# Severn Trent Region: River Sence, Hilton Brook

## Annex of R&D Note 456

Silsoe College, Cranfield University

R&D Project Record 317/18/ST

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NRA

National Rivers Authority

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Annex of R&D Note 456

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This document describes methods, results and conclusions of a study to evaluate the impacts of alternative river maintenance strategies on the River Sence and Hilton Brook in the Severn Trent Region. Its main purposes are to provide supporting information for R&D Note 456 'River Maintenance Evaluation' and to provide data which support routines for the prioritisation and programming of river maintenance.

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# RIVER SENCE

R&D 317/18/ST

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# 1. BACKGROUND

## 1.1 Introduction

In January 1989, the National Rivers Authority (NRA) Severn Trent Region commissioned Silsoe College to undertake a three year study within the NRA Severn Trent Region to evaluate river maintenance on six sites. The aims, methods, results and recommendations of this study have been presented in a series of reports to the NRA. This study lead to an interest in the development and appraisal of river maintenance in other NRA Regions. The Project Record entitled 'The Evaluation of River Maintenance' was submitted in May 1993. The River Sence (Lower Trent Area) was one of the six sites studied.

The NRA Severn Trent Region commissioned Silsoe College to continue this study throughout five NRA Regions during the period 1992 - 1995. The River Sence was included in this study to allow for an extended period of monitoring and evaluation. Full details on the study reach, benefit area and maintenance are included within the 'Baseline Report' presented to the NRA in 1990.

## 1.2 River Sence

The River Sence rises in Billesden, Leicestershire, and flows in a south-westerly direction to its confluence with the River Soar at Glen Parve, south west of Leicester. The catchment area is predominantly rural and is 133 square kilometres in size. The drift geology is alluvium, overlying Boulder and Upper Lias Clays.

## 1.3 Study Reach

The study reach runs for 4 km between 0.5 km upstream of Kilby Bridge (GR. 616 963) to Crow Mill Bridge (GR. 588 977). This site is characteristic of the main rivers in the region on which river maintenance in the form of desilting and weed clearance is regularly performed. The area of land benefiting from river maintenance in terms of its effect on land drainage and flooding is estimated to be 184 ha. This benefit area has been increased from 132 ha in the previous study due to changes in field boundaries and further analysis of the floodplain topography.

The dominant soil series is the Fladbury Series, bounded to the north by Ragdale and to the south by Beccles 3. Heavy clays are to be found under shallow silty clay loam topsoil.

## 1.4 River Characteristics

The bed width averages 3 m, bank height 1.5 m and discharge 29 cumecs. Several structures are found within the study reach. These include five bridges (two major road bridges, two minor road bridges and one footbridge, three outfalls (one sewage outfall and two concrete lined channels from the urban area to the north) and a weir. The weir lies towards the downstream end of the study reach and has been installed to raise the water level immediately behind it for a take-off stream which feeds Crow Foot Mill.

The Grand Union Canal runs parallel to the river at a distance of approximately 50 to 100 m.

## 1.5 Land Drainage

Eighteen ditches run into the river within the study reach. Ten feed in from the north (right) bank and eight from the south (left) bank. Just over half the benefit area (57 %) is drained by field pipes. The remainder is naturally draining.

## 1.6 River Maintenance

Desilting work was carried out on the River Sence during the winter and early spring of 1990. This was the first desilting maintenance since 1973, when the river was subject to a capital works scheme. The River Sence was identified for maintenance largely as a result of 'tradition', i.e. it was seventeen years since maintenance had last been performed.

This desilting was justified on two counts. Firstly, the River Information Maintenance System (RIMS), held within the NRA Severn Trent Region, was used to estimate the benefits of returning the Standards of Services (SoS) to 1973 levels, since it was felt that SoS had fallen in the previous 17 years. The agricultural benefits were calculated to be sufficiently high to justify the maintenance cost of £ 25000 (final cost following fencing and compensation payments was £ 32000). Secondly, the scheme justification was also based on conservation enhancement.

Plans were drawn up by the conservation department for protection and enhancement measures to be included as part of the maintenance activities. These measures included tree planting, leaving areas of bank and channel vegetation un-touched and the creation of shallow bays.

The design standard for the desilting maintenance was to provide protection against up to a 1 in 10 year flood event. The engineers used MicroFSR and FLUCOMP to calculate the river bed level required to cope with up to a 1 in 10 year event. An additional 50 mm was removed to account for initial sedimentation following maintenance.

Since the desilting of 1990, weed growth in the channel has increased significantly. An annual weed cut using a Bradshaw Bucket is now required in order to reduce the rate of sedimentation as a result of weed growth. Two thirds of the channel vegetation is removed in one cut down the channel centre.

### 1.6.1 Farmers views on maintenance

The majority of farmers interviewed expressed satisfaction with the type and level of maintenance currently performed on the River Sence. However, one voiced the opinion that since the river was desilted, the banks have become more unstable and bank slippage and increased rates of erosion are the result.

### 1.6.2 Alternative maintenance strategies

Various alternative maintenance strategies were suggested by the farmers. Some think that the banks should be protected from erosion and others would like to see more of the channel vegetation cut.

## 1.7 Climate

The impact of river maintenance on watertable depth and river levels depends on the particular weather conditions, especially rainfall, which vary from season to season and year to year. The seasonal and yearly rainfall totals for the period of this study (1992 - 1995) are presented in Table 1.1. Rainfall information for the period 1988 to 1991 is contained within the 'RIMS Project Evaluation River Sence' report submitted to NRA Severn Trent in March 1992.

**Table 1.1 Rainfall totals**

| Period | Season | Actual Rainfall (mm) | Average * Rainfall (mm) | % Average Rainfall |
|---|---|---|---|---|
| 1992 | Spring | 171.7 | 149.1 | 115.2 |
| | Summer | 193.4 | 114.4 | 169.1 |
| | Autumn | 311.5 | 166.9 | 186.6 |
| 1993 | Spring | 150.3 | 149.1 | 100.8 |
| | Summer | 223.9 | 114.4 | 195.7 |
| | Autumn | 240.8 | 166.9 | 144.3 |
| 1994 | Spring | 162.1 | 149.1 | 108.7 |
| | Summer | 187.4 | 114.4 | 163.8 |
| | Autumn | 82.7 | 166.9 | 49.6 |
| 1995 | Spring | 113.5 | 149.1 | 76.1 |
| Total | 1992 | 851.8 | | |
| | 1993 | 760.7 | | |
| | 1994 | 660.2 | | |

* Based on 27 year record from 1965 - 1991, Kilby Bridge

The summers of 1992 - 1994 were wet when compared to the average rainfall. This is confirmed by farmers who reported wet conditions on the land and an increased incidence of flooding. The other seasons are classed as average or dry.

Monthly rainfall records from Kilby Bridge (GR. 4609 2970), the nearest meteorological station to the study site, covering a period of 27 years (1965 - 1991) have been analysed in order to determine the probability of a dry, average and wet season and year occurring. The classification of the Food and Agricultural Organisation (FAO) was used to do this. Dry and wet seasons and years are classed as those with less than 75 % and greater than 125 % of the average rainfall total respectively. Further details are presented in the R&D Note 456, Section 3.5.4.

**Table 1.2 Probability of climatic conditions**

| Season | Dry * | Average * | Wet * |
|---|---|---|---|
| Spring | 0.17 | 0.76 | 0.07 |
| Summer | 0.14 | 0.65 | 0.21 |
| Autumn | 0.35 | 0.62 | 0.03 |
| Year | 0.48 | 0.45 | 0.07 |

* Based on records 1965 - 1991

The process by which financial benefits of maintenance are calculated according to the probability of each type of weather season and year occurring is explained in the R&D Note 456, Section 3.5.4.

## 1.8 Aquatic Vegetation

Aquatic vegetation within the channel was identified prior to weed clearance (Section 1.8.1 to 1.8.3). This vegetation has both hydraulic and environmental implications for the channel.

### 1.8.1 Submerged vegetation

*Potamogeton natans*; commonly known as Dogs Tongue or pondweed is the dominant species of aquatic weed within the study reach. Its preferred habitat is areas of sluggish to moderate flows such as drainage channels, lakes and ponds.

### 1.8.2 Emergent vegetation

The pondweed, with oval dark green leaves is classed as a broad-leaved emergent plant although it often may have some submerged leaves, which are linear in form. It is streamlined in the direction of flow.

The greater the discharge, the lower the resistance of the pondweed to flow. *Potamogeton natans* is the commonest of the Pondweed species with floating leaves. Unlike other pond weeds, its' leaves are jointed at their junction with a long stalk. As the *Potamogeton* regenerates through rhizomes (underground stems) it may be difficult to control. Any form of control which leaves these rhizomes intact may have only a short term benefit. Desilting may be necessary at times in order to reduce or remove the 'seed bank' of *Potamogeton* from the river.

The tall emergent grass *Glyceria* (Reed Sweet-grass) is found within the River Sence. This grass may reach up to 2 m in height and grows in dense stands in slow moving water. It provides greater resistance to flow than some submerged plants as it can create a fairly impermeable barrier to the flow of water, depending on the density of the vegetation stand.

Control of *Glyceria* may be difficult as it reproduces through a system of rhizomes (underground stems) which are buried in the mud and silt of the channel bed. Unless these rhizomes are removed through desilting, *Glyceria* will regrow the following year.

The Rush *(Juncus)* ranges in height from 0.1 to 1.5 m. This plant occurs throughout Britain and exists in two forms. One is a leafless, unbranched stem which supports flowers near the top. This commonly grows in clumps along the water margins. The second form is a leaf-bearing stem which can tolerate deeper water. Flowers are borne at the ends of branched stems.

Fool's Water-Cress *(Apium spp.)* is found lining the channel margins, often forming large stands. It has compound leaves with toothed edges and tiny white flowers which are clustered together in an umbrella shape. One of its characteristics is that once crushed, it smells like parsnip or carrot.

The Arrowhead *(Sagittaria spp.)* is classed as an emergent broad-leaved plant of still to slow moving water although it often exhibits submerged and floating leaves. It is characterised by bright green arrow-shaped leaves which have parallel veins and a slightly translucent appearance. White and purple flowers are borne on stems in whorls of three during July and August.

### 1.8.3 Algae

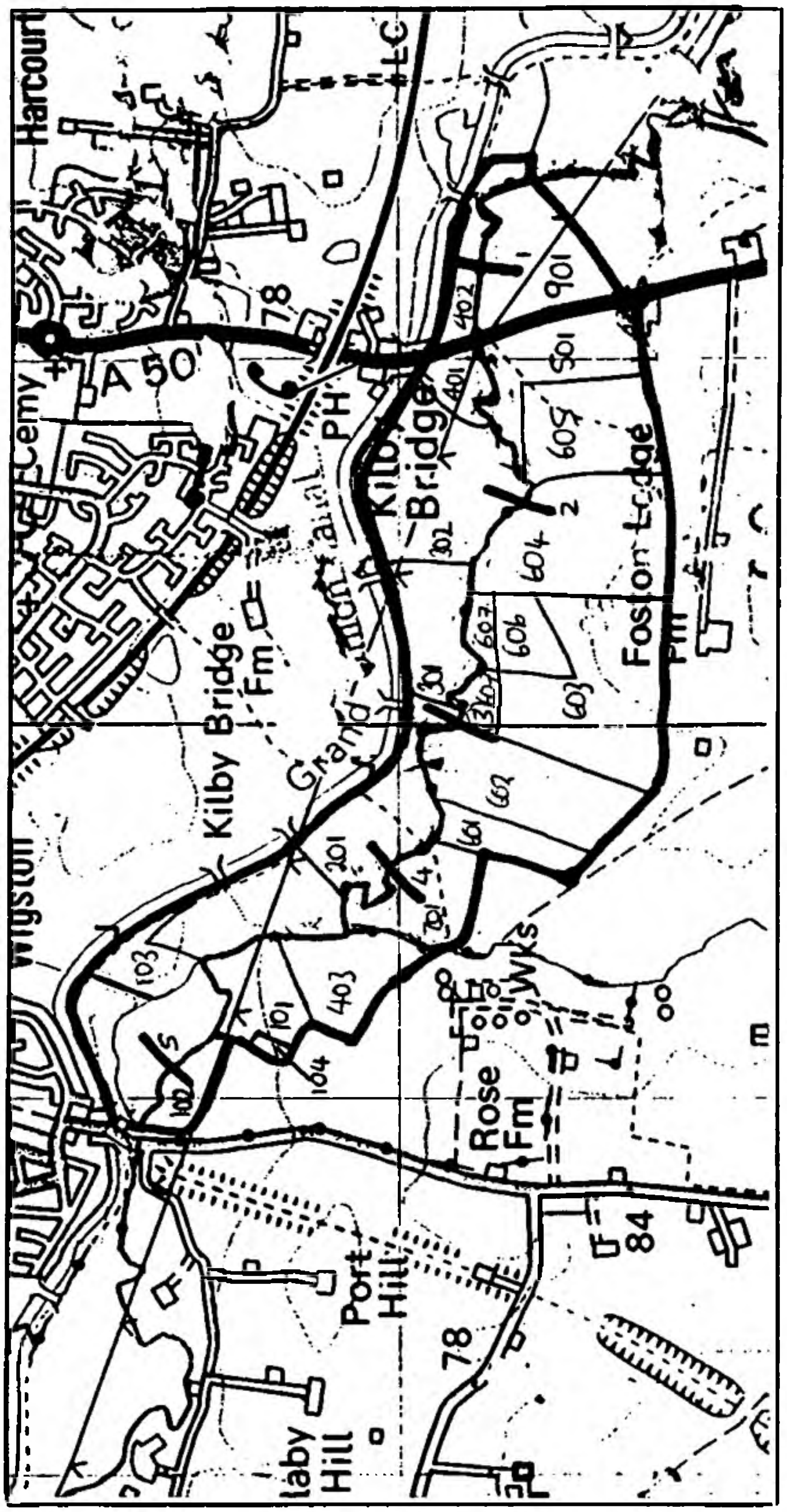
Filamentous algae is common. This algae grows in long chains from the hydrosoil. It is difficult to control as it can be found anywhere and grows rapidly through simple fission by which each cell divides. Algae is common in nutrient rich waters and frequently invades areas where other aquatic plants have been controlled or eradicated.

