the scheme offers a higher flood protection the cost of a flood is higher given the change to more intensive land use. Winter flooding which previously caused little damage, may now necessitate cereal reseeding. Summer flood events may destroy arable crops completely. Post-scheme winter and summer flooding events have been assumed at one in 5 and one in 25 year return periods respectively. Flood damage benefits are therefore relatively small at £750 per year.

(e) Without-Project Benefits:

A basic assumption of 1% compound per annum is used to allow for likely improvements in farming performance for the without-project situation (see Annexe V). Without-project benefits are charged on those areas on which there has been some post-scheme uptake, which was 94.8% of the total area. Without-project benefits are estimated at (£20,939 x .948 +) £19,395 x 1% compound per year.

(f) Project Worthwhileness:

Assuming that benefits continue at their 1984 level (which has been adjusted to allow for likely changes in rotations) over a 30 year project life, the net present value of the scheme at the Treasury's 5% discount rate is £77,500 in 1982 prices. The scheme's internal rate of return is 11.3%, which meets the Government's criteria for public sector investments.

(g) Sensitivity Analysis:

Table 12 examines the sensitivity of the scheme worthwhileness to relevant benefit and cost parameters. The estimate of net agricultural benefits would need to be reduced by more than 37% before the project became unprofitable at the 5% discount rate.

TABLE 12

River Severn : Bushley - Sensitivity Analysis

Run No.	Agricultural Benefits Factor	Without Project Benefits Compounding Factor	Flood Damage Reduction Factor	Capital Works Cost Factor	NPV at 5% £	IRR %	Switching Value
1	1.0	1	1	0	77513	11.3	.63
2	1.0	0.5	1	0	91169	12.1	.54
3	1.0	1.5	1	0	63155	10.4	.68
4	1.0	0	1	0	104155	12.9	.47
5	1.0	1	0	0	66533	10.4	.67
6	1.0	1	1	-1	64924	10.1	.65

* The factors show the weights applied to the original estimates eg a factor of 1.5 for the without-project benefits indicates that the new value is 1.5 x 1% compound per year (the original value) ie 1.5% compound.

* Switching value : change in agricultural net benefits needed to make the project breakeven at 5% discount rate eg a 1.5 switch value shows an increase of 1.5 x the original estimated is required.

15. Discussion

Upon the basis of benefits to agriculture, the scheme can be divided into two discrete parts.

In the area south of Mythe Causeway, pre-scheme conditions appeared to be less severe than the area to the north. The existing floodbanks were of a higher standard and almost all of the area had old underdrainage schemes, probably dating back to the days of the Forthampton Estates. The area is farmed by one major occupier who could graze sheep through the winter, cut a good crop of hay in the summer and reintroduce sheep to graze the aftermath in autumn. Although the farmer is aware of the potential benefits of arable cropping (and grows winter cereals elsewhere on the farm) this land's reputation as good meadow land has encouraged him to leave it under grass and improve it by increasing the quantity of fertilizer applied. Although it may be ploughed if there were a change of management.

North of Mythe Causeway the pre-scheme conditions presented more of a constraint upon agricultural production. The lowest land levels are found in this area and none of the land (with the exception of a small area of higher ground) had any underdrainage. Edaphically, the lowest areas were dominated by poorly drained clay with a seasonally high watertable. Grazing seasons were therefore restricted to the period between April and November but the risk of flooding would often restrict access at either end such that grazing seasons from late April to mid October were common. Since the scheme there has been a rapid change in the pattern of farming in the northern part of the Benefit Area. Almost all of the land has been drained (and soon all will have) and 97% of the permanent pasture has been ploughed and converted to arable use - either in rotation or continuous cereals.

The reasons for the large and rapid uptake of potential benefits are largely attributable to the association of the local farmers and the formation of a Local Drainage Group. The group, formed after the severe floods of 1968, was instrumental in the promotion of the scheme by pressurizing the Severn River Authority. They were able, through the raising of a levy according to area of benefit, to cooperate on the improvement of the internal drainage network and so provide, at an early stage, sufficient freeboard for effective underdrainage. The group was also able to assist in the dissemination of information; indeed, the first farmer to install drains within the Benefit Area presented, with the assistance of ADAS, a Farm Drainage Demonstration for local farmers.

Having now had several years of experience growing cereals within the Benefit Area, the farmer of the lowest lying area can see the limitations of the scheme. Internal flooding occurs frequently through the winter due to high levels in the Severn preventing efficient discharge at the Upper Lode outfall. As a result the field-drains are frequently surcharged and outfalls are often submerged. He feels that in order to continue growing winter crops it would be necessary to install a pump at the Upper Lode outfall to lower brook levels when there is no gravity discharge, and on one occasion a temporary pump was tried with a good deal of success. However, to install a permanent pump would require cooperation and financial contributions from downstream riparian owners, who, being grassland farmers with few problems of flooding, are not prepared to make such an investment. The solution therefore may be to revert to less productive spring cereals on the lowest ground (NB. This year (1982/83) was so wet in autumn and spring that in one field the farmer was unable to sow any crop at all).

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(4) Severn River Authority (1955-75)
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(6) D. Shuker, STWA Lower Severn Division, Malvern.
Personal communication.

APPENDIX O

Lower Severn Division

South Gloucs. IDB : Oldbury

SILSOE COLLEGE

STWA Lower Severn Division - Oldbury Scheme

Report on the background to and development of the scheme and the nature and rate of uptake of agricultural benefits.

1. Physical Background

The Oldbury area lies on the flats on the east bank of the Severn Estuary 20 km north of Bristol. The levels extend up to 5 km inland from the Severn and are backed by the foothills and scarp slope of the Cotswold Hills. The land levels fall away from the estuary, varying between 7.0 m and 5.0 m AOD(N), which is below the maximum high tide level (recorded at 9.25 m AOD(N) in 1910). The present survey relates to the Southern Pumping area of the Oldbury Drainage Scheme.

2. Soils and Land Capability

The soils of the Oldbury Southern Pumping Area are shown in Figure i . The soils of the area are dominated by estuarine and riverine alluvial clays on Quaternary peats, clays and silts overlying Keuper Marl. The Oldbury Drainage scheme was surveyed by the Soil Survey (Ref. 1) and the following soil series were recognised in the Southern Pumping Area:

(i) Wentlloog Series:

This is the dominant soil of the Oldbury Area, found mostly nearer the River Severn it is common throughout the Southern Pumping Area. It is a grey calcareous silty clay of estuarine origin and is naturally poorly drained. Such soils tend to pass very quickly from a wet, plastic, to a dry, hard state making timeliness of cultivation critical.

(ii) Fladbury Series:

This is found alongside the major rhines and tributaries and is a grey clay soil of riverine origin produced by localized flooding. It does not contain the silt that is present in the Wentlloog series and is therefore very poorly drained. The slow permeability and clay texture preclude arable cropping and the quality of permanent pasture is frequently poor.

(iii) Compton Series:

This is essentially a red variation of the Fladbury series and is found in one area adjacent to the Rockhampton Rhine. It is a very poorly drained clay and land use is limited to permanent pasture.

(iv) Midelney Series:

Around Henridge Hill the underlying peat layer is within 25-80 cm of the surface making the soil sufficiently different from the Fladbury series to warrent classification as Midelney. It is therefore characterized by riverine clay over peat. It is very poorly drained but any attempt at lowering the watertable could result in shrinkage of the peat and further lowering of the land surface.

(v) Latcham Complex:

This is characterized by a silty layer within the top 70 cm beneath the riverine clay. It is very poorly drained and has a high water holding capacity such that it is frequently wet even during summer months. It only occurs in one small part of the Southern Pumping Area, adjacent to the Oldbury Naite Rhine, where permanent pasture is of very poor quality.

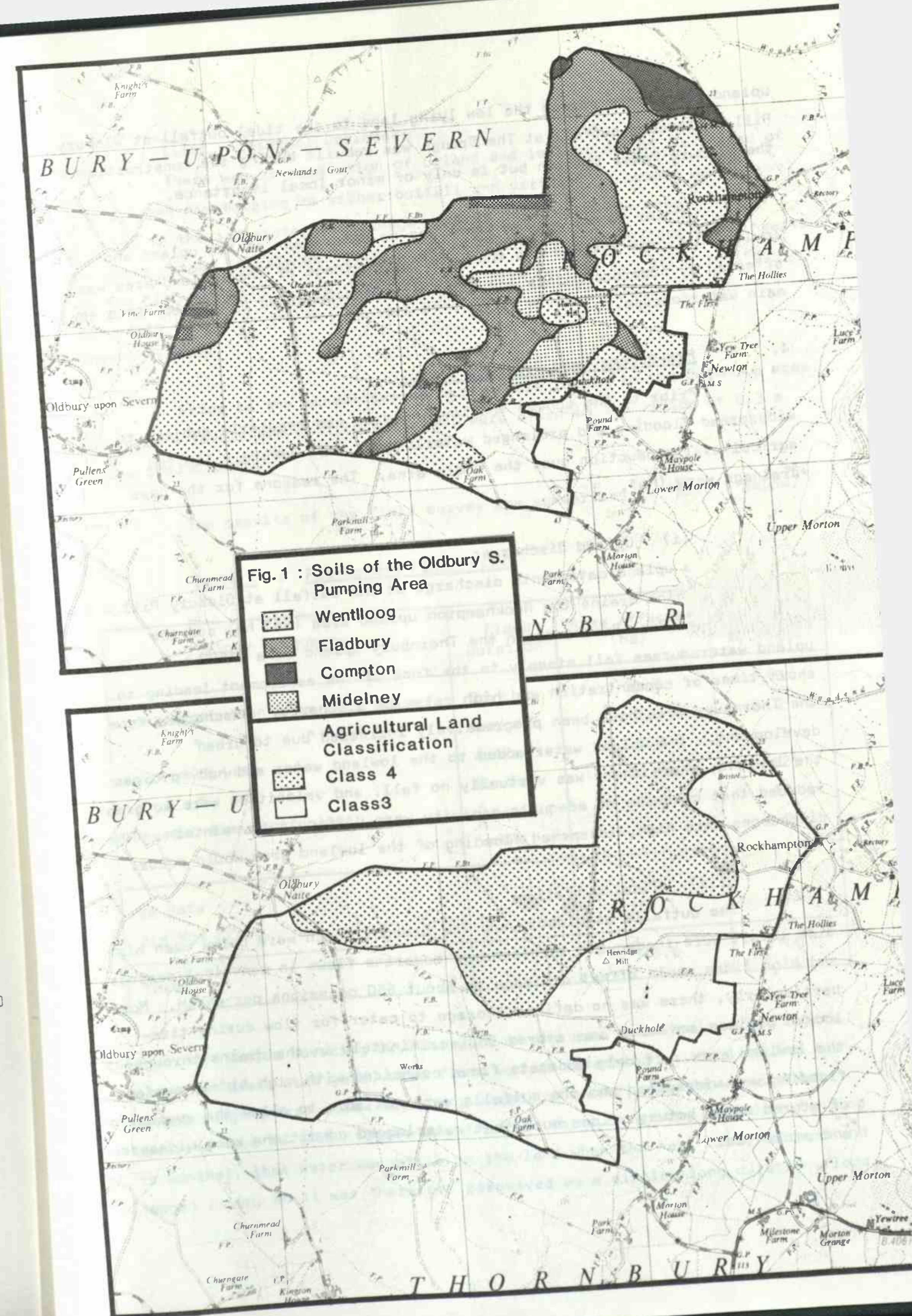
The land was classified by MAFF (Ref. 2) as grade 3 where flood risk was lower and grade 4 closer to the main Rockhampton and Oldbury Naite Rhines. The riverine clays (ie. Fladbury, Compton, Midelney and Latcham) were considered to be unsuitable for arable use due to the naturally slow permeability and clayey texture (Ref. 1). Trials suggest that the better drained Wentlloog soils could grow good cereal crops, although the timing of cultivations is critical and locally problems of wireworm infestation would have to be overcome (Ref. 1).

3. Land Drainage History

The Oldbury scheme area lies within the South Gloucestershire Internal Drainage Board which was constituted in 1936 to carry out the statutory duty of land drainage as described under the Drainage Acts of 1930 and later 1961 and 1975.

The lowland area is protected from tidal flooding from the Severn by embankments with a crest level of approximately 9.1 m AOD(N).

There are three main watercourses that cross the area; the Pool Brook, Pickedmoor Brook and the Rockhampton Rhine Each carry water from



upland catchments across the low lying land to the tidal outfall at Oldbury Pill. A second outfall at The Drough was rebuilt during the construction of the Oldbury Power Station but is only of minor local importance.