# 2. FARM SURVEY

## 2.1 Introduction

Through structured interviews and informal discussions with farmers and a topographical survey, the area deriving a benefit from the river maintenance work on the River Sence in terms of its impact on land drainage and flooding is estimated to be 184 ha. Detailed interviews and discussions have been held with nine farmers within the benefit area. The benefit area has been divided into blocks according to land use, drainage condition, flooding and land management practices (Figure 1).

Full details on farm size, type, arable and livestock enterprises, conservation and grazing systems and nitrogen application rates has been presented to the NRA in the report entitled 'RIMS Project Evaluation, River Sence', submitted to the NRA in March 1992.




Legend :

Scale 1 : 12 500

101 Land blocks

/1 Cross-section location

**Figure 1** **Land blocks and location of cross-sections**

## 2.2 Land Use In The Benefit Area

Details of land use and piped drainage in the benefit area are summarised in Table 2.1. The dominant land use is extensive grassland (50 % of benefit area). Grassland under the extensive system is used for permanent grazing of sheep and beef over a short season. Little, if any grass is conserved and nitrogen inputs are low. Intensive grassland is characterised by long grazing seasons, high rates of nitrogen input ( > 100 kg N/ha) and is commonly grazed with dairy cattle. The majority of land under an arable rotation is drained by pipes. Figure 2 provides further information on land use in the benefit area.

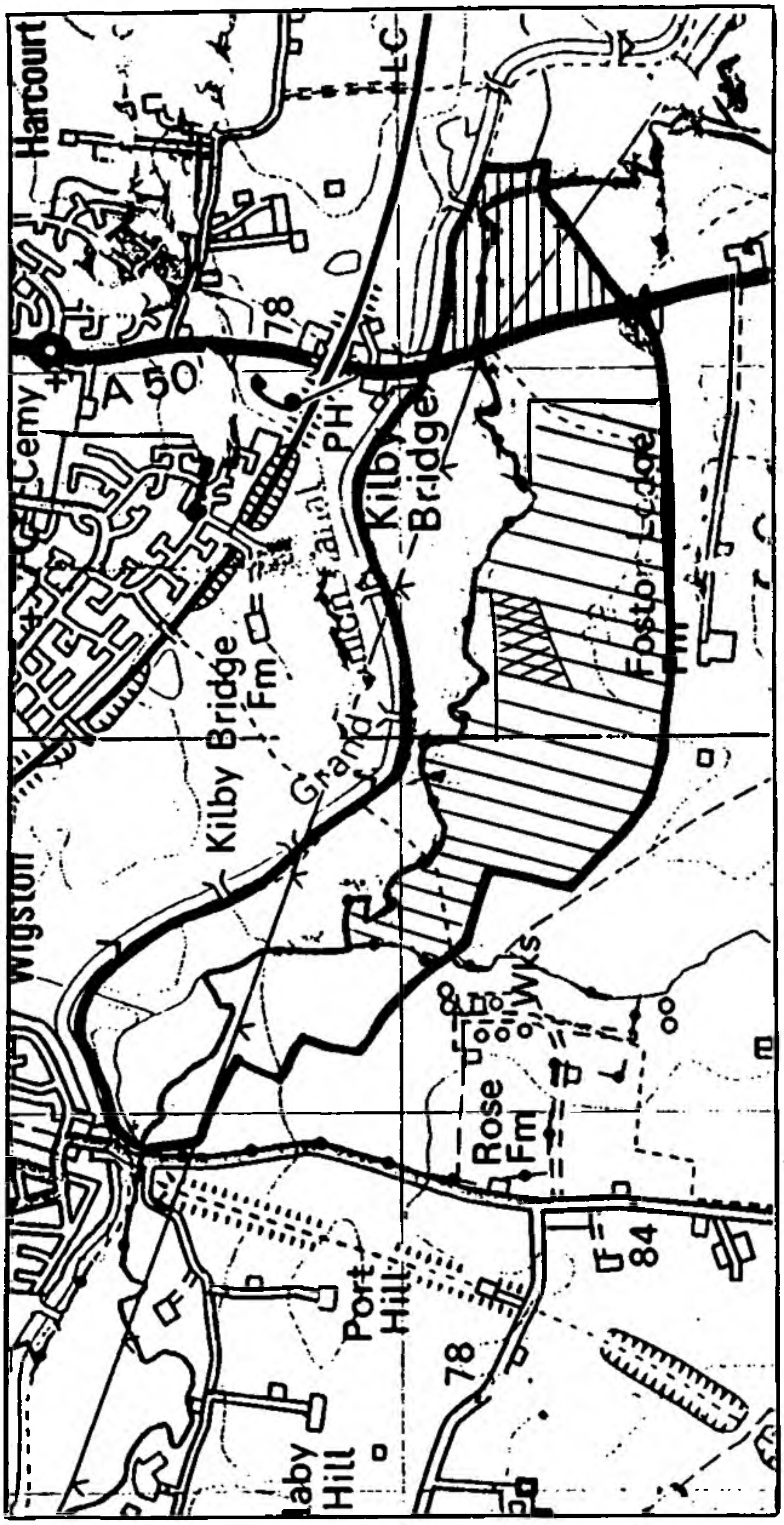
**Table 2.1 Land use in the benefit area**

| Land Use | Area (ha) | % of Benefit Area | % Drained By Pipes |
|---|---|---|---|
| Extensive Grass | 92.5 | 50.2 | 47 |
| Intensive Grass | 30.7 | 16.6 | 53 |
| Grass / arable | 53.6 | 29.1 | 72 |
| Cereal / Oilseed | 7.6 | 4.1 | 100 |

## 2.3 Flooding

Eight of the nine farmers within the benefit area reported flooding on their land during the course of this study. In each case the source of the flood water is said to be the river whose high levels are due to a combination of high rainfall and weed growth. The area which typically floods is shown in Figure 3. Flooding from surface runoff does not appear to be a major contributory factor to flooding.

The duration of flooding is reported to be between one and 10 days. Floods of longer duration correspond to areas which are under a system of extensive grassland. Crop damage, reduced yields and litter and debris are said to be the main consequences of flooding. One farmer reported livestock loss as a potential problem and has lost livestock in floods previously.

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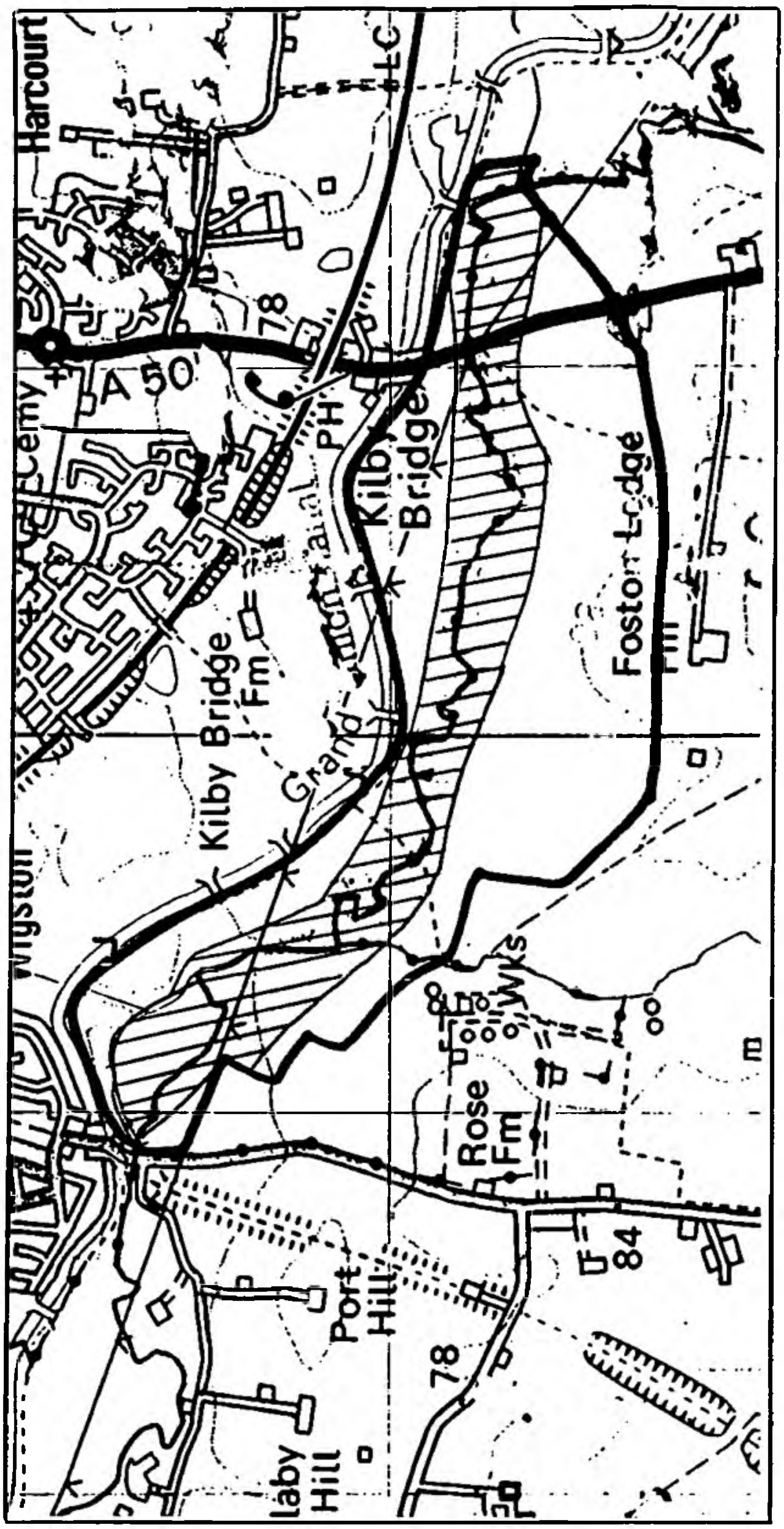
Intensive grass

Extensive grass

Grass / arable rotation

Cereal / oilseed rotation

**Figure 2** **Land use in the benefit area**




Legend :

Flooded areas

Scale 1 : 12 500

**Figure 3** **Areas prone to flooding**

## 2.4 Waterlogging

The wetness condition of the soil within the benefit area in spring, summer and autumn, as reported by farmers, is shown in Table 2.2.

In the summer, all the land within this area appears well drained, with 15 % of the land being rarely wet and the remainder only occasionally wet. The wetter conditions in spring and autumn have been attributed by the farmers to relatively high rainfall. During the autumn, 50 % of the benefit area is reported to be permanently waterlogged.

**Table 2.2 Farmer assessment of wetness condition**

| Season | Wetness Condition | Area (ha) | % Area |
|---|---|---|---|
| Spring | Rarely wet | 8.6 | 5 |
| | Occasionally wet | 86.5 | 47 |
| | Often wet | 89.3 | 48 |
| | Permanently wet | 0.0 | 0 |
| Summer | Rarely wet | 27.7 | 15 |
| | Occasionally wet | 156.7 | 85 |
| | Often wet | 0.0 | 0 |
| | Permanently wet | 0.0 | 0 |
| Autumn | Rarely wet | 15.4 | 8 |
| | Occasionally wet | 27.4 | 15 |
| | Often wet | 50.4 | 27 |
| | Permanently wet | 91.2 | 50 |

## 2.5 Statistical Analysis

It is apparent that land use, drainage and flooding are interrelated. Statistical methods were used to determine whether these relationships occurred more frequently than might be expected by pure chance. Full details of this analysis in which the 12 sites were grouped according to NRA Region, are presented in the Interim Report R&D 317/13/ST, presented to the NRA in December 1994.