Prior to the scheme there was no separation of the upland and lowland drainage systems and the internal drainage of the lowland area was effected by numerous rhines and ditches that discharged by gravity into the main watercourses.

4. Pre-scheme Land Drainage Status

Prior to the scheme the lowland area was regularly subject to widespread flooding and prolonged waterlogging that severely limited agricultural production over the whole area. The reasons for the poor drainage were (Ref. 3):

(i) Upland Discharge:

Two upland catchments discharge at the outfall at Oldbury Pill - the Rockhampton Rhine drains the Rockhampton upland area (563 ha) and the Pickedmoor and Pool Brooks drain the Thornbury upland area (1590 ha). The upland watercourses fall steeply to the foot of the escarpment leading to short times of concentration and high rates of discharge. Discharges from the Thornbury area have been progressively increased due to urban development. The upland water added to the lowland water and had to cross the lowland, where there was virtually no fall, and velocities were so greatly reduced that channels of adequate capacity were difficult to maintain. When discharges were high widespread flooding of the lowland area would occur.

(ii) Tidal Outfall:

The outfalls at Oldbury and The Drough, which were below mean high tide level, were inadequate to discharge moderate flows in non-tidal periods, and high tides would affect drainage on about 650 occasions per annum. More particularly, there was no defined storage to cater for flow during tide-locked periods and water was stored indiscriminately in the drains throughout the lowland area. If only moderate flows coincided with high tides, surface flooding was widespread and the outfalls were not able to allow the evacuation of stored water between tides such that waterlogged conditions were widespread and prolonged.

(iii) Internal Drainage:

There was no separation of upland and lowland water, or indeed of the systems discharging to either outfall and virtually a common water level existed in the labyrinth of drainage ditches throughout the area. Access culverts. known locally as 'gouts', were inadequate and provided with inverts at too high elevations. No drainage works were carried out prior to the scheme to cope with the detrimental effects of urban expansion in the Thornbury Area.

Prior to the scheme summer water table levels in the Duckhole area, where land levels are particularly low, were often in the region of 0.3 m below ground level

The results of the field survey are summarized in Table 1 below.

Table 1 : Pre-Scheme Flood Risk

Flood Frequency	Flood Duration	Area Affected (ha)	% of Area Surveyed
Less often than once in 5 years	Days	35.7	10
" " " " " " "	Weeks	8.9	2
Once each year	Weeks	3.2	1
" " "	Months	45.4	12
Several times each year	Days	48.5	13
" " " "	Weeks	34.2	9
No Data	-	35.6	10
Did Not Flood	-	157.1	43
Total		368.6	100

Fields covering 82.7 ha (22% of the area surveyed) would flood a number of times each year, with flood waters remaining on the land for a period ranging from a few days to a couple of weeks. In the worst areas covering 48.6 ha (13%) floods would remain for such a long period (extending to months), that water was still on the land when the next flood arrived and topped it up, so it was therefore perceived as a single, long duration flood.

The rare event floods, occurring less often than once in five years (eg. the summer of 1968) would affect fields covering a further 44.6 ha ie. giving a total area affected of 175.9 ha or 48% of the area surveyed.

Just over 10% of the area surveyed had underdrainage prior to the scheme, but most of this was still described as being 'commonly wet'. The qualitative assessments of field drainage status are summarized below.

Table 2 : Pre-Scheme Drainage Status

Drainage Status	Area (ha)	% of Area Surveyed
'Occasionally wet'	59.9	16
'Commonly wet'	221.0	60
'Usually wet'	33.1	9
No Data	54.6	15
Total	368.6	100

Sixty percent of the area surveyed was described as being 'Commonly wet' with a further 9% being usually wet.

5. The Impact of Pre-Scheme Land Drainage Status on Land Utilization

Prior to the scheme the dominant land use was the growing of grass for dairy cattle and there was very little arable use. The permanent pasture was generally poor with Agrostis and Juncus species standing out on the very poorly drained Fladbury soils and ryegrass and clover typifying the poorly drained Wentlloog soils (Ref.1).

The winter flooding would not cause a great deal of damage as land was generally used for summer grazing only. It was noticeable however (by the farmers) that on the land that was frequently inundated the grass species were very poor. Occasionally floodwater would enter some farm buildings, but only to shallow depths and rarely would domestic properties be affected.

The most serious damage caused by the floods was the loss of hay crops after a summer flood. Most of the farmers interviewed remember the severe flood of June 1968. Mowing had just begun when the flood arrived; grass that was standing ready for cutting was ruined, and where bales had been stacked only the top few bales were salvageable. Although such summer floods occur comparatively rarely, the damage they cause lingers in the minds of the farmers for many years.

6. Scheme Design

An improvement scheme was designed to separate the upland and lowland drainage systems and to discharge the design flows from both to the tidal estuary of the Severn. This would alleviate flooding from upland water and lower water levels in the lowland drains to eliminate waterlogging of the lowest lying areas and permit the installation of adequate field drainage (Ref. 3).

The works can be divided into three sections as follows:

(i) Upland Carrier Drains:

The three principal watercourses in the area, viz. the Oldbury Naite/Rockhampton Rhine, Pickedmoor Brook and Pool Brook, were to be improved and embanked to convey drainage water from the upland areas through the lowland area and discharge it by gravity to the River Severn via the tidal outfall at Oldbury Pill. The channel works included enlargement, regrading and embanking of 8.6 km of watercourses (as shown on Figure 2), and the rebuilding of 5 public road, and 24 farm access, clear span bridges.

(ii) Oldbury Outfall:

A new outfall with twin 2.5 m square box culverts fitted with both tidal flap gates and electrically operated penstocks, was to be located near the mouth of the pill to take advantage of the natural fall and gain up to 1.6 m for the deepening and regrading of the upland carrier drains. This would double the outfall discharge capacity and allow the full tide lock storage to be discharged between consecutive tides.

(iii) Lowland Pumping System:

The two lowland areas to the north and south of the Rockhampton Rhine were to be pumped into the upland carrier drain by a common pumping station at Oldbury Naite with a capacity of 2.18 cumecs. The channel works included enlargement, deepening and regrading of 27.5 km of watercourse and replacement of 75 bridges and was designed to provide a minimum freeboard of 1.3 m for field drainage.

7. Benefit Area

Benefits were anticipated to accrue to both agricultural and urban interests by providing sufficient freeboard in the lowland rhines to allow the installation of underdrainage systems; affording greater protection from flooding and permitting the discharge of urban storm water through the area.

With internal flood levels reaching, under adverse conditions, approximately 6.70 m (AOD), the agricultural area which was expected to receive drainage benefit was that area below the 9.15 m (30 ft) contour (Ref 1). This amounted to 1673 ha divided between the various catchments as follows:

Table 3 : Benefit Area

Catchment	Total Area (ha)	Benefit Area (ha)	% of Total Benefit Area
Upland			
Thornbury	1590	178	11
Rockhampton	563	59	3
Lowland			
Southern Pump Area	615	448	27
Northern Pump Area	842	842	50
Pill	162	146	9
Total	3772	1673	100

8. Anticipated Costs and Benefits

(a) Cost:

The cost estimate contained in the Engineers Report (Ref. 1) totalled £400,000 although it was noted that this was only a rough figure as rising prices over the period to 1976 were expected to increase the cost of materials and labour. A separate cost estimate was drawn up for the purpose of an application for EEC grant aid from the FEOGA Fund. This totalled £517,800 (Ref. 4) (1974), but did not include the Tidal Outfall works which were already underway. These two cost estimates, along with the "actual" costs as estimated in 1978 (Ref. 5) are shown in Table 4 below.

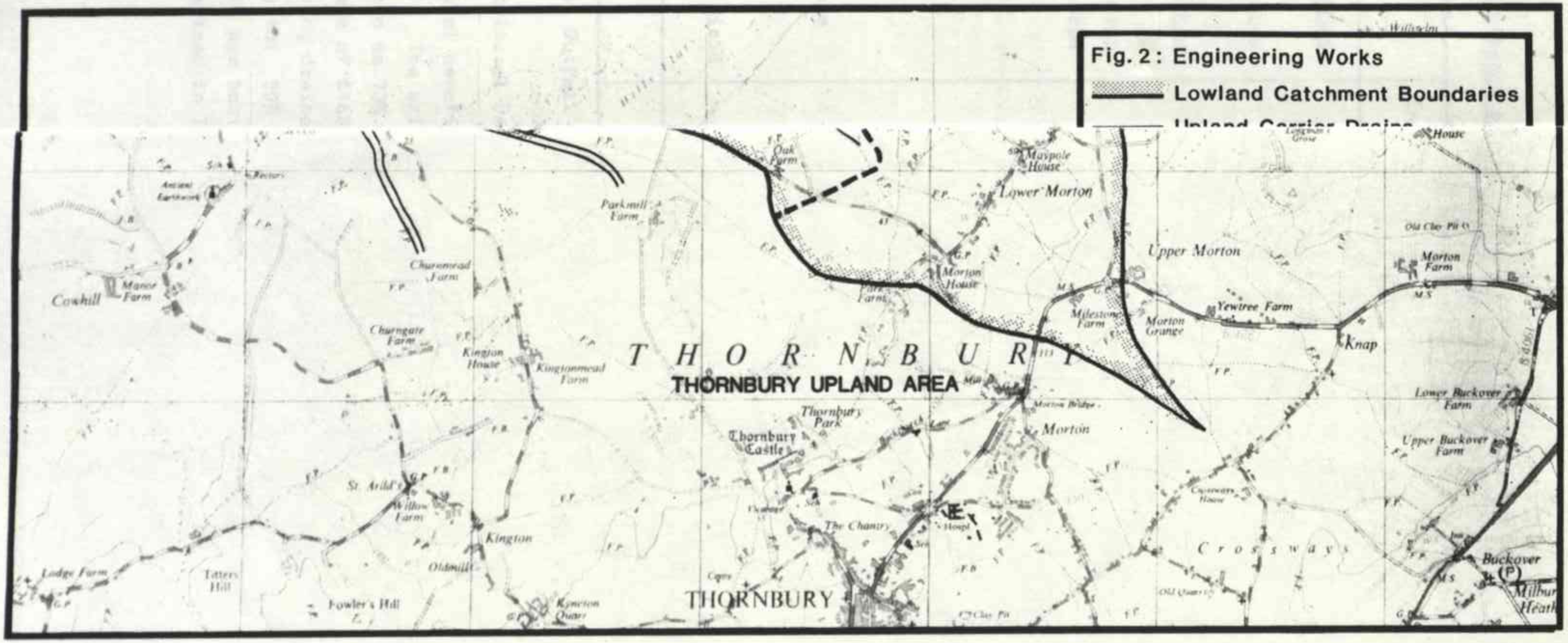


Fig. 2: Engineering Works

Table 4 : Estimates of Cost

Item	Engineers Report (£)	FEOGA (£)	1978 Estimate
Upland Carrier Drains			
Channel works	75,000	121,700	176,000
Bridge reconstruction	63,000	125,000	179,000
Lowland Pumping Scheme			
Pumping station	44,500	78,000	111,500
Northern Pumping Area	67,000	54,000	170,000
Southern Pumping Area		32,300	133,000
Tidal Outfall			
Total	132,000	-	92,000
Other costs			
Contingencies	-	8,200	-
Inflation allowance	-	21,000	-
Consultants Fees	-	44,000	-
Compensation	18,500	33,600	92,500
Reinstatement of field water supply	-	-	30,000
Total	400,000	517,800*	984,000

* excluding Tidal Outfall works.

(b) Agricultural Benefits:

The agricultural benefits were assessed for the FEOGA grant aid application (Ref. 4). The existing land utilization of the 1,675 ha benefit area was assessed as 73% dairy cows and 27% cattle rearing with gross outputs per hectare of £168 and £82 respectively (1974 prices). It was assumed that following drainage improvement the areas devoted to various enterprises would shift to: 59% dairy cows, 21% cattle rearing and 20% wheat with gross outputs per hectare of £356, £164 and £216 respectively. These figures are summarized in Table 5 below.

Table 5 : Change in gross output following the scheme (Ref. 4)

	Areas of Enterprise (ha)			Gross outputs per ha (£)			Total Gross Output (£)
	Dairy cows	Cattle Rearing	Arable	Dairy cows	Cattle Rearing	Arable	
Before scheme	1,230	445	-	168	82	-	243,270
After scheme	984	356	335	356	164	216	481,090
Change	-246	-89	+335				237,820

Extra production costs were estimated at £76,000 therefore the increase in gross margins is equal to the increase in gross output less extra production costs and is equal to £161,820. Additional fixed costs were estimated as follows:

Table 6 : Additional fixed costs

Item	Annual Charge (£)
Additional livestock (interest only @ 10%)	12,200
Additional housing, fencing, etc. (written off over 10 years @ 10% interest rate)	18,256
Additional machinery (written off over 5 years @ 10% interest rate)	10,560
Total	41,016

Deducting the annual charge on capital, the total net annual benefit is equal to £120,804, which, when capitalized over 30 years at 10% interest, has a present value of £1,140,000.