The following observations can be made from the statistical analysis of fields in the benefit area of the River Sence maintenance programme:

- A strong relationship exists between land use and the presence of field drainage. The majority of land under a grass / arable rotation and all land within the cereal / oilseed rotation is drained by pipes. Extensive grassland is predominantly naturally draining. (Statistically, there is a 92 % chance of correctly predicting the installation of field drainage on the basis of land use).

- Areas which flood most frequently and for the longest duration are under grassland systems. Areas under the cereal / oilseed rotation are not prone to flooding. (Statistically, there is an 81 % chance of correctly predicting the incidence of flooding on the basis of land use).

- Turnout dates for livestock are related to field wetness conditions in the spring. Turnout dates range from mid March on land which is rarely wet to mid May on land which is often wet underfoot in the spring. (Statistically, there is 90 % chance of correctly predicting turnout dates on the basis of field wetness condition in the spring).

- Yarding dates for livestock are related to field wetness condition in the autumn. Land which is often or permanently wet is closed to grazing in mid October. Land which is only occasionally wet, provides grazing over the winter period. (Statistically, there is an 85 % chance of correctly predicting yarding dates on the basis of field wetness condition in the autumn).

- A relationship exists between levels of nitrogen application and the grass conservation system. Grass cut for silage receives higher levels of application than that which is grazed only. (Statistically, there is an 87 % chance of correctly predicting the conservation system practised on the basis of nitrogen application rates).

# 3 HYDRAULIC AND HYDROLOGICAL INFORMATION

## 3.1 Introduction

Information on channel hydraulics and hydrological data has been used to determine the impact of maintenance on channel capacity and flood return periods.

## 3.2 Cross-section Surveys

Cross-sectional surveys of the river channel were taken at five points (Figure 1) along the study reach at an average interval of 830 m before and after the desilting work. Channel capacity and freeboard were determined from these cross-sections.

Prior to maintenance, the channel roughness was expressed in terms of the Manning's n coefficient, in accordance with the methodology developed by Cowan (1956). This coefficient is composed of six elements which include the degree of irregularity of the channel bed, level of vegetation growth, predominant bed material and channel sinuosity. Further details of this methodology are contained within the R&D Note 456, Appendix IV. Friction values were determined for the channel following maintenance using the same procedure in order to identify roughness values for the 'with' and 'without' maintenance situation.

Stage/discharge curves for the 'with' and 'without' maintenance situation have been constructed for each cross-section using the different values of Manning's 'n'. The cross-section surveys and stage / discharge curves are presented in Appendix II of the 'RIMS Project Evaluation - River Sence' report submitted to the NRA in March 1992. The bankfull channel capacities and associated return periods for the 'with' and 'without' maintenance scenario are presented in Table 3.1.

The bankfull capacity figures obtained from the cross-sections indicate an average increase in capacity attributable to maintenance of 50 % (from 8.04 cumecs to 12.1 cumecs) and an average increase in the interval between flood events of 114 %.

**Table 3.1 Bankfull capacity and return periods**

| Cross-Section | Without Maintenance Bankfull Capacity ($m^3/s$) | Without Maintenance Return Period (years) | With Maintenance Bankfull Capacity ($m^3/s$) | With Maintenance Return Period (years) |
|---|---|---|---|---|
| 1 | 4.97 | 0.23 | 9.30 | 0.47 |
| 2 | 5.43 | 0.24 | 9.88 | 0.49 |
| 3 | 5.55 | 0.25 | 8.59 | 0.47 |
| 4 | 7.06 | 0.31 | 10.73 | 0.65 |
| 5 | 17.17 | 0.50 | 22.25 | 1.20 |

(Source: modelled estimates)

## 3.3 Flood Return Period

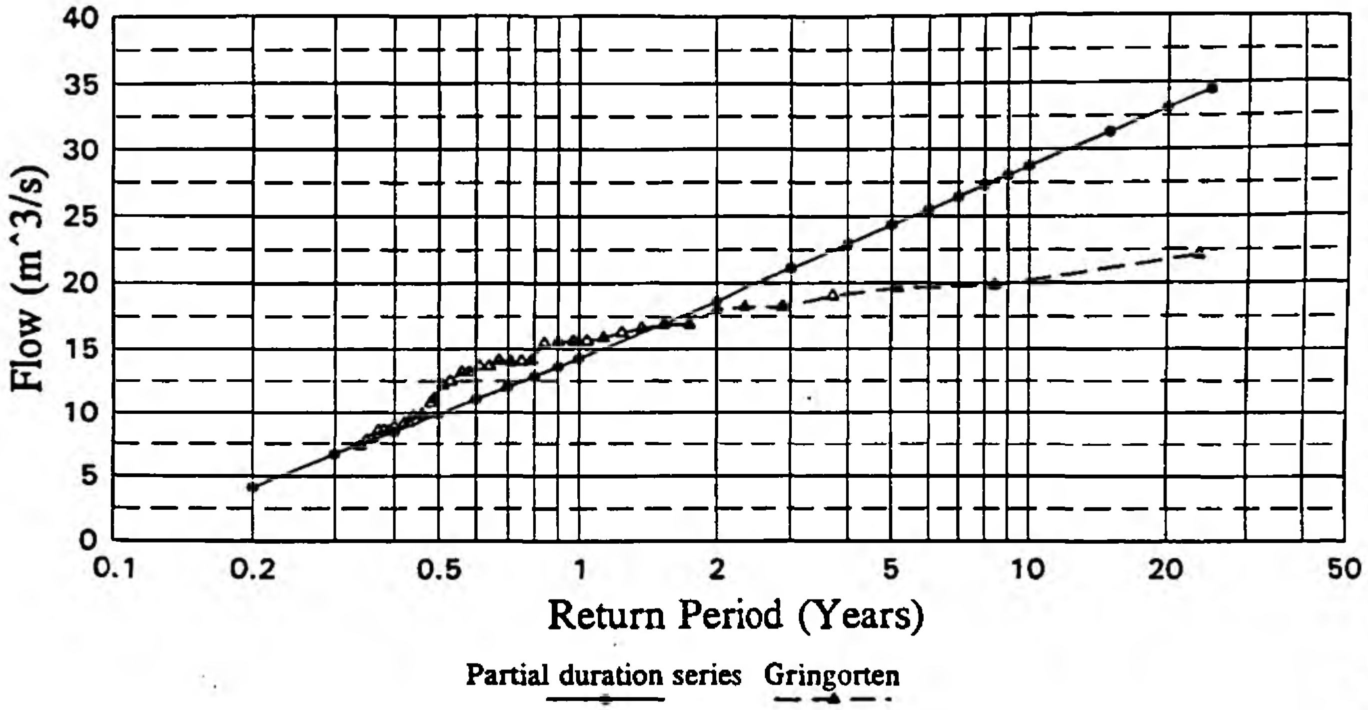
Throughout the period of study (1992 to 1995) river water level information was collected on a regular basis from the gauging station at Crow Mill and from a level recorder which was installed in the study reach in October 1993.

Information regarding frequency, duration and magnitude of flood flows has been collected from interviews with local farmers and NRA staff. Flood return period curves for the River Sence have been compiled from this information, using the methodology contained within the Flood Studies Report (NERC, 1975). The frequency of floods of different magnitudes can be estimated from these flood return period curves (Figure 4).

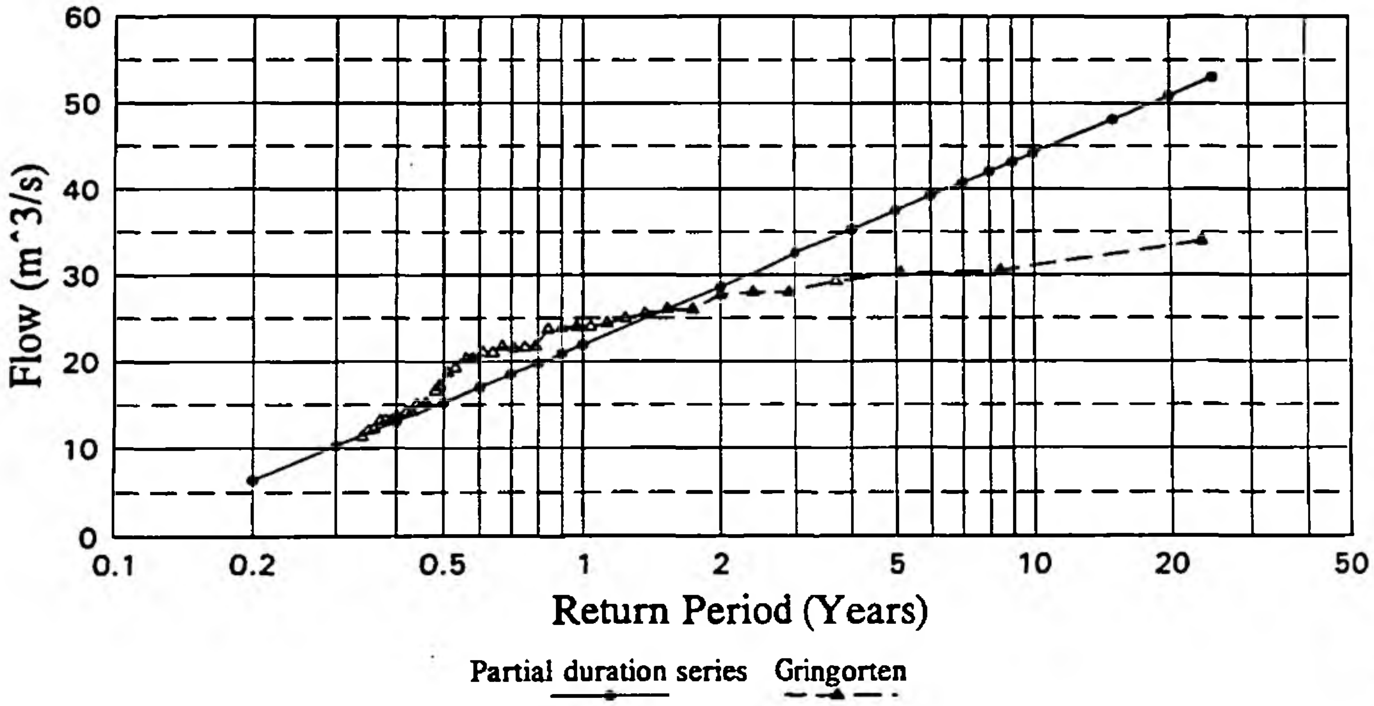
The flood return period and flooded areas for each block which floods are shown in Table 3.2. The 'without' maintenance return period is estimated by the farmer, the 'with' maintenance value is a modelled estimate using the cross-section information and Manning's n coefficient. It is assumed that the flooded area remains unchanged following maintenance.

**Table 3.2 Flood return periods and flooded areas**

| Block No. (Size, ha) | Flooded Area (ha) | Flood Return Period (Years) Without | Flood Return Period (Years) With | Block No. (Size, ha) | Flooded Area (ha) | Flood Return Period (Years) Without | Flood Return Period (Years) With |
|---|---|---|---|---|---|---|---|
| 101 (20.8) | 20.80 | 3.00 | 4.80 | 403 13.0) | 5.80 | 0.25 | 2.00 |
| 102 (6.8) | 1.70 | 3.00 | 4.80 | 501 (9.0) | 4.05 | 0.38 | 1.35 |
| 103 (3.1) | 1.55 | 3.00 | 4.80 | 601 (8.8) | 6.16 | 0.35 | 0.55 |
| 104 (2.4) | 0.96 | 3.00 | 4.80 | 603 (6.9) | 1.38 | 0.55 | 1.00 |
| 201 (8.6) | 2.15 | 0.73 | 1.15 | 604 (11.6) | 11.6 | 0.60 | 1.00 |
| 301 (10.4) | 7.80 | 0.35 | 0.55 | 606 (7.6) | 2.28 | 0.55 | 1.00 |
| 302 (13.4) | 6.70 | 0.38 | 1.35 | 607 (2.0) | 2.00 | 0.30 | 2.00 |
| 401 (3.4) | 1.49 | 0.25 | 2.00 | 701 (9.1) | 7.20 | 0.73 | 1.15 |
| 402 (16.4) | 3.20 | 0.25 | 2.00 | 901 (14.3) | 12.87 | 0.33 | 0.85 |




For cross-sections upstream of confluence




For cross-sections downstream of confluence

**Figure 4** **Flood return period**

# 4. LAND DRAINAGE

## 4.1 Field Drainage Status

Through an extensive literature and farmer survey, drainage status of the land has been classified into three bands according to watertable depth. These watertable bands have been identified as > 0.5 m from the surface, between 0.3 and 0.5 m from the surface and < 0.3 m from the surface. According to the time the watertable lies within these bands, the drainage status is classed as good (G, no limitations on land use), bad (B, some restrictions on agriculture) or very bad (VB, severe limitations to agriculture). Further details are presented in the R&D Note 456, Section 3.5.2.