(c) Cost-Benefit Ratio:

The benefits of the scheme were compared with the cost for the purposes of the FEOGA grant aid application. As the Outfall works were not included in the application the cost of the scheme includes the upland carrier drains and lowland pumping schemes only.

Estimated cost of scheme	£517,800	
Estimated cost of field underdrainage by farmers	£340,000	
Total cost	£857,800	(1974)
Total benefits	£1,140,000	(1974)
Cost-Benefit ratio	1:1.33	

9. **The Scheme**

The original scheme was approved in principle by the Ministry of Agriculture, Fisheries & Food for grant aid in January 1971 and detailed design and MAFF approval was phased over the period 1971-1977.

The construction of the tidal outfall works began in September 1972. In 1974 the non-tidal works, ie. the Upland Carrier and Pumping Scheme, were submitted for grant aid from the EEC (under the FEOGA scheme) by the South Gloucs. IDB. The carrier drains and pumping station were completed by July 1978 and the lowland pumping drains by Mid-1979.

Construction of the tidal works, main bridge works on the upland carrier drains and the lowland pumping station were carried out by contract. The rest of the works were carried out by the South Gloucs. IDB on a direct labour/plant hire basis.

Although the lowland rhine capacities were originally designed for continued grassland the specifications were changed upon the basis of Ministry recommendations (Ref. 6) to provide sufficient freeboard for arable use (although a shift to arable had never been visualized by the IDB). This led to a significant increase in costs.

The final cost of the scheme was £1.4 million before contributions comprised as shown in Table 7. Grant was paid by MAFF at 50% except for Tidal Defences at 75% and water supply which was not grant aided. Grants totalled £714,380. A further £112,000 was obtained from the FEOGA (Ref. 6).

Table 7 : Final Cost of the Scheme

Item	LDW code	Cost (£)	Contributions[1]
Site investigation	26,238	3,670	
Tidal defence	27,110	66,585	17,149
Land drainage	27,110	48,670	7,119
Main bridgeworks	29,326	174,844	
Upland carriers	29,331	394,906	25,732
Pumping station	31,100	89,648	
Pumping plant	30,031	50,544	
Lowland rhines	30,730	555,652	
Water supply	-	10,950	
Total		1,395,470	50,000

1. From Northavon District Council

10. Farm Survey

Fifteen farmers were interviewed during August and September 1983. Between them they farmed 365.3 ha within the Oldbury Southern Pumping Area. This amounts to 81% of the Benefit Area as defined in 7 above. Partial information was collected for a further 13 ha which are let out as grazing giving 84% coverage. Two farms have had a change of management since the scheme and in one case the ownership has also changed. However, in both cases, the present occupier had worked on the farm prior to the scheme.

11. Agriculture in the Benefit Area

(a) Farm Type, Size and Tenure:

The data relating to farm type and size are summarized in Tables 8-10. The dominant farm type is dairy with 13 of the 16 farms (89% of the area surveyed) being either 'Specialist' or 'Mainly Dairy'. One farm, accounting for 8% of the area surveyed was classified as 'Livestock Rearing and Fattening - Cattle and Sheep' and one was entirely under grass let off as keep (4%). There was one poultry farm within the Southern Pumping Area but, being entirely buildings, it accounted for less than 1% of the area surveyed.

Table 8 : Farm Type

Farm Type	N^o of Farms	% of Area Surveyed
Specialist dairy	9	59
Mainly dairy	3	28
Cattle and sheep	1	8
Poultry	1	1
Land let as grazing	1	4
Total	15	100

Table 9 : Farm Size (Hectares)

Size Group (ha)	N^o of Farms	% of Area Surveyed
2 - 5*	1	1
10 - 20	–	0
20 - 30	1	1
30 - 40	5	31
40 - 50	1	9
50 - 100	5	41
100 - 200	1	13
No Data	1	4
Total	15	100

Mean = 49 ha St. Dev. = 28.4 ha

* Poultry Farm 14 valid cases

Table 10 : Farm Size (SMD)

Size Group (SMD)	N° of Farms	% of Area Surveyed
100 - 174	1	8
175 - 249	0	0
250 - 499	4	19
500 - 999	5	36
1000 - 1499	2	27
1499 - 3500	0	0
> 3500	1	1
No Data	2	9
Total	15	100

Mean = 1060 SMD   St. Dev. = 1531 SMD

13 valid cases

Eleven out of the 15 farms (81% by area) are within the size range of 30-100 ha (mean 49 ha, St. Dev. 28.4 ha) and are between 250 and 1500 SMD (mean 1060 SMD, St. Dev. 1531 SMD).

Most of the farms are owner-occupied with nine out of the 13 valid cases being more than 50% owned and 6 being entirely owned. Nine of the farmers are in family partnerships, 2 are sole proprietors and one is a full-time manager. The poultry farm is a limited company.

(b) Dairy Enterprises:

The 12 dairy farms have an average herd size of 71 cows (St. Dev. 29.7 cows) ranging from 35 to 125 cows and milk yields average 5200 litres per cow per year. The average stocking rates on 'Specialist' and 'Mainly Dairy' farms are 1.95 and 1.73 Livestock Units per hectare[1] respectively. Land within the Benefit Area is almost entirely under permanent pasture which is largely cut for hay or silage and then grazed by dairy followers. Much of the land is in small fragmented units some distance away from the farm and therefore unsuitable for grazing dairy cows.

(c) Beef Enterprises:

Only one farm was classified as a 'Livestock Rearing and Fattening' farm and this farmer weans week old calves on nurse cows then

1. Weighted by area in benefit.

fattens them on grass for slaughter at 24 months old. About half of the dairy farms sell some yearlings as stores. The stocking rate on the livestock farm is 0.84 Livestock Units per hectare.

(d) Arable Enterprises:

There are only 10 hectares of arable land within the area surveyed (equivalent to 3% of the area) in two blocks both on the edge of the Benefit Area. One has been used for a variety of crops including potatoes and forage rape, the other has been in a rotation with cereals and grass leys.

(e) Other Enterprises:

There is one poultry farm in the Southern Pumping Area which, although run independantly, is managed by a farmer who has other land in the area. It has 97,000 laying hens and 54,000 pullets.

12. The Effect of the Scheme on Flooding and Land Drainage

One hundred and fifty-seven hectares (43% of the area surveyed) were free from flooding prior to the scheme. Flooding since the scheme has been reported in some areas, but it has been localised and only around for a day or so while the rhines have not been pumped.

The water levels in the rhines have been lowered considerably by the scheme - in some places by up to one metre. This has given a significant improvement in field drainage status although in some areas there have been suggestions that some land is over-drained (see 15 below). There is sufficient freeboard for field drains throughout the area.

13. The Agricultural Benefits of the Scheme

(a) Land Use Change:

Prior to the scheme, the agricultural land use pattern of the area surveyed in the Southern Pumping Area was as follows:

Permanent Grass - 97%

Temporary Grass - <1%

Grass/crop rotation - 2%

Crops - <1%

Since the scheme 15.6 ha of permanent pasture (4% of the area surveyed) have been ploughed and 12 ha reseeded as temporary grass and 3.6 ha brought into a grass/crop rotation. Ninety-three percent of the area surveyed is still under permanent pasture.

(b) Field Drainage Installation:

Nearly 50 ha (13% of the area surveyed) were drained prior to the scheme, of which 12.4 ha were drained in 1978. Although this was after the completion of the pumping station it was before the improvement of the internal rhines and, although some ditching work had been carried out by the farmer, these drains are generally shallow and cannot be attributed to the scheme. Since the scheme, 13.5 ha (3% of the area surveyed) have been drained in two blocks of land. Eighty-four per cent of the area surveyed remains undrained (see Table 11 below).

Table 11 : Underdrainage Status in 1983

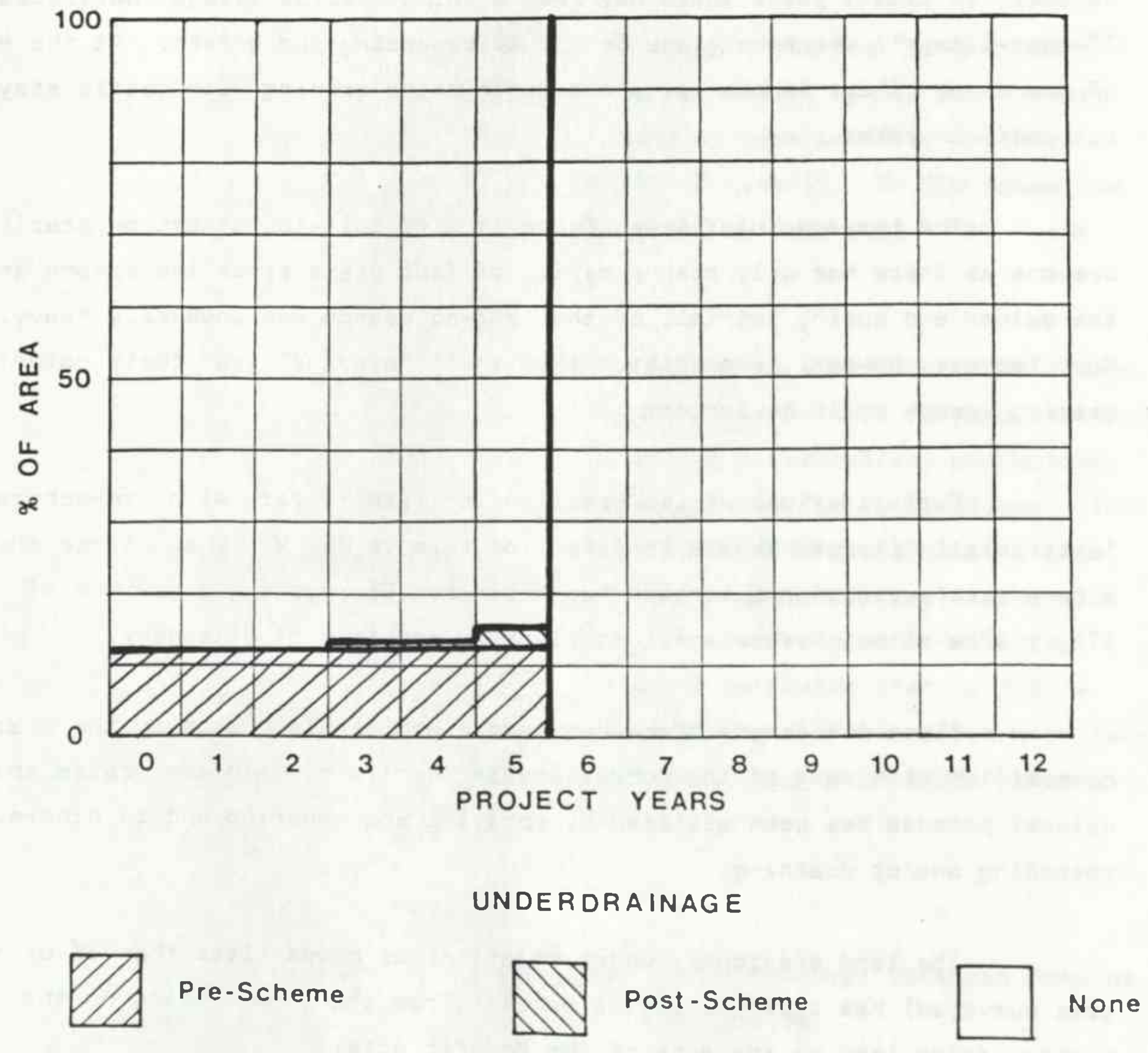
Status	Area (ha)	% of Area Surveyed
Drained Pre-Scheme	48.6	13
(Drained 1978)	(12.4)	(3)
Drained Post-Scheme	13.5	3
Total Drained	62.1	16
Undrained	316.0	84
Total	378.1	100

Of that that remains undrained, 25% is not judged (by the farmer) to be in need of further drainage, and 43% has not been drained because of financial constraints. On much of the rest, farmers are waiting to see how the scheme performs before investing in drainage. The rate of field drainage installation is shown in Figure 3.

(c) Improved Production from Existing Land Uses:

The dominant land use, both before and after the scheme is permanent grassland for conservation and for the aftermath grazing of dairy followers. As a result of the scheme there has generally been an extension of the grazing season. Potential turnout dates in spring have

Fig 3 : INSTALLATION OF UNDERDRAINAGE



been brought forward by two weeks or so from late April/early May to mid-April. Most of the land in the Benefit Area is closed up for conservation in spring so more important has been the improved trafficability allowing earlier top dressing with Nitrogen. Prior to the scheme almost all of the permanent grassland within the Benefit Area was cut once for hay, however, in recent years there has been a shift towards silage (particularly 'Bagged-Silage') and some grass is cut twice during the season. At the end of the season there is now up to one month extra grazing with cattle staying out until November.

The farmers interviewed found it difficult to comment on grazing seasons as there has only been a period of four years since the scheme and the autumn and spring rainfall of the 1982-83 season was unusually heavy. Most farmers, however, appreciated that in an 'average' year their potential grazing season would be longer.

Fertilizer use varies greatly from farm to farm with pre-scheme 'artificial' Nitrogen levels ranging from zero to 250 kg N/ha. Since the scheme the 'average' application has risen by 30% reaching a maximum of 375 kg N/ha although some still receives no dressing of Nitrogen.

Since the scheme there has been a noticeable change in the sward composition with many of the poorer species declining. In some cases this natural process has been assisted by spraying and manuring and in others, reseeding and/or draining.

The land previously under rotations or crops (less than 3% of the area surveyed) has received little benefit from the scheme being on the higher, drier land on the edge of the Benefit Area.

(d) The Rate of Benefit Uptake:

A financial assessment of the Oldbury: Southern Pumping Area scheme has been undertaken by identifying, on the basis of farmer interview, the change in farm enterprise gross margins attributable to drainage improvements, net of any additional fixed costs, and including the benefit of extended grazing if relevant. The procedures used for this purpose are described in Annexe V.

A summary of benefits (before field drainage costs) by farm in the benefit area is given in Table 12. Twelve of the 14 potential beneficiaries reported actual benefits. One reported reduced returns due to changes in stocking management. One farmer accounted for 42% of total benefits on 14% of the area.

Figure 4 shows the rate of uptake over the first 5 years of project life. Average net returns had increased by £40 per hectare. Seventy-three percent of the area reported some benefit, whether 'automatic' or due to conscious uptake of benefit. On the areas for which benefits were observed, average net returns were £55 per hectare extra.

Figure 5 expresses benefit uptake as a percentage of scheme potential which is based on land capability and local farming practice. About 60% of the area (Wentloog) is suited to cereal/ley production, with limitations on field workday availability for cultivations. The remainder (Fladbury) is best suited to permanent grass or long leys, and capable of supporting intensive stocking providing measures are taken to reduce poaching. On this basis, with a view to existing intensive practices in the area, Figure 5 estimates that by 1983/4 22% of the potential gross margin afforded by the scheme had been taken up. This measure of relative uptake needs careful interpretation as discussed in Annexe IX, section 4.4.

14. FINANCIAL ANALYSIS

A summary of the cash flow of the Oldbury: Southern Pumping Area scheme is given in Table 13, in 1982 prices.

(a) Net Agricultural Benefits:

The increase in net agricultural benefits attributable to the scheme are those contained in Table 12, grossed up by a factor of 1.24 to allow for the fact that financial data was collected for 81% of the total agricultural benefit area. It is considered reasonable to assume that benefit uptake on the unsurveyed area is not significantly different from the surveyed area.

Table 12 : Distribution of Benefits by Farm

SCHEME 73 NET AGRICULTURAL BENEFIT

FARM CODE	YEAR FIRST	YEAR 2	YEAR 5	YEAR LAST	% OF BENEFITS	% OF AREA
1	238	238	954	1192	8	4
2	572	572	572	572	4	9
3	1156	1156	1276	1276	9	16
5	0	0	0	0	0	6
6	52	52	436	436	3	4
7	0	0	2031	2031	14	11
8	320	320	320	320	2	10
9	127	127	127	127	1	6
10	-154	-154	-615	-769	-5	6
11	117	117	254	1498	11	8
12	192	192	574	702	5	2
13	1718	1718	4643	5889	42	14
14	75	75	769	845	6	5
TOTAL				14125	100	336

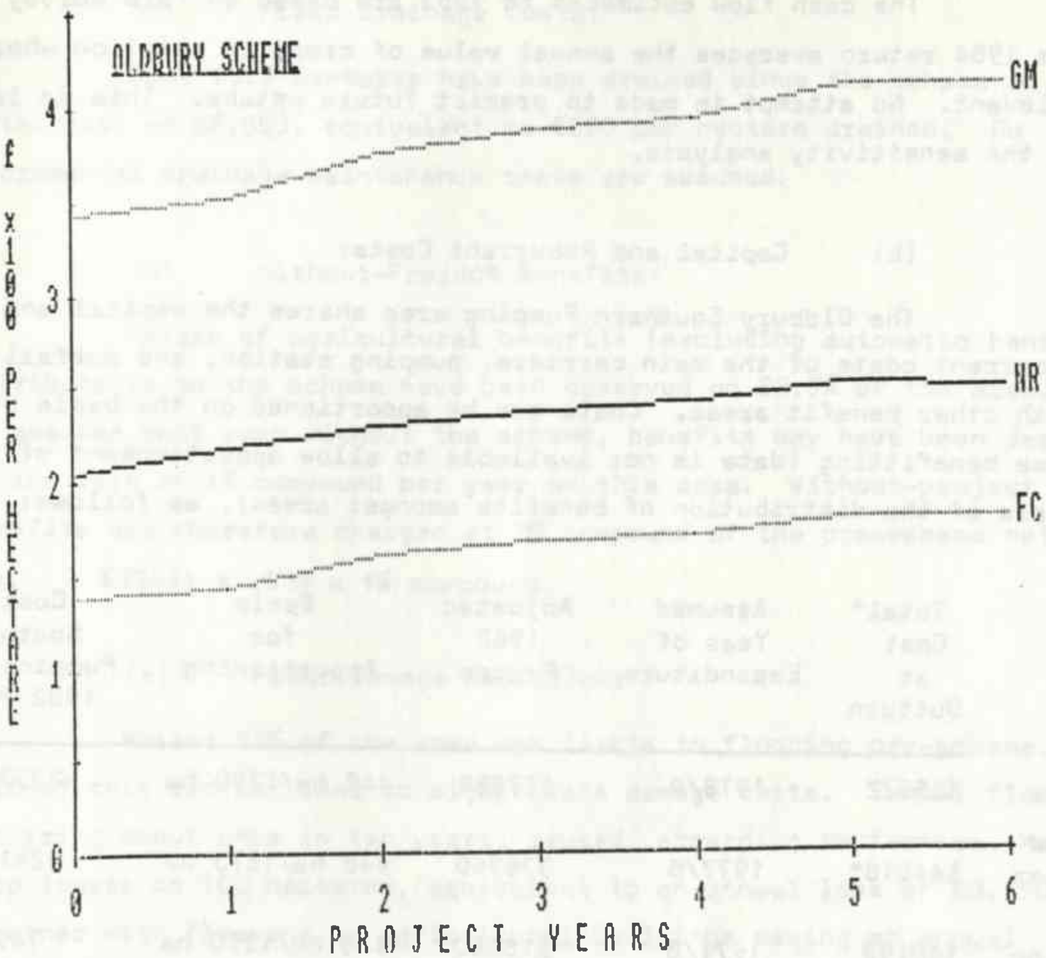
Table 13 : Summary of Cash Flow and NPV

OLDBURY : SOUTHERN PUMPING AREA

PROJECT YEAR	0	1	2	3	4	5	6 TO 30
CALENDAR YEAR	1978	1979	1980	1981	1982	1983	1984 TO 2008
AGRICULTURAL BENEFITS							
Net Agric Benefits	0	5325	9633	12592	14030	17701	17336
Flood Damage Reduction	0	3850	3850	3850	3850	3850	3850
less Without Proj Ben	0	499	1004	1513	2027	2547	3072
less Field Drain Cost	0	0	0	2335	0	4468	0
NET AGRIC CASH FLOW	0	8676	12479	12594	15853	14536	18114
SCHEME COSTS							
Capital	338645	240157	0	0	0	0	0
Recurrent	0	0	9446	9446	9446	9446	9446
TOTAL COSTS	338645	240157	9446	9446	9446	9446	9446
SCHEME NET CASH FLOW	-338645	-231481	3033	3148	6407	5090	8668

NET PRESENT VALUE AT %	0	2.5	5	7.5	10	12.5	15
	-335746	-397280	-427288	-440159	-443473	-441349	-436103

FIGURE 4 : Degree and Rate of Financial Uptake



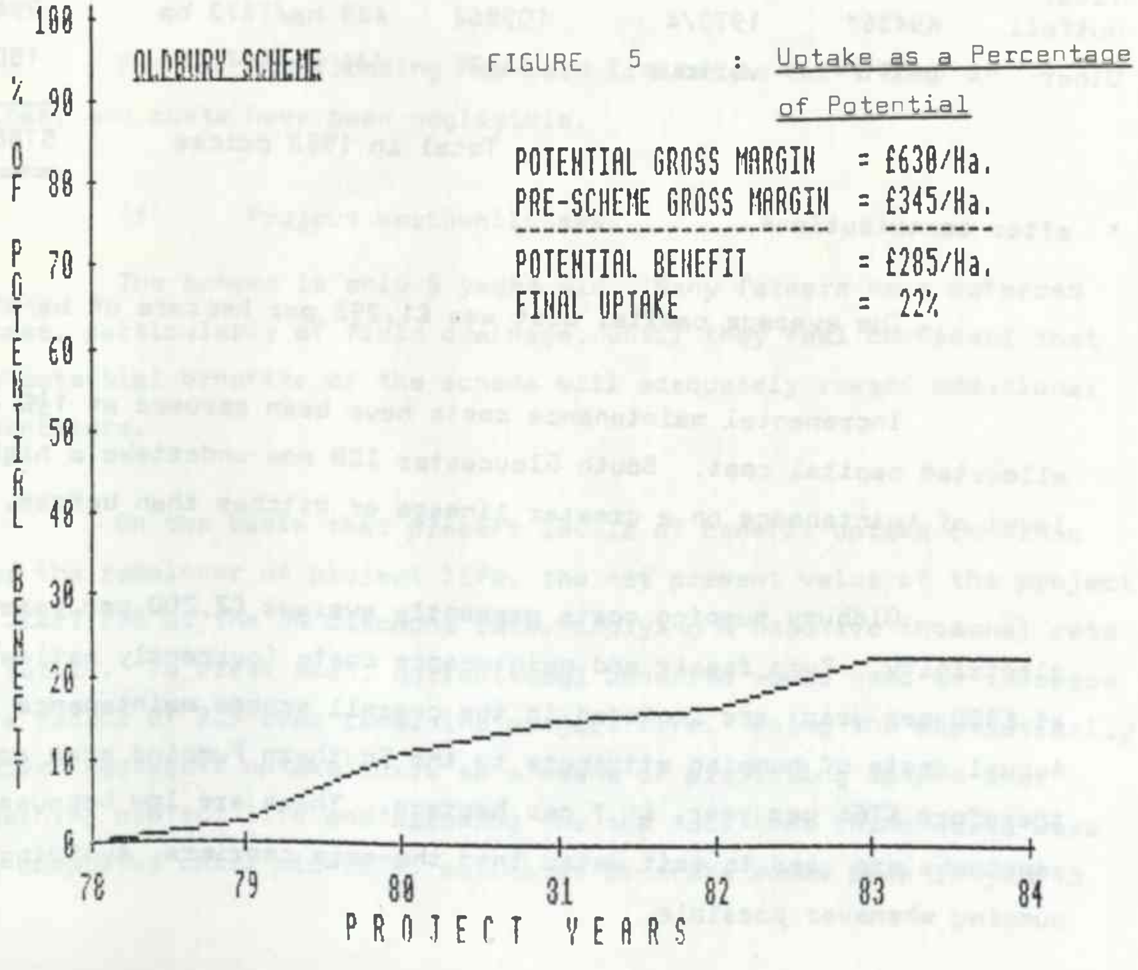


FIGURE 5 : Uptake as a Percentage of Potential

The cash flow estimates to 1983 are based on farm survey data. The 1984 return averages the annual value of crops in rotation where relevant. No attempt is made to predict future uptake. This is left to the sensitivity analysis.