The drainage status of land within the benefit area has been determined on a seasonal basis using a non-steady state watertable model which relates infield watertable levels (and hence drainage conditions) to observed water levels in the river and ditch system (see R&D Note 456, Section 3.5.2 for further details). The model has been run using river water levels for the 'with' and 'without' maintenance scenario and the same climatic data in order to isolate the impact of maintenance on drainage status. An example of the input and output data of the model is shown in Appendix I.

The results of the watertable model and the assessment of drainage status made by farmers are shown in Table 4.1. In some cases, there may be a change in the number of weeks that the watertable lies within the good, bad and very bad drainage bands following maintenance. However, these changes may not be of sufficient magnitude to change the drainage status classification. Where a sufficient change in drainage status has occurred due to maintenance, the changes appear in bold print in Table 4.1.

These assessments confirm that the drainage status in the benefit area 'with' maintenance is generally good under dry climatic conditions, mixed under average conditions and very bad under wet climatic conditions. If maintenance were not performed, drainage conditions would deteriorate towards very bad in a wet season and bad under average and dry conditions. In a wet season, there is 65 % agreement between farmer and modelled assessment of field drainage conditions 'with' maintenance. In an average and dry season, agreement between the two estimates for the drainage condition 'with' maintenance is 75 % and 70 % respectively.

In the 'without' maintenance situation, there is 85 % agreement between farmer assessment of field drainage conditions and those predicted by the model under average weather conditions.

**Table 4.1 Drainage status for wet, average and dry seasons, without/with maintenance**

| Block No | | Wet Season * | | Average Season * | | Dry Season * | | Farmer Assessment With Maintenance | | | Without |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Without | With | Without | With | Without | With | Wet | Average | Dry | |
| 101 | N | **VB** | **B** | B | B | B | B | B | B | *G* | B |
| 102 | N | **VB** | **B** | B | B | B | B | B | B | *G* | B |
| 103 | N | **VB** | **B** | B | B | B | B | B | B | *G* | B |
| 104 | N | B | B | **B** | **G** | **B** | **G** | B | G | G | B |
| 201 | N | VB | VB | B | B | B | B | *B* | *G* | G | B |
| 301 | Y | **VB** | **B** | B | B | **B** | **G** | *VB* | *G* | G | B |
| 302 | N | VB | VB | B | B | **B** | **G** | VB | B | G | VB |
| 401 | Y | **VB** | **B** | B | B | **B** | **G** | B | *G* | G | B |
| 402 | Y | **VB** | **B** | B | B | **B** | **G** | *VB* | *VB* | *B* | VB |
| 403 | N | **VB** | **B** | B | B | **B** | **G** | B | *G* | G | B |
| 501 | Y | **B** | **G** | **B** | **G** | G | G | G | G | G | B |
| 601 | Y | G | G | G | G | G | G | G | G | G | G |
| 602 | N | VB | VB | B | B | B | B | *B* | B | *G* | B |
| 603 | N | VB | VB | B | B | B | B | *B* | B | *G* | B |
| 604 | Y | B | B | **B** | **G** | G | G | B | G | G | B |
| 605 | Y | **B** | **G** | G | G | G | G | *B* | G | G | G |
| 606 | N | **VB** | **B** | **B** | **G** | G | G | B | G | G | B |
| 607 | N | **VB** | **B** | **B** | **G** | G | G | B | G | G | B |
| 701 | Y | G | G | G | G | G | G | *B* | B | G | B |
| 901 | N | B | B | **B** | **G** | **B** | **G** | B | G | G | B |

NB : * Modelled results
Y or N refers to the presence or absence of field drainage
Bold type indicates a change in drainage status due to maintenance
Italics indicate a difference in farmer and modelled assessment of drainage status with maintenance

River maintenance results in the prevention of a deterioration of drainage status on 11 blocks of land in a wet season, six in an average season and seven in a dry season.

- In a wet season maintenance prevents deterioration from :

  B to VB over 84 ha (46 % of BA)

  G to B over 18 ha (10 % of BA)

- In an average season maintenance prevents deterioration from :

  G to B over 47 ha (25 % of BA)

- In a dry season maintenance prevents deterioration from :

  G to B over 74 ha (40 % of BA)

Farmer perception of drainage deterioration due to lack of maintenance (under average conditions) was from good to bad on 45 % of the benefit area and from bad to very bad on 7 % of the benefit area.

# 5 SCHEME APPRAISAL

## 5.1 Benefit Assessment

For each block of land, agricultural production scenarios were created which reflect different levels of field management under conditions of good, bad and very bad drainage (see R&D Note 456 Section 3.5.4). These scenarios are based on discussions with farmers in the benefit area over the period 1992-1994.

Changes in field drainage status as a result of maintenance under dry, average and wet climatic conditions have been identified. Changes in flood risk due to maintenance have also been determined. Estimates have been derived of the monetary value of changes in field management and productivity associated with changes in the standards of drainage service.

Two perspectives have been used to value agricultural performance. The first perspective is that of financial analysis which uses the prices paid and received by farmers to estimate the added-value associated with drainage. Financial analysis shows the benefits of maintenance to farmers in the benefit area.

The second perspective is that of economic analysis which modifies the financial analysis to make allowance for the direct and indirect subsidies paid to farmers by Government. In accordance with the MAFF Project Appraisal Guidance Notes on Flood Defence (PAGN, 1993), these modifications involve reductions in the financial value of output (including subsidies) by 10% in the case of cereals, oil seeds and grain legumes, 35 % for beef and 25 % for sheep. Commodities subject to quota such as potatoes, sugar beet and milk are treated as winter wheat. The set aside areas are also treated as wheat. The reasons for these adjustments are discussed in the R&D Note 456 Section 2.7.2.

Using the results of watertable modelling, Table 5.1 shows the financial net returns (1995/96 prices) for each block of land within the benefit area under conditions of good, bad and very bad drainage. Changes in net returns relating to a change in drainage status are also shown. Table 5.2 presents similar data using economic prices. Table 5.3 shows the flood costs for each block of land assuming 'with' and 'without' maintenance and specified field drainage conditions. It is assumed that there is no difference between financial and economic values in the case of flood damage to standing crops.

Table 5.4 combines data on changes in drainage status, flood risk and financial performance to determine the financial benefits and change in financial net returns due to maintenance for wet, average and dry weather conditions for each block of land in the benefit area. These benefits are the avoidance of losses which would occur in the absence of maintenance. Benefits, weighted by field size for wet, average and dry seasons are multiplied by the relative probability of the occurrence of the season to give an average expected annual benefit. These are summed for the benefit area as a whole.

Table 5.4 estimates a total expected annual benefit of about £ 5800 in 1995 financial prices, equivalent to about £ 32/ha per year. Table 5.5 shows the benefits attributable to maintenance using economic prices based on the current MAFF Project Appraisal Guidance Notes. Total average expected annual benefits are about £ 5160 in economic prices for the benefit area, equivalent to £ 28/ha. On this basis, the benefit to the national economy is 65 % of the benefits which accrue to farmers. This difference reflects the adjustments required by MAFF to remove government subsidy from the assessment of benefits.

**Table 5.1 Financial net returns**

| Block | Area | Net Return (£/ha) | | | Change in Net Return (£/ha) | | |
|---|---|---|---|---|---|---|---|
| | (ha) | Good | Bad | Very | Good to | Bad to | Good to |
| | (ha) | | | Bad | Bad | Very Bad | Very Bad |
| 101 | 20.79 | 278 | 266 | 221 | 12 | 45 | 57 |
| 102 | 6.83 | 352 | 266 | 221 | 87 | 45 | 131 |
| 103 | 3.10 | 295 | 284 | 238 | 10 | 47 | 57 |
| 104 | 2.40 | 260 | 253 | 181 | 8 | 72 | 80 |
| 201 | 8.62 | 214 | 138 | 105 | 76 | 33 | 109 |
| 301 | 10.44 | 153 | 122 | 93 | 31 | 29 | 61 |
| 302 | 13.38 | 124 | 122 | 93 | 2 | 29 | 31 |
| 401 | 3.40 | 421 | 329 | 247 | 92 | 81 | 174 |
| 402 | 16.40 | 154 | 148 | 87 | 6 | 61 | 67 |
| 403 | 13.00 | 503 | 380 | 287 | 123 | 94 | 216 |
| 501 | 9.01 | 194 | 176 | 146 | 18 | 30 | 48 |
| 601 | 8.77 | 269 | 242 | 149 | 27 | 93 | 120 |
| 602 | 7.47 | 264 | 237 | 146 | 27 | 92 | 119 |
| 603 | 6.90 | 579 | 499 | 316 | 79 | 183 | 263 |
| 604 | 11.60 | 526 | 311 | 192 | 215 | 119 | 334 |
| 605 | 8.90 | 522 | 302 | 176 | 219 | 127 | 346 |
| 606 | 7.60 | 468 | 390 | 262 | 78 | 128 | 207 |
| 607 | 2.03 | 165 | 134 | 112 | 31 | 22 | 53 |
| 701 | 9.11 | 321 | 297 | 180 | 24 | 117 | 141 |
| 901 | 14.30 | 168 | 176 | 87 | -8 | 89 | 81 |

**Table 5.2 Economic net returns**

| Block | Area | Net Return (£/ha) | | | Change in Net Return (£/ha) | | |
|---|---|---|---|---|---|---|---|
| | (ha) | Good | Bad | Very | Good to | Bad to | Good to |
| | (ha) | | | Bad | Bad | Very Bad | Very Bad |
| 101 | 20.79 | 86 | 58 | 35 | 28 | 22 | 51 |
| 102 | 6.83 | 6 | 58 | 35 | -52 | 22 | -30 |
| 103 | 3.10 | 88 | 60 | 38 | 28 | 22 | 50 |
| 104 | 2.40 | 54 | 54 | 33 | -1 | 21 | 21 |
| 201 | 8.62 | 108 | 41 | 19 | 66 | 23 | 89 |
| 301 | 10.44 | 42 | 21 | 3 | 21 | 18 | 39 |
| 302 | 13.38 | -9 | 21 | 3 | -30 | 18 | -12 |
| 401 | 3.40 | 148 | 111 | 71 | 37 | 39 | 76 |
| 402 | 16.40 | -33 | -21 | -29 | -12 | 7 | -4 |
| 403 | 13.00 | 179 | 123 | 78 | 56 | 45 | 101 |
| 501 | 9.01 | 88 | 79 | 60 | 9 | 19 | 28 |
| 601 | 8.77 | 130 | 105 | 46 | 24 | 59 | 84 |
| 602 | 7.47 | 126 | 105 | 46 | 21 | 59 | 80 |
| 603 | 6.90 | 464 | 395 | 232 | 69 | 163 | 232 |
| 604 | 11.60 | 423 | 187 | 92 | 236 | 95 | 331 |
| 605 | 8.90 | 519 | 104 | 43 | 415 | 61 | 476 |
| 606 | 7.60 | 406 | 329 | 204 | 78 | 124 | 202 |
| 607 | 2.03 | 58 | 37 | 25 | 22 | 11 | 33 |
| 701 | 9.11 | 131 | 120 | 57 | 12 | 63 | 74 |
| 901 | 14.30 | -161 | -123 | -107 | -38 | -17 | -54 |

**Table 5.3 Flood costs**

| | | | GOOD DRAINAGE | | BAD DRAINAGE | | VERY BAD DRAINAGE | | CHANGE IN FLOOD COSTS | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Block Number | Without maintenance return period | With maintenance return period | Without maintenance flood cost | With maintenance flood cost | Without maintenance flood cost | With maintenance flood cost | Without maintenance flood cost | With maintenance flood cost | GOOD Without -with | BAD Without -with | VERY BAD Without -with | GOOD TO BAD Without -with | BAD TO VERY BAD Without -with | GOOD TO VERY BAD Without -with |
| 101 | 3.00 | 4.80 | 1.66 | 1.04 | 1.78 | 1.11 | 1.62 | 1.01 | 0.62 | 0.67 | 0.61 | 0.74 | 0.51 | 0.58 |
| 102 | 3.00 | 4.80 | 1.10 | 0.69 | 0.45 | 0.28 | 0.40 | 0.25 | 0.41 | 0.17 | 0.15 | -0.24 | 0.12 | -0.29 |
| 103 | 3.00 | 4.80 | 0.83 | 0.52 | 0.90 | 0.56 | 0.80 | 0.50 | 0.31 | 0.34 | 0.30 | 0.38 | 0.24 | 0.28 |
| 104 | 3.00 | 4.80 | 1.22 | 0.76 | 1.12 | 0.70 | 0.85 | 0.53 | 0.46 | 0.42 | 0.32 | 0.36 | 0.15 | 0.09 |
| 201 | 0.73 | 1.15 | 1.78 | 1.13 | 1.64 | 1.04 | 1.47 | 0.93 | 0.65 | 0.60 | 0.54 | 0.51 | 0.43 | 0.34 |
| 301 | 0.35 | 0.55 | 13.51 | 8.60 | 12.54 | 7.98 | 11.49 | 7.31 | 4.91 | 4.56 | 4.18 | 3.94 | 3.51 | 2.89 |
| 302 | 0.38 | 1.35 | 12.83 | 3.61 | 7.71 | 2.17 | 7.07 | 1.99 | 9.22 | 5.54 | 5.08 | 4.10 | 4.90 | 3.46 |
| 401 | 0.25 | 2.00 | 13.56 | 1.70 | 10.88 | 1.36 | 8.86 | 1.11 | 11.87 | 9.52 | 7.75 | 9.19 | 7.50 | 7.17 |
| 402 | 0.25 | 2.00 | 11.80 | 1.48 | 9.63 | 1.20 | 6.59 | 0.82 | 10.33 | 8.43 | 5.77 | 8.16 | 5.39 | 5.12 |
| 403 | 0.25 | 2.00 | 16.21 | 2.03 | 9.63 | 1.20 | 10.55 | 1.32 | 14.18 | 8.43 | 9.23 | 7.60 | 9.35 | 8.52 |
| 501 | 0.38 | 1.35 | 3.98 | 1.12 | 5.65 | 1.59 | 5.04 | 1.42 | 2.86 | 4.06 | 3.62 | 4.53 | 3.45 | 3.92 |
| 601 | 0.35 | 0.55 | 77.24 | 49.15 | 65.14 | 41.45 | 49.22 | 31.32 | 28.09 | 23.69 | 17.90 | 15.99 | 7.77 | 0.07 |
| 603 | 0.55 | 1.00 | 20.13 | 11.07 | 16.90 | 9.30 | 12.98 | 7.14 | 9.06 | 7.61 | 5.84 | 5.83 | 3.69 | 1.91 |
| 604 | 0.60 | 1.00 | 72.82 | 43.69 | 67.17 | 40.30 | 52.55 | 31.53 | 29.13 | 26.87 | 21.02 | 23.48 | 12.25 | 8.86 |
| 606 | 0.55 | 1.00 | 37.15 | 20.43 | 31.53 | 17.34 | 24.53 | 13.49 | 16.72 | 14.19 | 11.04 | 11.10 | 7.19 | 4.10 |
| 607 | 0.30 | 2.00 | 17.38 | 2.61 | 15.87 | 2.38 | 14.23 | 2.13 | 14.77 | 13.49 | 12.10 | 13.26 | 11.85 | 11.62 |
| 701 | 0.73 | 1.15 | 40.17 | 25.50 | 33.35 | 21.17 | 25.88 | 16.43 | 14.67 | 12.18 | 9.45 | 7.85 | 4.71 | 0.38 |
| 901 | 0.33 | 0.85 | 56.62 | 21.98 | 58.57 | 22.74 | 38.07 | 14.78 | 34.64 | 35.83 | 23.29 | 36.59 | 15.33 | 16.09 |

**Table 5.4 Changes in net returns due to maintenance and climate, 1995/96 financial prices**

| Block | Area (ha) | Wet Season | | | Average Season | | | Dry Season | | | Total Change (£/yr) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Benefit due to drainage (£/ha/yr) | Benefits of flood alleviation (£/ha) | Change in net return due to maintenance | Benefit due to drainage (£/ha/yr) | Benefits of flood alleviation (£/ha) | Change in net return due to maintenance | Benefit due to drainage (£/ha/yr) | Benefits of flood alleviation (£/ha) | Change in net return due to maintenance | |
| 101 | 20.79 | 45 | 0.51 | 45 | 0 | 0.67 | 1 | 0 | 0.67 | 1 | 218 |
| 102 | 6.83 | 45 | 0.12 | 45 | 0 | 0.17 | 0 | 0 | 0.17 | 0 | 68 |
| 103 | 3.10 | 47 | 0.24 | 47 | 0 | 0.34 | 0 | 0 | 0.34 | 0 | 33 |
| 104 | 2.40 | 0 | 0.42 | 0 | 8 | 0.36 | 8 | 8 | 0.36 | 8 | 15 |
| 201 | 8.62 | 0 | 0.54 | 1 | 0 | 0.60 | 1 | 0 | 0.60 | 1 | 5 |
| 301 | 10.44 | 29 | 3.51 | 33 | 0 | 4.56 | 5 | 31 | 3.94 | 35 | 144 |
| 302 | 13.38 | 0 | 5.08 | 5 | 0 | 5.54 | 6 | 2 | 4.10 | 6 | 74 |
| 401 | 3.40 | 81 | 7.50 | 89 | 0 | 9.52 | 10 | 92 | 9.19 | 102 | 123 |
| 402 | 16.40 | 61 | 5.39 | 67 | 0 | 8.43 | 8 | 6 | 8.16 | 14 | 358 |
| 403 | 13.00 | 94 | 9.35 | 103 | 0 | 8.43 | 8 | 123 | 7.60 | 130 | 539 |
| 501 | 9.01 | 18 | 4.53 | 23 | 18 | 4.53 | 23 | 0 | 2.86 | 3 | 188 |
| 601 | 8.77 | 0 | 28.09 | 28 | 0 | 28.09 | 28 | 0 | 28.09 | 28 | 246 |
| 602 | 7.47 | 0 | 0.00 | 0 | 0 | 0.00 | 0 | 0 | 0.00 | 0 | 0 |
| 603 | 6.90 | 0 | 5.84 | 6 | 0 | 7.61 | 8 | 0 | 7.61 | 8 | 50 |
| 604 | 11.60 | 0 | 26.87 | 27 | 215 | 23.48 | 239 | 0 | 29.13 | 29 | 1987 |
| 605 | 8.90 | 219 | 0.00 | 219 | 0 | 0.00 | 0 | 0 | 0.00 | 0 | 430 |
| 606 | 7.60 | 128 | 7.19 | 136 | 78 | 11.10 | 89 | 0 | 16.72 | 17 | 701 |
| 607 | 2.03 | 21.9 | 11.85 | 34 | 31.21 | 13.26 | 44 | 0 | 14.77 | 15 | 79 |
| 701 | 9 | 0 | 4.71 | 5 | 0 | 14.67 | 15 | 0 | 14.67 | 15 | 114 |
| 901 | 14.3 | 0 | 35.83 | 36 | -8.11 | 36.59 | 28 | -8.11 | 36.59 | 28 | 430 |
| Total | 184 | | | | | | | | | Total | 5801 |

| | | | | |
|---|---|---|---|---|
| Probability of : | Wet season | 0.22 | Benefit (£/ha) | 32 |
| | Average season | 0.68 | | |
| | Dry season | 0.10 | | |

**Table 5.5 Changes in net returns due to maintenance and climate, 1995/96 economic prices**

| Block | Area (ha) | Wet Season: Benefit due to drainage (£/ha/yr) | Wet Season: Benefits of flood alleviation (£/ha) | Wet Season: Change in net return due to maintenance | Average Season: Benefit due to drainage (£/ha/yr) | Average Season: Benefits of flood alleviation (£/ha) | Average Season: Change in net return due to maintenance | Dry Season: Benefit due to drainage (£/ha/yr) | Dry Season: Benefits of flood alleviation (£/ha) | Dry Season: Change in net return due to maintenance | Total Change (£/yr) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 101 | 20.79 | 22 | 0.51 | 23 | 0 | 0.67 | 1 | 0 | 0.67 | 1 | 115 |
| 102 | 6.83 | 22 | 0.12 | 22 | 0 | 0.17 | 0 | 0 | 0.17 | 0 | 35 |
| 103 | 3.10 | 23 | 0.24 | 23 | 0 | 0.34 | 0 | 0 | 0.34 | 0 | 17 |
| 104 | 2.40 | 0 | 0.42 | 0 | -1 | 0.36 | -1 | -1 | 0.36 | -1 | -1 |
| 201 | 8.62 | 0 | 0.54 | 1 | 0 | 0.60 | 1 | 0 | 0.60 | 1 | 5 |
| 301 | 10.44 | 18 | 3.51 | 22 | 0 | 4.56 | 5 | 21 | 3.94 | 25 | 109 |
| 302 | 13.38 | 0 | 5.08 | 5 | 0 | 5.54 | 6 | -30 | 4.10 | -26 | 31 |
| 401 | 3.40 | 39 | 7.50 | 47 | 0 | 9.52 | 10 | 37 | 9.19 | 46 | 73 |
| 402 | 16.40 | 7 | 5.39 | 13 | 0 | 8.43 | 8 | -12 | 8.16 | -3 | 135 |
| 403 | 13.00 | 46 | 9.35 | 55 | 0 | 8.43 | 8 | 56 | 7.60 | 63 | 314 |
| 501 | 9.01 | 9 | 4.53 | 13 | 9 | 4.53 | 13 | 0 | 2.86 | 3 | 110 |
| 601 | 8.77 | 0 | 28.09 | 28 | 0 | 28.09 | 28 | 0 | 28.09 | 28 | 246 |
| 602 | 7.47 | 0 | 0.00 | 0 | 0 | 0.00 | 0 | 0 | 0.00 | 0 | 0 |
| 603 | 6.90 | 0 | 5.84 | 6 | 0 | 7.61 | 8 | 0 | 7.61 | 8 | 50 |
| 604 | 11.60 | 0 | 26.87 | 27 | 236 | 23.48 | 259 | 0 | 29.13 | 29 | 2145 |
| 605 | 8.90 | 415 | 0.00 | 415 | 0 | 0.00 | 0 | 0 | 0.00 | 0 | 813 |
| 606 | 7.60 | 124 | 7.19 | 131 | 78 | 11.10 | 89 | 0 | 16.72 | 17 | 694 |
| 607 | 2.03 | 11 | 11.85 | 23 | 22 | 13.26 | 35 | 0 | 14.77 | 15 | 62 |
| 701 | 9 | 0 | 4.71 | 5 | 0 | 14.67 | 15 | 0 | 14.67 | 15 | 114 |
| 901 | 14.3 | 0 | 35.83 | 36 | -38 | 36.59 | -1 | -38 | 36.59 | -1 | 99 |
| Total | 184 | | | | | | | | | Total | 5163 |
| Probability of : | | Wet season | | 0.22 | | | | | | Benefit (£/ha) | **28** |
| | | Average season | | 0.68 | | | | | | | |
| | | Dry season | | 0.10 | | | | | | | |

As an alternative estimate to that based on watertable modelling, Table 5.6 estimates the benefits due to maintenance which were perceived by farmers (earlier reported in Table 4.1) where they identified a change in drainage conditions between the 'with' and 'without' maintenance situations in an average, representative season. These estimates include the flood damage costs identified in Table 5.3, which were based on a combination of farmer and modelled data.

**Table 5.6 Farmer asessment of maintenance benefits**

| Block | Area (ha) | Average Season Financial Prices: Benefit due to drainage (£/ha/yr) | Average Season Financial Prices: Benefits of flood alleviation (£/ha) | Change in net return due to maintenance | Average Season Economic Prices: Benefit due to drainage (£/ha/yr) | Average Season Economic Prices: Benefits of flood alleviation (£/ha) | Change in net return due to maintenance |
|---|---|---|---|---|---|---|---|
| 101 | 20.79 | 0 | 0.51 | 11 | 0 | 0.67 | 14 |
| 102 | 6.83 | 0 | 0.12 | 1 | 0 | 0.17 | 1 |
| 103 | 3.10 | 0 | 0.24 | 1 | 0 | 0.34 | 1 |
| 104 | 2.40 | 8 | 0.42 | 19 | -1 | 0.36 | -2 |
| 201 | 8.62 | 76 | 0.54 | 659 | 66 | 0.60 | 574 |
| 301 | 10.44 | 31 | 3.51 | 365 | 21 | 4.56 | 267 |
| 302 | 13.38 | 29 | 5.08 | 457 | 18 | 5.54 | 315 |
| 401 | 3.40 | 92 | 7.50 | 340 | 37 | 9.52 | 158 |
| 402 | 16.40 | 0 | 5.39 | 88 | 0 | 8.43 | 138 |
| 403 | 13.00 | 123 | 9.35 | 1719 | 56 | 8.43 | 838 |
| 501 | 9.01 | 18 | 4.53 | 206 | 9 | 4.53 | 122 |
| 601 | 8.77 | 0 | 28.09 | 246 | 0 | 28.09 | 246 |
| 602 | 7.47 | 0 | 0.00 | 0 | 0 | 0.00 | 0 |
| 603 | 6.90 | 0 | 5.84 | 40 | 0 | 7.61 | 53 |
| 604 | 11.60 | 215 | 26.87 | 2810 | 236 | 23.48 | 3010 |
| 605 | 8.90 | 0 | 0.00 | 0 | 0 | 0.00 | 0 |
| 606 | 7.60 | 78 | 7.19 | 649 | 78 | 11.10 | 677 |
| 607 | 2.03 | 31.21 | 11.85 | 87 | 22 | 13.26 | 72 |
| 701 | 9 | 0 | 4.71 | 43 | 0 | 14.67 | 134 |
| 901 | 14.3 | -8.11 | 35.83 | 396 | -38 | 36.59 | -20 |
| Total | 184 | Total financial benefit (£) | | 8138 | Total economic benefit (£) | | 6597 |
| | | Benefit (£/ha) | | 44 | Benefit (£/ha) | | 36 |

Farmer assessment gave an average annual financial benefit of £ 8138 (£ 44/ha) and an economic benefit of £ 6597 (£ 36/ha).