(b) Capital and Recurrent Costs:

The Oldbury Southern Pumping area shares the capital and recurrent costs of the main carriers, pumping station, and outfall, with other benefit areas. Costs can be apportioned on the basis of area benefitting (data is not available to allow apportionment of the basis of the distribution of benefits amongst areas), as follows:

	Total* Cost at Outturn	Assumed Year of Expenditure	Adjusted 1982 Prices	Basis for Apportioning	Cost to Southern Pumping Area 1982 Prices
Rhines	555622	1978/9	677588	448 ha/1290 ha	235317
Upland Carrier	544018*	1977/8	836950	448 ha/1673 ha	224120
Pump Station	140192	1977/8	215680	448 ha/1290 ha	74903
Tidal Outfall	49436*	1973/4	109864	448 ha/1673 ha	29420
Other	56171*	various	56171	448 ha/1673 ha	15042
				Total in 1982 prices	578802

* after contributions

The average capital cost was £1,292 per hectare of benefit.

Incremental maintenance costs have been assumed at 1½% of allocated capital cost. South Gloucester IDB now undertake a higher level of maintenance on a greater lineage of ditches than before.

Oldbury pumping costs presently average £2,200 per year for electricity. Pump repair and maintenance costs (currently estimated at £500 per year) are included in the overall scheme maintenance charge. Annual costs of pumping attribute to the Southern Pumping area are therefore £764 per year, £1.7 per hectare. These are low because penstocks are used to exit water into the main carriers, avoiding pumping whenever possible.

(c) Field Drainage Costs:

Some 13.6 hectares have been drained since the scheme at a total cost of £6,803, equivalent to £500 per hectare drained. No incremental drainage maintenance costs are assumed.

(d) Without-Project Benefits:

Uptake of agricultural benefits (excluding automatic benefits) attributable to the scheme have been observed on 53.9% of the area. It is assumed that even without the scheme, benefits may have been derived at the rate of 1% compound per year on this area. Without-project benefits are therefore charged at 1% compound of the pre-scheme net returns i.e. £92641 x .539 x 1% compound.

(e) Flood Damage Reduction:

Whilst 53% of the area was liable to flooding pre-scheme, much of this did not lead to significant damage costs. Summer floods, occurring about once in ten years, caused, according to farmers, hay crop losses on 100 hectares, equivalent to an annual loss of £3,750, together with flooding to agricultural buildings making an annual average loss of £3,850.

Post-scheme flooding has been limited to backing up in Rhines, and costs have been negligible.

(f) Project Worthwhileness:

The scheme is only 5 years old. Many farmers have deferred uptake, particularly of field drainage, until they feel confident that the potential benefits of the scheme will adequately reward additional expenditure.

On the basis that present levels of benefit uptake continue over the remainder of project life, the net present value of the project is -£427,288 at the 5% discount rate, implying a negative internal rate of return. To break even, agricultural benefits would need to increase by a factor of 2.9 over remaining project life. Using the statistically derived aggregate uptake curve as a means of predicting uptake over remaining project life and allowing for the fact that rhine works were not completed until mid-1979, estimated benefits would peak in year 13 at 3.2 times the observed 1983 level. If this happens, and this order of improvement is both technically feasible and consistent with the pattern of uptake on the Lapper Ditch scheme, net present value would be -£140,000 and the internal rate of return would be 3%.

Oldbury uptake has been slower than at the Lapper Ditch. Many farmers have been waiting to see how drainage regimes have changed, whilst at the same time pointing to the benefits that have accrued to the Lapper Ditch counterparts as an indicator of the benefits they themselves might derive.

(g) Sensitivity Analysis:

Table 14 examines the sensitivity of the project to selected cost and benefit assumptions.

15. Summer Droughtiness

A few of the farmers interviewed noted, and some felt quite strongly about, the increased proneness to summer drought. This problem was particularly apparent at the time of the interview (September 1983) which was just after the driest summer for some years. Many pointed out that whilst their land had continued to provide good grazing throughout the summer of 1976, it was much drier this year and there was less grass growth after the cut for hay or silage. One farmer complained that this year (1983) he had had to supplement the aftermath grass with hay at an equivalent cost of £150 per hectare of grazing.

This problem could possibly be alleviated by more careful control of pumping during the spring and summer to maintain rhine water levels during the drier months.

16. Discussion

Apart from a small number of farmers who had recently suffered from a shortage of grass due to drought, most of the farmers were pleased with the benefits of the scheme. Many who had seen the benefits of similar schemes elsewhere in the South Gloucestershire Internal Drainge District (such as board members) could see a three tier system of benefits.

TABLE 14

Oldbury : Southern Pumping Area - Sensitivity Analysis

Run No.	Agricultural Benefits Factor	Without Project Benefits Compounding Factor	Flood Damage Reduction Factor	Capital Works Cost Factor	NPV at 5% £	IRR %	Switching Value *
1	1.0	1	1	1.0	-427288	-4.8	2.9
2	1.0	0	1	1.0	-388927	-ve	2.7
3	1.0	1	0	1.0	-483657	-ve	3.2
4	1.0	1	1	0.20	0	5.0	0
5	x	1	1	1.0	-139178	3.1	1.6

The factors show the weights applied to the original estimates, eg. a factor of 1.5 for the without-project benefits indicates that the new value is 1.5 x 1% compound per year (the original value) is 1.5% compound.

* Switching value : change in agricultural net benefits needed to make the project break even at 5% discount rate, eg. a 1.5 switch value shows an increase of 1.5 x the original estimated is required.

x Predicted increased benefits up to year 13 using aggregate uptake curve, see Annexe IX, section 4.5.

The first stage is the automatic benefit from reduced summer flooding,- longer grazing, improved sward and improved trafficability. This is the stage that most are currently at. Secondly the benefits resulting from private investment in the land, such as field drainage and spraying or reseeding (a few have reached this stage) and thirdly the benefits from a change of land use to mixed arable systems. They appreciate that to reach the third stage will take many years (at least ten) but many are watching closely those who have invested in field drainage before committing themselves. With respect to land use change, there is a feeling that if somebody tries ploughing the grass and grows wheat, and he is successful others will follow. As yet, the innovator has not appeared.

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4. South Gloucestershire IDB (1974) <u>Oldbury Drainage Improvement Scheme</u>. E.E.C. FEOGA Grant Application, unpublished.

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APPENDIX P

Lower Severn Division

South Gloucs. IDB : Epney Rhine

SILSOE COLLEGE

STWA LOWER SEVERN DIVISION - EPNEY RHINE SCHEME

Report on the background to, and development of the scheme and the nature and rate of uptake of agricultural benefits.

1. Physical Background

The Epney scheme was one of a number of schemes carried out by the South Gloucestershire IDB and the Severn River Authority on land adjacent to the River Severn downstream of Gloucester. The low lying area is protected from the tidal Severn by natural and artificial levees as the general slope of the ground level is away from the Severn. Prior to the scheme, internal drainage was effected by a system of rhines (ditches) discharging into the Severn through flapped outfalls that breached the floodbanks.

The present study relates to the catchment of the Lapper Ditch which covers an area of 169 ha between the villages of Epney and Longney and lies entirely within the boundary of the S. Gloucestershire IDB.

2. Soils and Land Capability

The National Soil Map (Ref 1) identifies two broad soil types in the area. Adjacent to the Severn on the levees, deep, stoneless permeable silty soils of the Blacktoft association are found, formed in estuarine alluvium. Inland, on the lowest lying ground the soil is classified as Newchurch 2 association. Boreholes in the Lapper Ditch Catchment (Ref 2) show that the soil in the lowest area is dominantly a grey brown clay to a depth of 60-90 cm overlying peat to a depth of up to 5.2 m. The locations and logs of boreholes is shown in Figure 1.

The whole area was classified by MAFF as grade 3 land (Ref 3), although as the dates of the survey and scheme coincide, this probably reflects the post- rather than pre- scheme status.

3. Land Drainage History

Prior to the present scheme, works were last carried out on the Epney Rhine in 1962 when the rhine was improved and the sluice gate replaced at a total cost of £2,410 (1962). Although pumping was considered at this time, it was not pursued and the system of gravity drainage was continued.

Extensive flooding occurred throughout the area in 1965, and local farmers were angered enough to contact their local Member of Parliament and exert pressure for an improvement scheme. Although the IDB blamed the floods on farmers who had left the flood gates open, engineers of the Severn River Authority made an investigation of the area and in a report dated October 1965 recommended the improvement and embankment of those watercourses which conveyed predominantly upland water to the Severn at the Epney outfall.

The construction of the nearby M5 motorway between 1967 and 1970 necessitated improvements to the upland carrier system and the IDB agreed to go ahead with an improvement scheme on the Epney Rhine in 1968.

4. Pre-Scheme Land Drainage Status

Prior to the scheme, flooding was a severe problem, affecting all of the low lying land behind the levees. The flood area is shown in Figure 1. The results of the farm survey are given in Table 1 below.

Table 1 : Pre-scheme Flood Risk

Flood Risk: Frequency	Flood Risk: Duration	Area (ha)	% of area surveyed
Less than 1 in 5 years	Days	16.7	14
More than once a year	Weeks	22.6	19
More than once a year	Months	34.0	29
Total flood prone area		73.3	62

Fifty-seven hectares (48% of the area surveyed) would flood a number of times each year, with flood water remaining on the land for a period of weeks, and in the wettest areas months. A further 17 hectares (14%) would flood under extreme conditions that did not occur more often than once every ten years or so. The remainder of the area, including the area not surveyed in detail, was not prone to flooding. This is the higher ground of the levees.

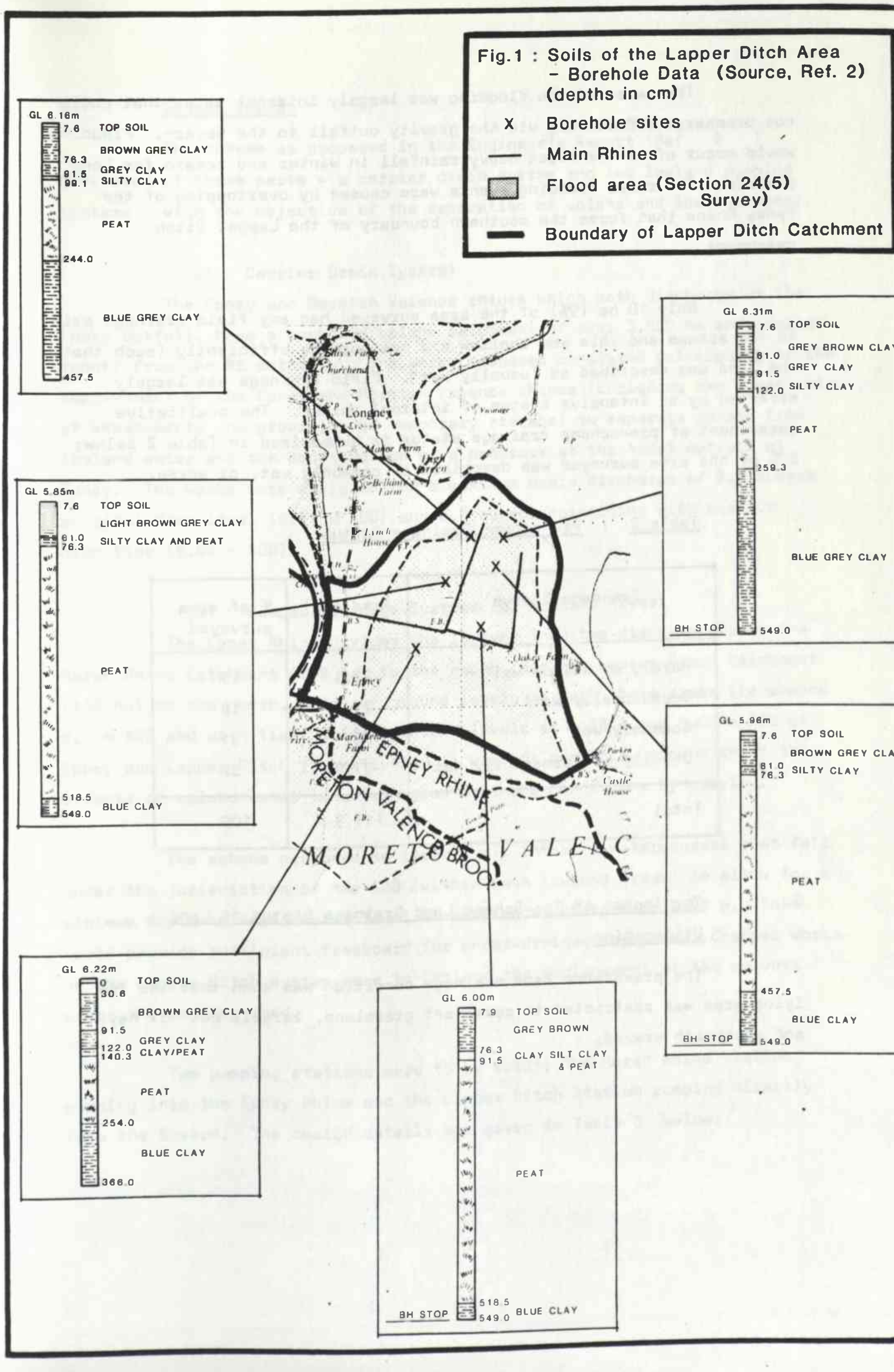


Fig.1 : Soils of the Lapper Ditch Area - Borehole Data (Source, Ref. 2) (depths in cm)

The cause of the flooding was largely internal water that could not discharge effectively via the gravity outfall to the Severn. Flooding would occur after the first heavy rainfall in winter and remain for long periods. The rarer flooding events were caused by overtopping of the Epney Rhine that forms the southern boundary of the Lapper Ditch catchment.