According to the criteria used, these financial and economic benefit estimates show the limits which farmers and the nation respectively could justifiably spend on maintenance. These estimates require cautious interpretation as explained in the R&D Note 456 Section 2.7.2.

## 5.2 Maintenance Costs

Maintenance activities on the River Sence involved desilting in 1990 at a cost of £ 32000 (in 1995 prices). This was initially perceived to have a 15 year life. Annual weed cutting was deemed necessary to prevent rapid sedimentation. In 1992 and 1993 respectively £ 4255 and £ 6663 were spent on weed clearance. In addition, tree and bush work (£ 1622 and £ 4131 for 1992 and 1993 respectively) and debris removal (£ 1842 and £ 1399 for 1992 and 1993 respectively) were carried out.

The following average annual costs can be identified and expressed in 1995 prices: Desilting £ 3300 (over 15 years at 6 %), weed cutting £ 5687, and debris removal £ 1696. The tree and bush work totalled £ 5980 in 1995 prices equivalent to an annual cost of £ 813 over 10 years at 6 %. On this basis, the total annual cost for all activities is about £ 11490, £ 63/ha of benefit. Weed clearance and debris removal only cost about £ 7380 per year, £ 41/ha of benefit.

The annual equivalent cost of combined desilting (15 years) and weed cutting programme is about £ 8990. This is a cheaper option than a desilting programme only as long as the latter has a longevity of greater than four years. The modelling of sedimentation processes on the River Sence suggested that the river would return to previous bed levels within 6 years. Of the two options, annual weed cutting is a preferred option (with or without long term desilting if required) especially given the reductions in flooding attributable to annual vegetation control.

## 5.3 Scheme Appraisal

The estimated benefits attributable to maintenance can be compared with estimated costs to determine the justification for expenditure. A simple comparison of equivalent annual benefits and costs is used. Different assumptions are made regarding the charging of costs.

Table 5.7 shows that, using the modelled results, the benefits of maintenance are insufficient to recover the costs of the scheme in financial and in economic terms, whether full or partial costs are charged. This partly attributable to the relatively high costs of maintenance per ha.

Farmer assessment gave an average annual financial benefit of £ 8138 and an economic benefit of £ 6597 due to maintenance in average weather conditions. The scheme generates an annual benefit : cost ratio of 0.71 and 0.57 in financial and economic terms respectively for desilting, weed clearance and tree and bush and debris removal.

**Table 5.7 Maintenance scheme appraisal: River Sence**

| Operations | | Desilting, weed cutting, tree and bush and debris removal | Weed and Blockage Removal only |
|---|---|---|---|
| Annual Costs (£) | | 11490 | 7380 |
| Average Annual Benefit (£) | Average Annual Benefits (£) | Benefit: Cost Ratio | Benefit: Cost Ratio |
| *Modelled Estimates* | | | |
| Financial Prices | 5800 | 0.54 | 0.70 |
| Economic Prices | 5100 | 0.44 | 0.69 |
| *Farmer Estimates* | | | |
| Financial Prices | 8138 | 0.71 | 1.10 |
| Economic Prices | 6597 | 0.57 | 0.89 |

These conclusions must be interpreted cautiously as discussed in the R&D Note 456 Section 2.7.2.

# 6 ENVIRONMENT

## 6.1 Introduction

The environmental quality of the River Sence is outlined in this chapter. Reference is made to river corridor surveys, public consultation and farmer assessment.

## 6.2 River Corridor Survey

A river corridor survey was completed for each 500 m section of the study reach pre- and post-maintenance in 1989. The survey methodology developed by the Nature Conservancy Council, (NCC, now English Nature, EN) was followed. A record card and sketch map was completed for each section. The maps and cards can be found in Appendix V of the RIMS Project Evaluation - River Sence Report.

## 6.3 Farmer Assessment

Farmers interviewed along the study reach were asked if they were aware of any flora or fauna of environmental interest along this section. Most farmers thought the river to be of significant environmental interest in terms of bids, fish, flora and fauna. Recreational interest was also said to be important due to a number of footpaths which run close to the river.

## 6.4 Channel and Bank Quality

The environmental quality of the River Sence has been determined by following the procedure outlined in the 'Guidelines for the Justification of River Maintenance' (R&D Note 511) produced within the framework of the NRA R&D Note 456 (River Maintenance Evaluation).

The quality of both the river channel and banks is classed as low. There is no transitional zone between the channel edge and the river at times of low flow, the sediment is uniform, no riffles and pools are present and the channel is of a uniform habitat.

The banks are of simple structure, consisting of predominantly two or three vegetation types without large areas of trees or scrub. Bank width is typically 2 to 5 m. The banks consist of uniform grass cover which is grazed by sheep and dairy cattle. The bank structure varies slightly and there are no dense stands of single species or flowering herbs.

# 7 CONCLUSIONS

## 7.1 Scheme Appraisal

The existing maintenance scheme is not viable in financial and economic terms. The average annual economic benefit of desilting, tree and bush, debris removal and weed cutting, in terms of its prevention in a deterioration in drainage status and increase in flooding is £ 5100. Average annual maintenance costs are £ 11490. The benefit : cost ratio is therefore 0.54.

For weed cutting and blockage removal only, in economic prices, the benefit : cost ratio is 0.79.

## 7.2 Guidelines for River Maintenance

The 'Guidelines for the Justification of River Maintenance' (R&D Note 511), produced as a result of this River Maintenance Evaluation Study were used to provide an alternative method for justification of river maintenance on the River Sence.

According to this method, if maintenance comprises weed cutting and debris removal only, the economic benefit : cost ratio is 1.1. This value is slightly greater than the 0.71 value obtained through detailed analysis; the results of which are summarised in Section 7.1. If maintenance involved weed cutting, tree and bush work, debris removal and desilting, the benefit : cost ratio is 0.72. This approximates to the 0.69 benefit : cost ratio obtained through detailed analysis.

## 7.3 Impact of Maintenance on Channel Vegetation

The types of vegetation found within the River Sence are discussed in Section 1.9. The impact of the submerged, emergent and floating vegetation on channel capacity is also discussed. Different vegetation types respond to maintenance in different ways.

Pondweed (*Potamogeton*) and sweet-grass (*Glyceria*) are the dominant types of vegetation found within the channel. They reproduce through a system of rhizomes (underground stems). The current method of maintenance - regular cutting, actually stimulates regrowth of this vegetation. The pondweed is a rooted plant. Desilting of the channel every few years is necessary in order to remove the rhizomes and to reduce the *Potamogeton* seed bank in the channel sediments.

The current maintenance regime may stimulate regrowth of the aquatic vegetation. However, desilting which is performed every few years will reduce the seed and rhizome bank in the channel sediments.

## 7.4 Maintenance Best Practice

The 'best practice' vegetation maintenance methods for the River Sence were determined using the procedures outlined in the Guidelines for the Justification of River Maintenance' (R&D Note 511), produced as a result of the Environmental Impact Assessment Study.

**Channel**

Best practice maintenance operations for emergent weed are identified as :

- Biennial cutting;
- Cutting on a 3 to 5 year rotation; and,
- Desilting / raking at an interval of 2 to 7 years.

Best practice maintenance operations for floating and submerged weed are identified as :

- Biennial cutting;
- Cutting on a 3 to 5 year rotation - 10 to 30 %; and,
- Cutting on a 3 - 5 year rotation.

All these maintenance operations should be selective, concentrating on those areas which are particularly choked by vegetation or areas in which the weed is liable to cause an obstruction, hazard or restriction to flow.

Since the beginning of this study, annual weed maintenance has taken place. Approximately 60 % of the vegetation is removed in a central strip down the channel - the maintenance is selective. Generally, the maintenance regimes recommended as best practice in environmental terms for vegetation management are currently being applied to this reach of the River Sence. Areas of vegetation are left un-cut along the channel margins which improves the environmental quality of the channel.

**Bank**

Best practice maintenance operations for bank vegetation are identified as :

- Single annual flail mowing in the autumn / winter, leaving a toe strip over 1 m wide; and,
- Light grazing.

The majority of the banks are grazed by sheep and beef cattle and are not mown. However, the grazing regimes are relatively intensive and if the bank is un-fenced, the bank vegetation remains short and uniform in structure.

If the bank maintenance regime recommended as best practice in environmental terms were implemented, the grazing intensity of the banks would be reduced and a toe strip of un-cut and un-grazed vegetation must be left. This would enhance the bank and channel environmental quality but may impede flow and reduce channel capacity. Allowing this vegetation to grow un-checked could increase the rate of sedimentation at the channel margins and thus reduce the life of the desilting programme.

## 7.5 Recommendations

It is recommended that further research is carried to examine :-

- the impact of weed cutting on rates of sedimentation;
- the impact of reduced channel maintenance on channel environmental quality; and,
- the impact of leaving a toe strip of vegetation on channel hydraulics, flooding, land drainage and environmental quality.

## 7.6 Epilogue

This report has assessed the impacts of the current maintenance regime on the study reach. It has been used along with other study sites to formulate guidelines on the appraisal of maintenance works and best environmental practice. These draft guidelines are summarised in Chapter 5 of the R&D Note 456 and presented in full under separate covers.

# 8. REFERENCES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Map: Landranger 140. Leicester and Coventry Area. 1: 50 000, Ordnance Survey Southampton (1988).

# APPENDIX I

Example of input and output data for the watertable model

River Sence
Block Number 901
Cross-section 1

| | Input Data | Output Data |
|---|---|---|
| | River height (m AOD) | Watertable height (m AOD) |
| Week | | |
| 1992 | | |
| 1 | 74.49 | 74.04 |
| 2 | 73.24 | 74.42 |
| 3 | 73.14 | 74.02 |
| 4 | 73.14 | 73.84 |
| 5 | 73.15 | 73.64 |
| 6 | 73.22 | 73.59 |
| 7 | 73.15 | 73.6 |
| 8 | 73.12 | 73.47 |
| 9 | 73.07 | 73.49 |
| 10 | 73.09 | 73.47 |
| 11 | 73.49 | 73.52 |
| 12 | 73.85 | 73.83 |
| 13 | 73.67 | 74.08 |
| 14 | 73.22 | 73.91 |
| 15 | 73.19 | 73.75 |
| 16 | 73.07 | 73.67 |
| 17 | 73.03 | 73.63 |
| 18 | 73.04 | 73.48 |
| 19 | 73.14 | 73.56 |
| 20 | 72.98 | 73.44 |
| 21 | 73.14 | 73.36 |
| 22 | 73.14 | 73.6 |
| 23 | 72.99 | 73.48 |
| 24 | 72.98 | 73.38 |
| 25 | 72.98 | 73.35 |
| 26 | 73.07 | 73.76 |
| 27 | 73.14 | 73.89 |
| 28 | 73.14 | 73.83 |
| 29 | 73.09 | 73.68 |

Example of drainage status classification, River Sence

With maintenance

Block 901

| | Watertable depth (m) | No. of weeks 1992 | Spring 1992 |
|---|---|---|---|
| >0.5 | 73.79 | 38 | 73.79 |
| 0.3><0.5m | 73.99 | 5 | 73.99 |
| <0.3m | 74.29 | 9 | 74.29 |

Drainage status classification, according to time watertable is within the G, B, VB drainage bands

Without maintenance

| | Watertable depth (m) | No. of weeks 1992 | Spring 1992 |
|---|---|---|---|
| >0.5 | 73.79 | 21 | 73.79 |
| 0.3><0.5m | 73.99 | 10 | 73.99 |
| <0.3m | 74.29 | 21 | 74.29 |

Drainage status classification, according to time watertable is within the G, B, VB drainage bands

| No. of weeks | Summer 1992 | No. of weeks | Autumn 1992 | No. of weeks |
|---|---|---|---|---|
| 13 | 73.79 | 13 | 73.79 | 3 |
| 0 | 73.99 | 0 | 73.99 | 4 |
| 0 | 74.29 | 0 | 74.29 | 6 |
| Good | | Good | | Bad |

| No. of weeks | Summer 1992 | No. of weeks | Autumn 1992 | No. of weeks |
|---|---|---|---|---|
| 9 | 73.79 | 9 | 73.79 | 2 |
| 3 | 73.99 | 4 | 73.99 | 0 |
| 1 | 74.29 | 0 | 74.29 | 11 |
| Bad | | Bad | | Very Bad |

# HILTON BROOK

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### HILTON BROOK

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# SEVERN TRENT    HILTON BROOK

# 1 BACKGROUND

## 1.1 Introduction

In January 1989, the National Rivers Authority (NRA) Severn Trent Region commissioned Silsoe College to undertake a three year study within the NRA Severn Trent Region to evaluate river maintenance on six sites. The aims, methods, results and recommendations of this study have been presented in a series of reports to the NRA. This study lead to an interest in the development and appraisal of river maintenance in other NRA Regions. The Project Record entitled 'The Evaluation of River Maintenance' was submitted in May 1993. The Hilton Brook (Upper Trent Area) was one of the six sites studied.