Only 10 ha (9%) of the area surveyed had any field drainage prior to the scheme and this was shallow and not working efficiently (such that the land was described as 'usually wet'). Field drainage was largely effected by an intensive system of internal rhines. The qualitative assessment of pre-scheme drainage status is summarized in Table 2 below; 63% of the area surveyed was described as commonly wet, or worse.

Table 2 : Pre-scheme Drainage Status

Drainage Status	Area (ha)	% of area surveyed
'Rarely or seldom wet'	23.1	19
'Occasionally wet'	21.5	18
'Commonly wet'	36.1	31
'Usually or Permanently wet'	37.2	32
Total	117.9	100

5. The Impact of Pre-Scheme Land Drainage Status on Land Utilization

The pre-scheme land drainage condition was such that the low lying area was restricted to permanent grassland, largely cut for hay and aftermath grazed.

6. Scheme Design

The scheme as proposed in the Engineer's Report (Ref 2) consisted of three parts - a carrier drain system and two lowland pumping systems - with the objective of the separation of upland and lowland water.

(i) Carrier Drain System:

The Epney and Moreton Valence rhines which both discharge at the Epney outfall, have a combined upland catchment of over 3,000 ha and include runoff from the M5 motorway. The works proposed consisted principally of the improvement of the Epney and Moreton Valence rhines (including the constuction of embankments and provision of temporary storage) to separate upland from lowland water and the construction of a penstock at the tidal outfall at Epney. The works were designed for a maximum drain discharge of 8.5 cumecs at tidal free level (6.71 m AOD) and 2.8 cumecs coinciding with maximum high tide (9.64 m AOD).

(ii) Pumped Drainage Systems for Lowland Areas:

The Epney Rhine divides the lowland into two discrete areas; the Marsh Rhine Catchment (228 ha) to the south, and the Lapper Ditch Catchment (169 ha) to the north. Minimum ground levels in both these areas lie around 6.0 m AOD and with tidal outfall invert levels at 4.88 m and 5.03 m AOD at Epney and Lapper Ditch respectively, it was not possible, even without the effects of upland water to obtain good drainage conditions by gravity.

The scheme proposed to improve all internal watercourses that fall under the jurisdiction of the IDB (within both lowland areas) to allow for a minimum depth to drain water level at pumping discharges of 0.92 m. This would provide sufficient freeboard for under-drainage systems. Channel works on the Lapper Ditch system were to include the replacement of the culvert under the Longney road.

Two pumping stations were to be built; the Marsh Rhine station pumping into the Epney Rhine and the Lapper Ditch station pumping directly into the Severn. The design details are given in Table 3 below.

Table 3 : Pumping Station Design Data

	Marsh Rhine	Lapper Ditch
Discharge (cumecs)	0.368	0.255
Minimum ground level (m AOD)	6.039	5.978
Drain invert at pump (m AOD)	3.66	3.66
Pumping levels : start (m AOD)	5.03	5.03
stop (m AOD	4.27	4.27

The Lapper Ditch outfall was in satisfactory order but it was considered desirable to install a penstock on the upstream face.

7. Benefit Area

A total of 485 ha were expected to derive benefit from the works. This was sub-divided as follows:

Table 4 : Area of Benefit

Catchment	Area of Benefit (ha)
Carrier Drain	197
Marsh Rhine	143
Lapper Ditch	145
Total	485

The areas of benefit are shown on Figure 2 . It is pertinent to note that the Marsh Rhine Catchment was also prone to flooding from the River Frome which was improved in the mid-1970's.

8. Predicted Costs and Benefits

(a) Cost:

The original cost estimate contained in the Engineer's Report (Ref 2) totalled £62,900 and was comprised as follows:

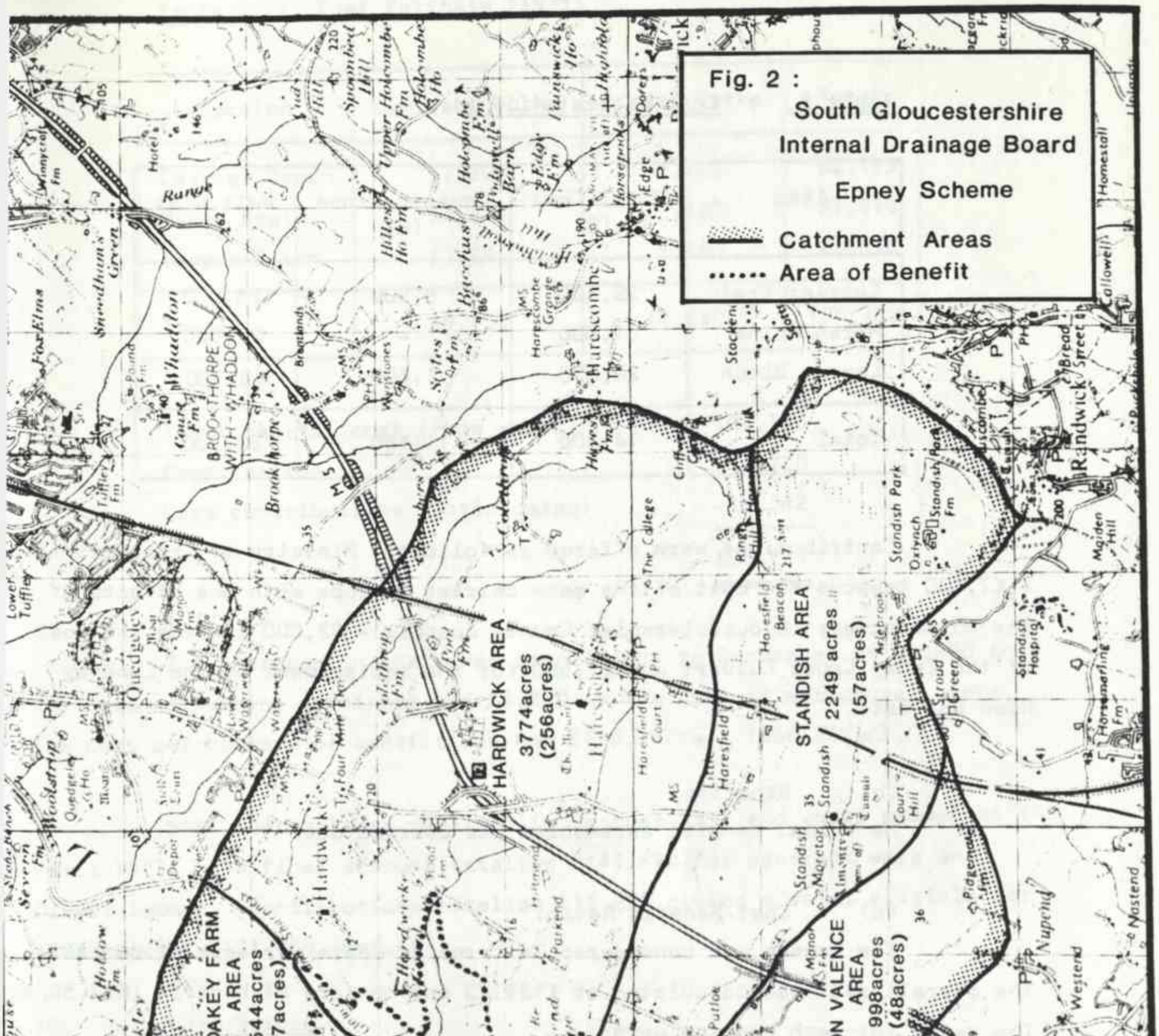


Fig. 2 :
South Gloucestershire
Internal Drainage Board
Epney Scheme
Catchment Areas
Area of Benefit
HARDWICK AREA
3774acres
(256acres)
STANDISH AREA
2249 acres
(57acres)
MORTON VALENCE AREA
998acres
(48acres)
OAKEY FARM AREA
544acres
(87acres)
LAPPER DITCH AREA
418acres
(358acres)
MARSH RHYNE AREA
563acres
(354acres)
LONGNEY AREA

Table 5 : Cost Estimate (1970)

Item	Total Cost (£)	Contributions (£)	Nett Cost (£)
Carrier Drain	32,500	9,500	23,000
Marsh Rhine	21,000	-	21,000
Lapper Ditch	20,500	1,600	18,900
Total	74,000	11,100	62,900

Contributions were offered as follows: Ministry of Transport - £7,500 towards the cost of the main carrier to cope with the effects of the M5 motorway; Gloucestershire County Council - £2,000 towards the cost of the Epney Cross Culvert and £1,600 for the replacement of the Longney Road Culvert.

(b) Benefits:

No formal benefit assessment was carried out.

(c) Cost/Benefit Ratio:

The scheme was considered in terms of costs per acre of benefit. The overall rate was calculated at £129.73 per hectare of benefit (£52.50/ac). The rates for each section were:

Carrier drain	£116.14/ha (£47.0/ac)
Marsh Rhine	£146.78/ha (£59.4/ac)
Lapper Ditch	£130.47/ha (£52.8/ac)

9. The Scheme

Although works were planned to commence in 1970 (Ref 2) the start was delayed. The costs were re-assessed in 1971 and totalled £96,111 made up as follows:

Table 6 : Cost Estimate (1971)

Section	Contract Works	Direct Works	Total
Carrier Drain	57,209	4,980	62,189
Marsh Drain	14,648	7,230	21,878
Lapper Ditch	17,296	5,340	22,636
Total	89,153	17,550	106,703

	£
Total capital cost (from above)	106,703
Compensation	3,750
Less contributions (anticipated)	-14,342
	£96,111

The increase in costs was largely due to increases of £5,800 in the cost of pumping machinery and £8,300 in the cost of structural works. The cost per hectare of benefit was now £198.17/ha. (£80.20/ac).

MAFF approval was received in October 1971 and works commenced in April 1972. The final account totalled £147,690 for contract work and direct labour. Contributions totalled £15,931 giving a total eligible for grant aid of £131,759 (Ref. 5).

10. Farm Survey

The farm survey was restricted to the Lapper Ditch Benefit Area. This was for two reasons:

(i) The Lapper Ditch pumped catchment is a discrete area that can be studied apart from any other works. In the Marsh Rhine catchment it is difficult to isolate benefits of the Epney Rhine scheme from benefits of the River Frome scheme as both watercourses were responsible for local flooding.

(ii) To limit the number of farmers and so economise on fieldwork.

Two farmers were interviewed during September 1983 who between them farmed 118 ha within the Lapper Ditch Benefit Area. This is equal to 81% of the Benefit Area identified in the Engineer's Report (Ref 2). It should be noted that much of the remainder is occupied by houses and gardens or is west of the Epney-Longney road, and therefore on higher, dryer ground. The lowest lying, and wettest, ground has been covered by the survey.

11. Agriculture in the Benefit Area

Much of the land surveyed within the Lapper Ditch area has changed hands within the last 20 years. The two farmers interviewed took over their farms in 1967 and 1975 respectively.

One farmer owns 283 ha of land in three farms, one including the Lapper Ditch area, one nearby with land in the Marsh Rhine Benefit Area and a third on upland. The second farmer rents one 81 ha farm. One farm is classified as 'Specialist Dairy' and the other as 'General Cropping' but land within the Benefit Area today is largely under grass/arable rotations with winter cereals being intersperced with temporary leys (often long leys) cut for silage and then grazed.

Both farms keep early lambing sheep flocks that are grazed on the new leys and cattle are wintered on silage and grazed on the aftermath. Both farms have between 40 and 50% of their land under winter cereals although as each has less than 50% of its land within the Lapper Ditch area, much is grown on upland outside of the Benefit Area. The average stocking rate (weighted by area in benefit) is 1.76 LU/ha.

12. The Effect of the Scheme on Flooding and Land Drainage

Following the scheme, flooding has been eliminated and adequate freeboard for field-drainage has been provided throughout the Lapper Ditch area.

13. Agricultural Benefits of the Scheme

(a) Land Use Change:

The land use data are shown in Table 7 and Figure 3 below.

Table 7 : Land Use Change 1972-83 (Areas in Hectares)

Pre-scheme \ Post-scheme	Permanent Grass	Grass/Crop Rotation	Crops	Total Pre-Scheme
Permanent Grass	45.0	52.7	4.8	102.5
Temporary Grass	-	15.4	-	15.4
Total Post-Scheme	45.0	68.1	4.8	117.9

Fig 3 : LANDUSE CHANGE

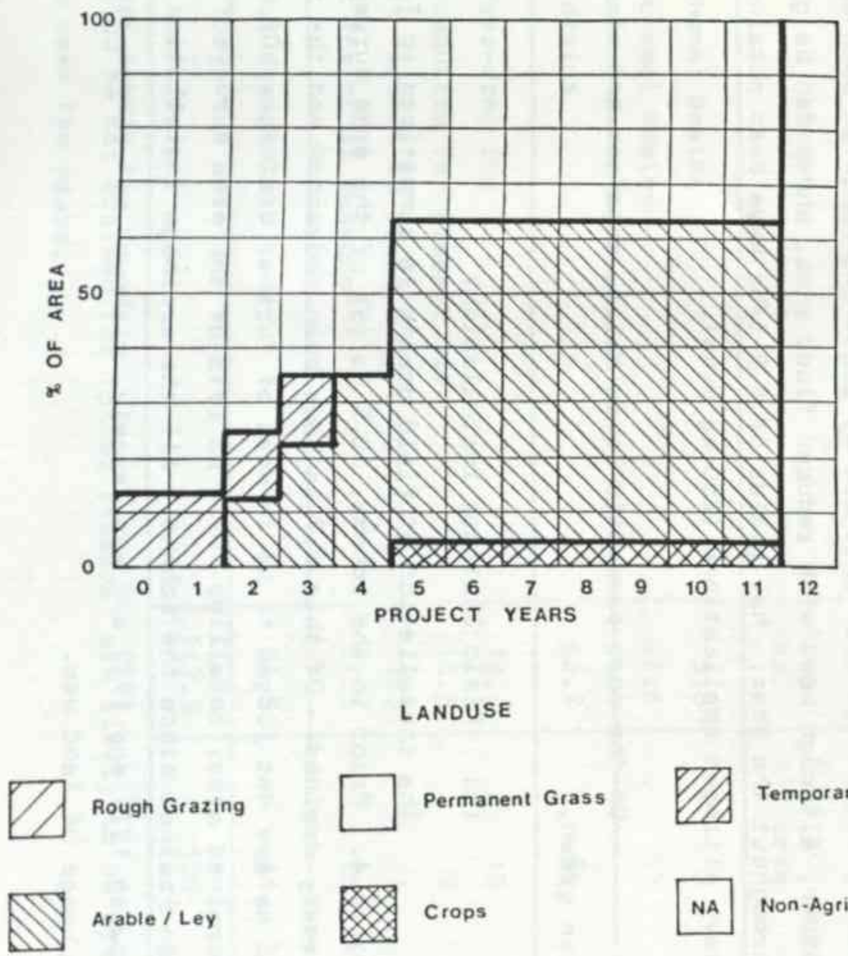
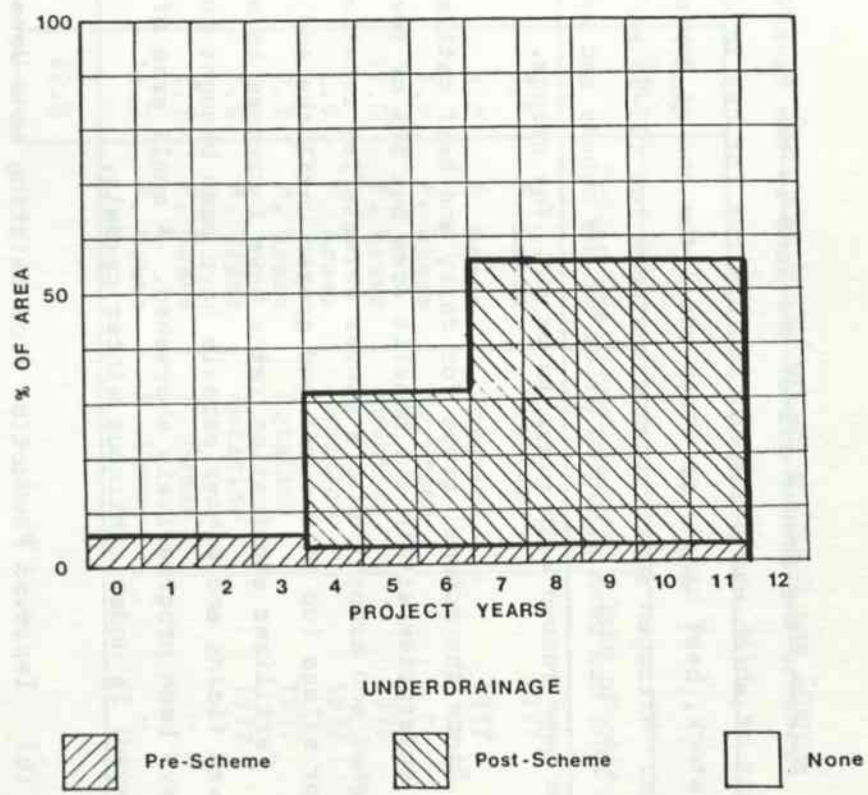


Fig 4 : INSTALLATION OF UNDERDRAINAGE



Prior to the scheme all of the land in the Benefit Area was under grass, most of which was permanent pasture cut for hay in June and grazed by dairy stock, beef cattle or sheep until the end of September/beginning of October. Nitrogen application rates were low (55-65 kg N/ha). Some of the drier land had been ploughed prior to the scheme and after 2 years of barley had been resown with grass to be cut for silage.

Since the scheme, grass for dairy and beef cattle has remained the major enterprise within the Benefit Area but 62% of the grassland has been ploughed and brought into a winter cereals/ley rotation. The leys are cut for silage (up to 3 cuts) and grazed until the end of October/early November. Fertilizer application rates have increased to over 250 kg N/ha on conserved fields and winter cereals have been brought into the rotations as leys have been progressively shortened. A small area of 4.8 ha (4% of the area surveyed) is under continous winter cereals.

(b) Improved Production from Existing Land Uses:

Forty-five hectares have remained under permanent pasture; some of which is summer keep that is grazed and some is closed up for hay and then grazed. Sixty percent of the land that is still under permanent grass has been reseeded since the scheme with improved varieties, in some cases after one or two years of corn have been grown to 'clean' the land. The grazing season has been extended by about one month in both spring and autumn, although now, with reduced flood risk, sheep can be grazed throughout the year. Hay yields of 8.9 t/ha have been obtained with heavy nitrogen applications (250 kg N/ha).

On the more permeable levee soils, potatoes and strawberries have been grown.

(c) Field Drainage Installation:

The installation of field drains is summarized in Table 8 and on Figure 4. Prior to the scheme, 10.5 ha (9% of the area surveyed) were already drained. Of this 6.9 ha have been redrained and the remaining 3.6 ha are not judged to be in need of further drainage. Of the previously undrained area, totalling 107.4 ha (91% of the area surveyed) 55.9 ha have been drained since the scheme. All the drainage installation took place between 1976 and 1979 and was largely, although not always associated with a change of land use.

Table 8 : Drainage Installation and Land Use Change

Date of drainage	Area (ha)	Land Use		
		Pre-scheme	Post-scheme	Date of change
1976	8.9	P. Grass	Rotation	1977
	4.0	P. Grass	Rotation	1977
	1.6	P. Grass	P. Grass	-
	11.0	P. Grass	Rotation	1975
	6.9	P. Grass	Rotation	1977
	2.9	P. Grass	Rotation	1977
1979	4.5	P. Grass	Rotation	1977
	8.9	P. Grass	P. Grass	-
	14.2	P. Grass	P. Grass	-
Total	62.8			

Today, 51.5 ha (44% of the area surveyed) remains undrained. The present underdrainage status is summarized in Table 9 below.

Table 9 : Underdrainage Status 1983

Status	Area (ha)	% of surveyed area
Old (pre-scheme) drains	3.6	3
New (post-scheme) drains	62.8	53
Total with drains	66.4	56
Naturally free-draining	14.6	12
Drains not required for present use	10.5	9
Insufficient finance to drain	5.3	4
Not drained for other reasons	21.1	18
Total without drains	51.5	44
Total	117.9	100

NB: Nearly 30 ha not drained for 'other reasons' are likely to be drained in the next few years.

(d) Rate of Benefit Uptake:

A financial assessment of the Epney Rhine: Lapper Ditch scheme has been undertaken by identifying, on the basis of farmer interview, the change in farm enterprise gross margins attributable to drainage improvements, net of any additional fixed costs, and including the benefit of extended grazing if relevant. The procedures used for this purpose are described in Annexe V.

A summary of benefits (before field drainage costs) by farm in the benefit area is given in Table 10. The distribution of benefits between the two surveyed farmers largely reflects their relative share of the benefit area.

Figure 5 shows the rate of uptake of financial benefits attributable to the scheme to the present time. Net returns have increased over a 12 year period of uptake by an average £183 per hectare. Benefit uptake was recorded on 100% of the potential benefit area.

Figure 6 expresses actual gross margin improvement as a percentage of potential. The latter is largely based on an assessment of land capability and local farming practice. Seventy percent of the area is light permeable silty soils suited to arable/ley systems comprising 4 cereals and 2/3 grass. Yields of 8 t/ha are currently being achieved. The low lying clay areas (30%) are better suited to intensive livestock production, particularly dairy, with 350 kg N/ha.

Figure 6 shows that 73% of potential gross margin had been exploited by 1983/4.

14. Financial Analysis

A summary of the cash flow of the Epney Rhine: Lapper Ditch scheme is contained in Table 11 in 1982 prices.

(a) Net Agricultural Benefits:

The estimate of net agricultural benefits used for scheme evaluation is that based upon the extra net returns attributable to the scheme which are contained in Table 10. The farm survey covered

Table 10 : Distribution of Agricultural Benefits by Farm

SCHEME 74 NET AGRICULTURAL BENEFIT
********* *************************

FARM CODE	YEAR FIRST	YEAR 5	YEAR 9	YEAR LAST	% OF BENEFITS	% OF AREA
1	0	1894	6800	8247	42	39
2	0	5584	6741	11324	58	61
TOTAL				19571	100	106

Table 11 : Summary of Scheme Cash Flow and NPV

EPNEY RHINE : LAPPER DITCH

PROJECT YEAR	0	1	2	3	4	5	6	7	8	9	10	11	12 TO 30
CALENDAR YEAR	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984 TO 2002
AGRICULTURAL BENEFITS													
Net Agric Benefits	0	4185	6810	8899	7073	13026	13963	16114	16114	25804	23274	23274	23291
Flood Damage Reduction	0	1120	1120	1120	1120	1120	1120	1120	1120	1120	1120	1120	1120
less Without Proj Ben	0	223	449	677	907	1140	1374	1612	1851	2093	2337	2584	2833
less Field Drain Cost	0	0	0	0	7373	6785	0	0	4686	0	0	0	0
NET AGRIC CASH FLOW	0	5082	7481	9342	-87	6221	13709	15622	10697	24831	22057	21810	21578
SCHEME COSTS													
Capital	140010	0	0	0	0	0	0	0	0	0	0	0	0
Recurrent		2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500
TOTAL COSTS	140010	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500
SCHEME NET CASH FLOW	-140010	2582	4981	6842	-2587	3721	11209	13122	8197	22331	19557	19310	19078
NET PRESENT VALUE AT %	0	2.5	5	7.5	10	12.5	15	17.5	20				
	331729	163559	66092	7663	-28424	-51274	-66019	-75648	-81957				