The NRA Severn Trent Region commissioned Silsoe College to continue this study throughout five NRA Regions during the period 1992 - 1995. The Hilton Brook was included in this study to allow for an extended period of monitoring and evaluation. Full details on the study reach, benefit area and maintenance are included within the 'Baseline Report' presented to the NRA in 1990.

## 1.2 Hilton Brook

The Hilton Brook runs for 13.5 km from head of main river at Longford, to its confluence with the River Dove, north-east of Burton-upon-Trent. The Brook is fed by several tributaries which rise in the Ashbourne area. The catchment area is predominantly rural in character. The geology is characterised by alluvium, bounded by first river terrace deposits on the western bank (right bank) and gypsum on the eastern bank (left bank).

## 1.3 Study Reach

The study reach runs for approximately 2.75 km between Bartonfields (GR. 221 352) to upstream of Sutton Mill Bridge (GR. 229 339). This site is characteristic of the main rivers in the region on which tree and bush maintenance is performed. The area of land benefiting from river maintenance in terms of its effect on land drainage and flooding is estimated to be 94 ha.

The dominant soil association is the Wimple 3 Association. Fine loamy or fine silty horizons overlay slowly permeable clay shale on gently or moderate slopes.

## 1.4 River Characteristics

The bed width is variable, averaging 4.5 m on some lower sections and 2.5 m further upstream. Bank angles range from vertical cliffs to 30 degrees. Some are densely vegetated by trees, scrub and herbs. Several structures are found within the study reach. These include six fords, two bridges and a weir at the downstream end of the reach where Sutton Mill used to be.

Due to the erosion of the gravel layers, the substrate consists of a high percentage of gravel, pebbles and cobbles. Runs and pools are interspersed with slower moving areas which are dominated by silty substrates.

## 1.5 Land Drainage

Five ditches run into the Brook within the study reach. Much of the land has been drained by pipes. Field drainage pipes on the western bank drain into the Hilton Brook. Land on the eastern bank slopes away from the Brook and so field drains on this bank, flow into a small brook which runs parallel to the Hilton Brook.

## 1.6 River Maintenance

Since the War Ag. scheme during the Second World War, when the channel was deepened, little work has been performed on the Hilton Brook. During the period 1989 - 1990, removal of shoals and the desilting of high spots took place.

The level of maintenance was determined by using the Severn Trent River Information Maintenance System (RIMS) to calculate the minimum freeboard at the maximum cost/ benefit ratio. The design standard for maintenance was concerned primarily with the removal of high points along the reach, rather than regrading or large scale channel size increases. The original plans for regrading and channel excavation (a capital scheme) were dropped following objections from fisheries and conservation groups.

The cost of the maintenance work from Sutton Bridge to Langford was £ 48500. This included a stretch running for approximately 2 kilometres upstream of Bartonfields and the reconstruction of a weir. The net cost for the study site was estimated to be in the region of £ 25-35000. The scheme appraisal contained within the Hilton Brook scheme report submitted to the NRA in 1993, determined the benefits associated with these various maintenance costs.

The justification for the work was agricultural land drainage and flood protection. The main reasons given for the decision to perform maintenance were recent inspection highlighting the need for maintenance and customers demands.

Since the tree and bush maintenance scheme and shoal removal of 1990, no maintenance has been carried out on the Hilton Brook. The evaluation of river maintenance has been carried out over the period 1989 - 1995.

### 1.6.1 Farmers views on maintenance

The majority of farmers interviewed expressed satisfaction with the type and level of maintenance currently performed on the Hilton Brook. However, one voiced the opinion that the meanders should be straightened thus allowing a more direct route for flow and thus reducing the risk of flooding.

## 1.7 Climate

The impact of river maintenance on watertable depth and river levels depends on the particular weather conditions, especially rainfall, which vary from season to season and year to year. The seasonal and yearly rainfall totals for the period of this study (1992 - 1995) are presented in Table 1.1. Rainfall information for the period 1988 to 1991 is contained within the 'RIMS Project Evaluation - Hilton Brook' report submitted to NRA Severn Trent in March 1992.

Monthly rainfall records from Clay Mills Waste Reclamation Works (GR. 265 259), the nearest meteorological station to the study site, covering a period of 11 years (1983 - 1992), have been analysed in order to determine the probability of a dry, average and wet season and year occurring. The classification of the Food and Agricultural Organisation (FAO) was used to do this. Dry and wet seasons and years are classed as those with less than 75 % and greater than 125 % of the average rainfall total respectively. Further details are presented in the R&D Note 456, Section 3.5.2.

According to this classification system, the summer of 1992 and autumn of 1993 and 1994 were wet when compared to the average rainfall. This is confirmed by farmers who reported wet conditions on the land and an increased incidence of flooding. The summer of 1994 and spring of 1995 are classed as dry. The remaining seasons are classed as average.

**Table 1.1 Rainfall totals**

| Period | Season | Actual Rainfall (mm) | Average * Rainfall (mm) | % Average Rainfall |
|---|---|---|---|---|
| 1992 | Spring | 141.9 | 150.3 | 94 |
| | Summer | 219.5 | 157.1 | 140 |
| | Autumn | 231.5 | 167.3 | 128 |
| 1993 | Spring | 159.5 | 150.3 | 106 |
| | Summer | 138.5 | 157.1 | 88 |
| | Autumn | 265.5 | 167.3 | 153 |
| 1994 | Spring | 169.9 | 150.3 | 113 |
| | Summer | 102.6 | 157.1 | 65 |
| | Autumn | 255.2 | 167.3 | 153 |
| 1995 | Spring | 91.9 | 150.3 | 61 |
| Total | 1992 | 687.6 | | |
| | 1993 | 737.5 | | |
| | 1994 | 735.5 | | |

* Based on 11 year record from 1983 - 1992, Clay Mills

**Table 1.2 Probability of climatic conditions**

| Season | Dry * | Average * | Wet * |
|---|---|---|---|
| Spring | 0.18 | 0.73 | 0.09 |
| Summer | 0.08 | 0.58 | 0.34 |
| Autumn | 0.33 | 0.50 | 0.17 |
| Year | 0.36 | 0.37 | 0.27 |

* Based on records 1983 - 1992

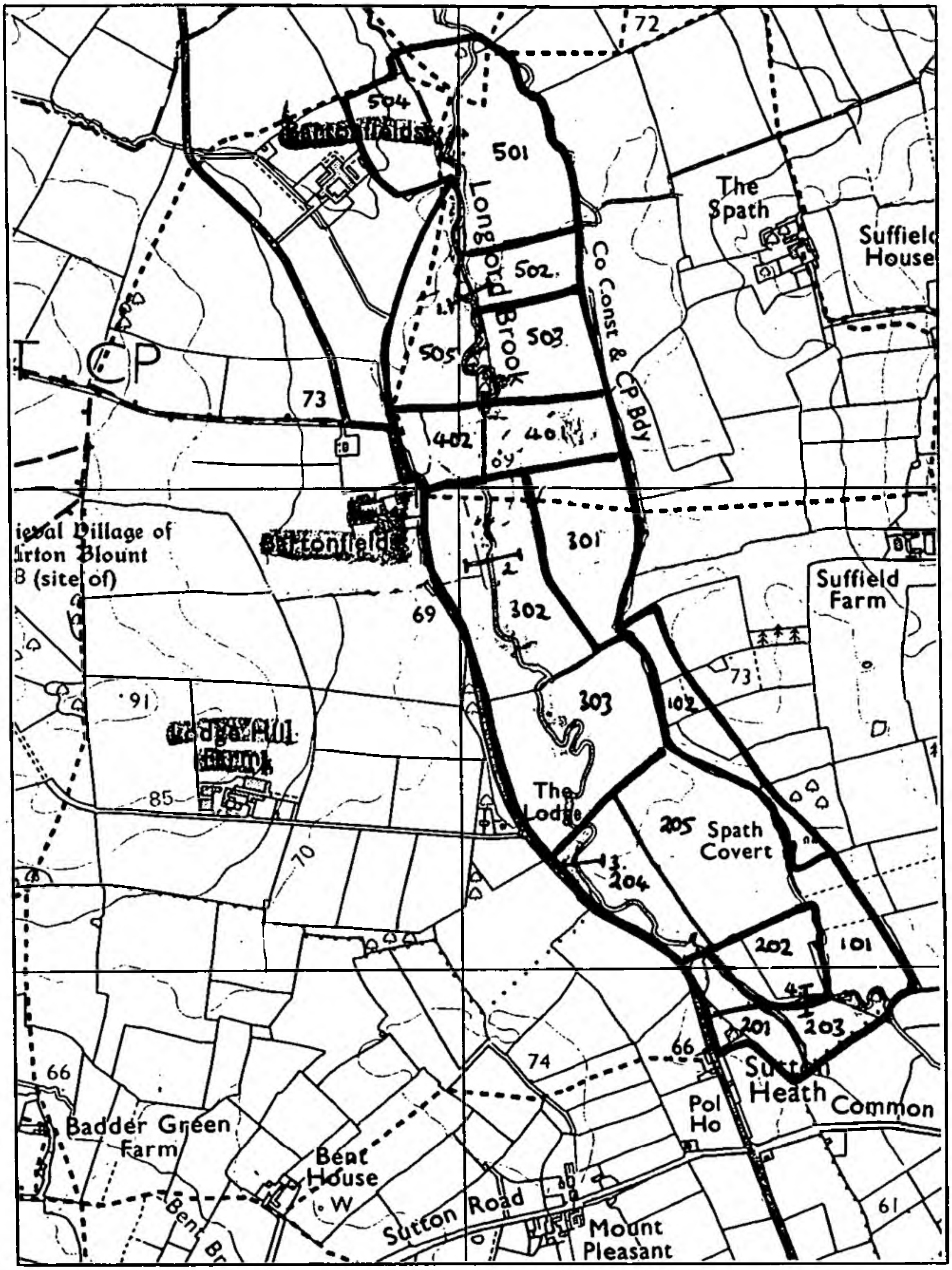
The process by which financial benefits of maintenance are calculated according to the probability of each type of weather season and year occurring is explained in the R&D Note 456, Section 3.5.4.

# 2 FARM SURVEY

## 2.1 Introduction

Through structured interviews and informal discussions with farmers and a topographical survey, the area deriving a benefit from the river maintenance work on the Hilton Brook in terms of its impact on land drainage and flooding is estimated to be 94 ha. Detailed interviews and discussions have been held with five farmers within the benefit area. The benefit area has been divided into blocks according to land use, drainage condition, flooding and land management practices (Figure 1).

Full details on farm size, type, arable and livestock enterprises, conservation and grazing systems and nitrogen application rates has been presented to the NRA in the report entitled 'RIMS Project Evaluation - Hilton Brook', submitted to the NRA in March 1992.




Legend :

Scale 1: 12 000

101 Land blocks

1 Cross-section location

**Figure 1 Land blocks and location of cross-sections**

## 2.2 Land Use In The Benefit Area

Details of land use and piped drainage in the benefit area are summarised in Table 2.1. The dominant land use is grassland, which accounts for 65 % of the benefit area (including grass in rotation). Grassland under the extensive system is used for permanent grazing of sheep and beef over a short season. Little, if any grass is conserved and nitrogen inputs are low. Intensive grassland is characterised by long grazing seasons, relatively high rates of nitrogen input ( > 100 kg N/ha) and is commonly grazed with dairy cattle. Figure 2 provides further information on land use in the benefit area.