FIGURE 5 : Degree and Rate of Financial Uptake

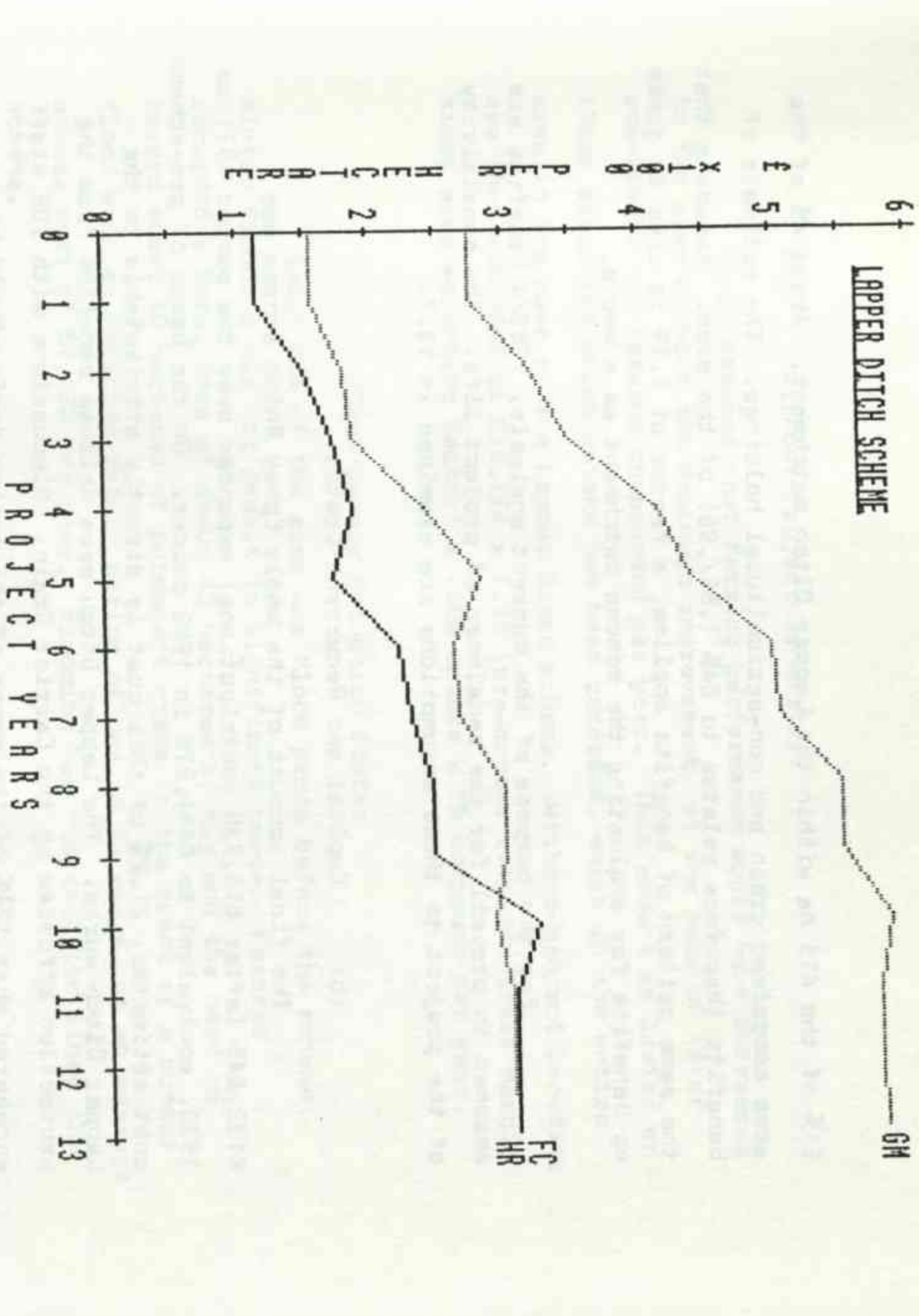
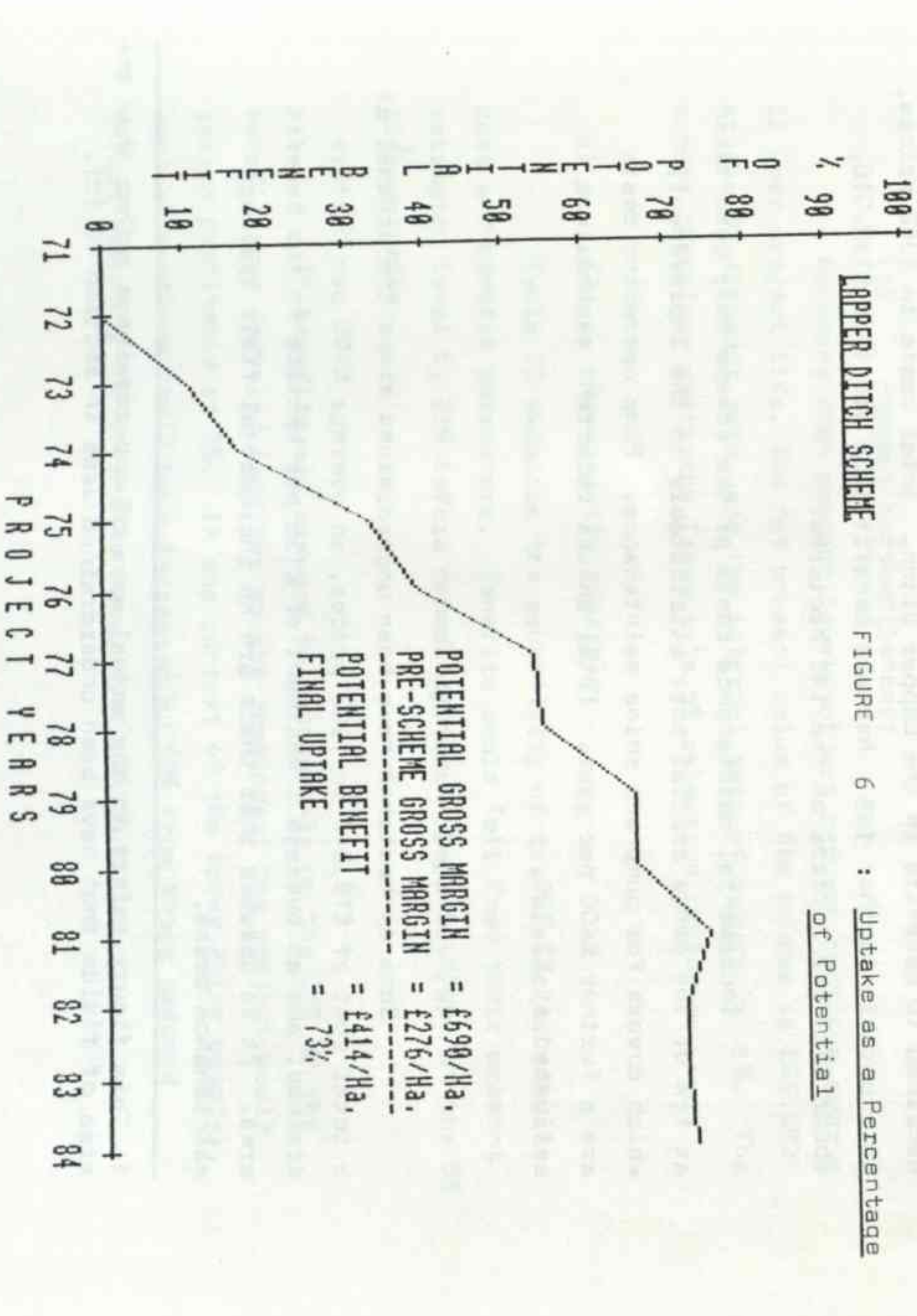


FIGURE 6 : Uptake as a Percentage of Potential



81% of the 415 ha within the Lapper Ditch catchment. About 4% of the area comprised urban and non-agricultural holdings. The estimate of benefits therefore relates to 84% (.81/.96) of the area. Assuming that the same pattern of benefits applies, a factor of 1.19 is used to gross up benefits for evaluating the scheme catchment as a whole.

For the purpose of the current analysis, 1983/4 benefits are assumed to prevail for the remainder of project life. The sensitivity of the project to these assumptions are examined in 13.7.

(b) Capital and Recurrent Costs:

The final account of the whole Epney Rhine scheme was £132,645 (after £15,930 contributions) expended over the period 1971 to 1973, equivalent to £491,278 in 1982 prices. On the basis of pre-scheme cost estimates, 21.2% of this cost is directly attributable to the Lapper Ditch works. The Lapper Ditch area derives benefits from the protection afforded by the Carrier Drain. Discussions with IDB staff suggested that 12½% of the costs of the latter drain should be ascribed to benefits in the Lapper Ditch. Total costs in 1982 prices, attributable to the 145 hectare benefit area are thus £140,010, abour £967 per hectare on the 145 hectares.

Incremental maintenance costs of the scheme have been taken at 1½% of the gross capital cost attributable to the improvement, which covers for pump and rhine maintenance. Pump operating costs are a further £400 per year. Total annual recurrent expenditure is estimated at £2,500.

(c) Field Drainage Costs:

Some 47 hectares have been underdrained since the scheme[1], at a total cost of £18,844 in 1982 prices, an average £400 per hectare drained, and an average investment of £130 per hectare in the benefit area. It is assumed that there are no incremental field drainage maintenance costs.

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1 This figure refers to the actual area of underdrainage rather than the area of fields that have been underdrained used in section 13 (c).

(d) Without-Project Benefits;

It is assumed that farming performance would have increased in the area without the drainage improvement, at the rate of 1% of pre-scheme net returns compounded per year. This amount is levied on those areas for which uptake has been recorded, which is the entire area in the case of the Lapper Ditch scheme. Without-project benefits are thus recorded at £18,774 x 1.19 (pre-scheme recorded gross margin times area weighting factor) x 100% uptake x 1% compound per year.

(e) Flood Damage Reduction Costs:

About 62% of the area was flood prone before the scheme. Winter flooding did not result in significant costs. Farmers recorded a total loss of about 43 hectares of hay and the need to reseed about 10 hectares of permanent grass in the event of a summer flood with an expected return period of one in 15 years, at an average annual cost of £1,120 per year. Flooding has not recurred since the scheme.

(f) Project Worthwhileness:

Assuming that present levels of net returns continue over a 30 year project life, the net present value of the scheme is £66,092 at the 5% discount rate, and the internal rate of return is 8%. The scheme therefore meets the Treasury's 5% selection criteria.

(g) Sensitivity Analysis:

Table 12 examines the sensitivity of the scheme to selected cost and benefit parameters. Benefits could fall from their present estimated level by 25% before the scheme would be prejudiced at the 5% discount rate.

If benefits are assumed to accrue only on the 81% of the benefit area surveyed (and not on the remainder) the project would remain profitable at 5%. In the context of the Epney Rhine complex, cost allocations could have increased by 50% from those assumed before reducing the scheme to break even point.

TABLE 12

Epney Rhine : Lapper Ditch - Sensitivity Analysis

Run No.	Agricultural Benefits Factor	Without Project Benefits Compounding Factor	Flood Damage Reduction Factor	Capital Works Cost Factor	NPV at 5% £	IRR %	Switching Value
1	1.0	1	1	1	66092	8.0	0.75
2	1.0	1.5	1	1	50476	7.3	0.81
3	1.0	0.5	1	1	80995	8.5	0.70
4	1.0		1	1	95219	9.0	0.64
5	1.0	1	0	1	49694	7.2	0.82
6	0.84[a]	1	1	1	24071	6.3	0.89 (of 0.84)
7	1.0	1	1	1.5	0	5.0	0

* The factors show the weights applied to the original estimates eg a factor of 1.5 for the without-project benefits indicates that the new value is 1.5 x 1% compound per year (the original value) ie 1.5% compound.

* Switching value : change in agricultural net benefits needed to make the project breakeven at 5% discount rate eg a 1.5 switch value shows an increase of 1.5 x the original estimated is required.

a Excludes unsurveyed area.

15. Discussion

In terms of meeting its design objectives the scheme has been a success - flooding has not occurred since the scheme and adequate freeboard has been provided for field drainage. The response of farmers to the improvement potential has been good: 53% of the land has been drained and more is likely to be drained in the next few years as both farmers interviewed would like to drain more of their land (although one, being a tenant farmer needs permission from the landlords first); 56% of the peramanent pasture has been ploughed and brought into arable rotations such that in 1983 less than 40% of the Benefit Area is under grass. The lowest lying area (known as 'The Meadows') is still largely under grass, however the productivity of this land has improved markedly (one farmer estimated a 50% increase in production) as land that was previously flooded for most of the winter, unsuitable for trafficking in spring and fit only for one cut of hay is now cut three times a year for silage and grazed until November. In some years wheat has been grown on this land to 'clean' it prior to resseding with grass.

Both farmers have only been on these farms for a relatively short period in relation to the scheme - one arriving a few years prior to, and the other a few years after the commencement of works - although both had farmed in the locality previously. They had both taken over somewhat 'rundown' farms and, largely due to the improvement opportunities presented by the scheme, both have invested heavily in the land in drainage, ditching and reseeding.

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5. South Gloucester IDB, personal communication.