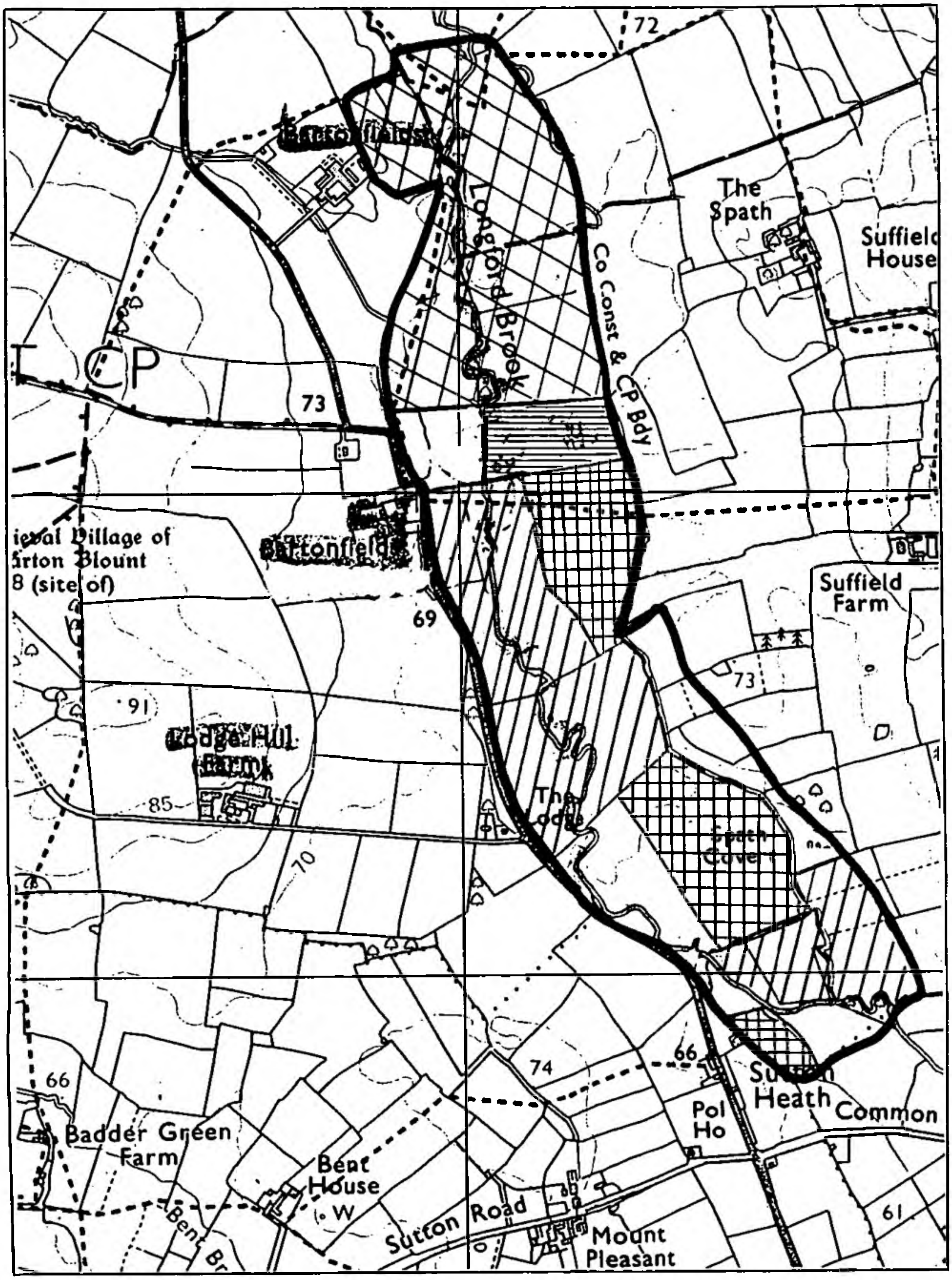
**Table 2.1 Land use in the benefit area**

| Land Use | Area (ha) | % of Benefit Area | % Drained by Pipes |
|---|---|---|---|
| Extensive Grass | 17.1 | 18 | 9 |
| Intensive Grass | 26.0 | 28 | 3 |
| Cereal / Root | 28.4 | 30 | 30 |
| Grass / Arable | 17.7 | 19 | 11 |
| Cereal / Oilseed | 4.3 | 5 | 0 |

## 2.3 Flooding

All farmers within the benefit area reported flooding on their land during the course of this study. In each case the source of the flood water is said to be the Hilton Brook whose high levels are due to a combination of high rainfall and weed growth at the channel margins. The areas which typically flood are shown in Figure 3. Flooding from surface runoff does not appear to be a major contributory factor to flooding.

In each case, the duration of flooding is reported to be between one and two days. Crop damage, reduced yields, litter and debris and erosion are said to be the main consequences of flooding.

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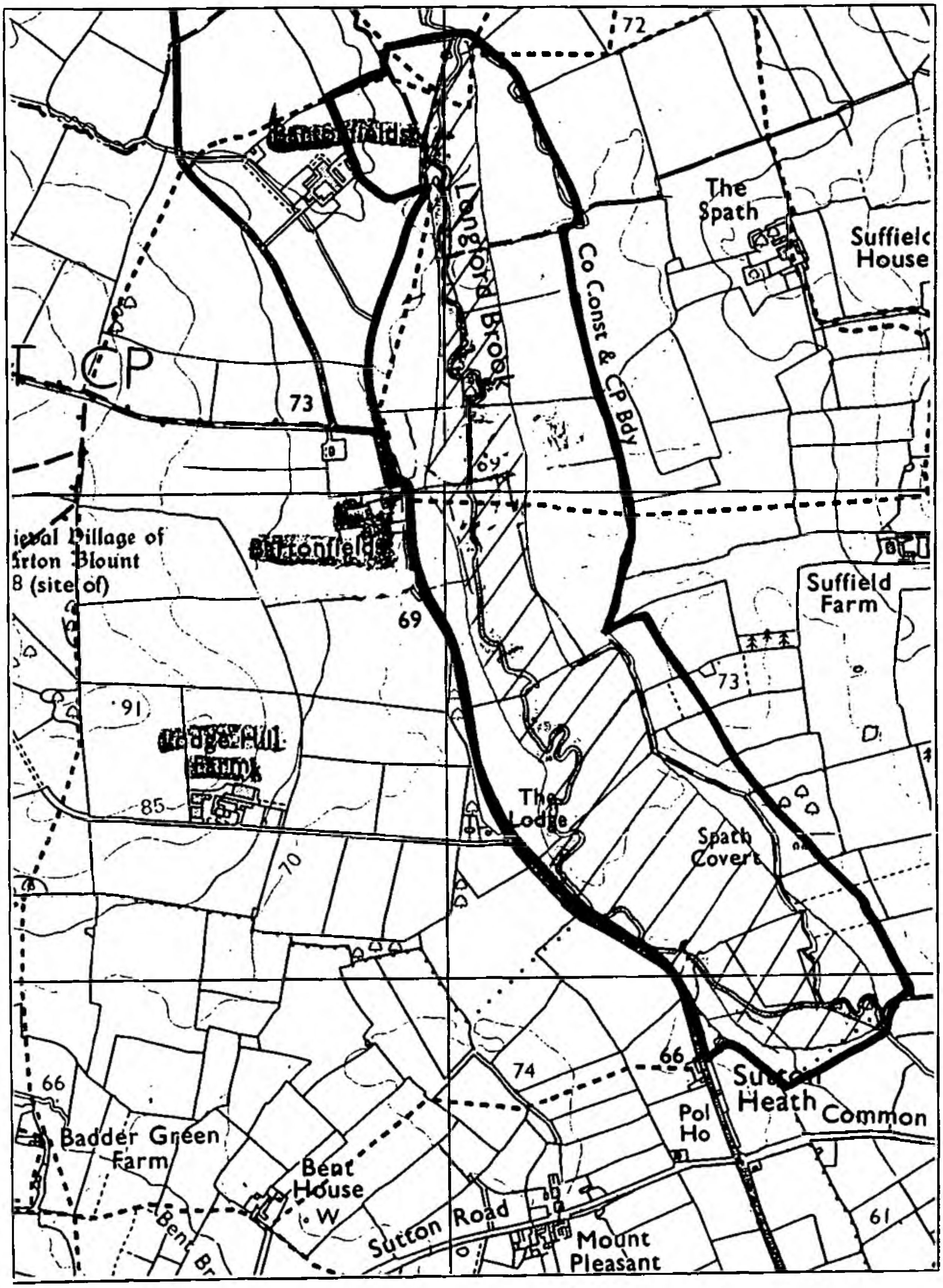
- Intensive grass
- Extensive grass
- Grass / arable
- Cereal / root crop
- Cereal / oilseed

**Figure 2 Land use**

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Flooded areas

**Figure 3** **Areas prone to flooding**

## 2.4 Waterlogging

The wetness condition of the soil within the benefit area in spring, summer and autumn as reported by farmers, is shown in Table 2.2.

Throughout each season, some land within the benefit area remains poorly drained. In the summer, 23 % of the benefit area is often wet. The wetter conditions in spring and autumn have been attributed by the farmers to relatively high rainfall during these seasons.

**Table 2.2 Farmer assessment of wetness condition**

| Season | Wetness Condition | Area (ha) | % Area |
|---|---|---|---|
| Spring | Rarely wet | 0.0 | 0 |
| | Occasionally wet | 46.5 | 50 |
| | Often wet | 25.6 | 27 |
| | Permanently wet | 21.9 | 23 |
| Summer | Rarely wet | 10.9 | 12 |
| | Occasionally wet | 61.4 | 65 |
| | Often wet | 21.7 | 23 |
| | Permanently wet | 0.0 | 0 |
| Autumn | Rarely wet | 0.0 | 0 |
| | Occasionally wet | 64.9 | 69 |
| | Often wet | 0.0 | 0 |
| | Permanently wet | 29.1 | 31 |

## 2.5 Statistical Analysis

It is apparent that land use, farming practice, drainage and flooding are interrelated. Statistical methods were used to determine whether these relationships occurred more frequently than might be expected by pure chance. Full details of this analysis in which the 12 sites were grouped according to NRA Region, are presented in the Interim Report R&D 317/13/ST, presented to the NRA in December 1994.

The following observations can be made from the statistical analysis of fields in the benefit area of the Hilton Brook maintenance programme:

- A strong relationship exists between land use and the presence of field drainage. The majority of land under arable crops is drained by pipes. Extensive and intensive grassland is predominantly naturally draining. (Statistically, there is an 87 % chance of correctly predicting the presence of field drainage on the basis of land use).

- Areas which flood most frequently are under grassland systems. Most areas under the cereal / root crop rotation and cereal / oilseed rotation are not prone to flooding. (Statistically, there is a 63 % chance of correctly predicting the incidence of flooding on the basis of land use).

- Grazing seasons are related to field wetness conditions in the spring and autumn. Turnout dates for livestock range from mid March on land which is rarely wet to after the first cut of silage on land which is permanently wet underfoot in the spring. Land which is often or permanently wet in the autumn is closed to grazing in mid October, compared to land which is only occasionally wet on which some livestock graze until December. (Statistically, there is a 61 % chance of correctly predicting the grazing season on the basis of field wetness conditions).

# 3 HYDRAULIC AND HYDROLOGICAL INFORMATION

## 3.1 Introduction

Information on channel hydraulics and hydrological data have been used to determine the impact of maintenance on channel capacity and flood return periods.

## 3.2 Cross-section Surveys

Cross-sectional surveys of the river channel were taken at four points (Figure 1) along the study reach at an average interval of 726 m before and after the desilting and tree and bush maintenance of 1990. Channel capacity and freeboard were determined from these cross-sections.

Prior to maintenance, the channel roughness was expressed in terms of the Manning's n coefficient, in accordance with the methodology developed by Cowan (1956). This coefficient is composed of six elements which include the degree of irregularity of the channel bed, predominant bed material and channel sinuosity. Further details of this methodology are contained within the R&D Note 456, Appendix IV. Friction values were determined for the channel following maintenance using the same procedure in order to identify roughness values for the 'with' and 'without' maintenance situation.

Stage / discharge curves for the 'with' and 'without' maintenance situation have been constructed for each cross-section using the different values of Manning's 'n'. The cross-section surveys and stage / discharge curves are presented in Appendix II of the 'RIMS Project Evaluation - Hilton Brook' report submitted to the NRA in March 1992. The bankfull channel capacities and associated return periods for the 'with' and 'without' maintenance scenario are presented in Table 3.1.

The bankfull capacity figures obtained from the cross-sections indicate an average increase in capacity attributable to maintenance of 20 % (from 7 cumecs to 9 cumecs) and an average increase in the interval between flood events from three times a year to once every 1.25 years.

**Table 3.1 Bankfull capacity and return periods**

| Cross-Section | Without Maintenance Bankfull Capacity ($m^3/s$) | Without Maintenance Return Period (years) | With Maintenance Bankfull Capacity ($m^3/s$) | With Maintenance Return Period (years) |
|---|---|---|---|---|
| 1 | 5.90 | 0.20 | 7.70 | 0.60 |
| 2 | 6.23 | 0.25 | 8.30 | 0.65 |
| 3 | 8.95 | 0.70 | 9.80 | 0.95 |
| 4 | 6.89 | 0.30 | 10.15 | 1.10 |

(Source: modelled estimates)

## 3.3 Flood Return Period

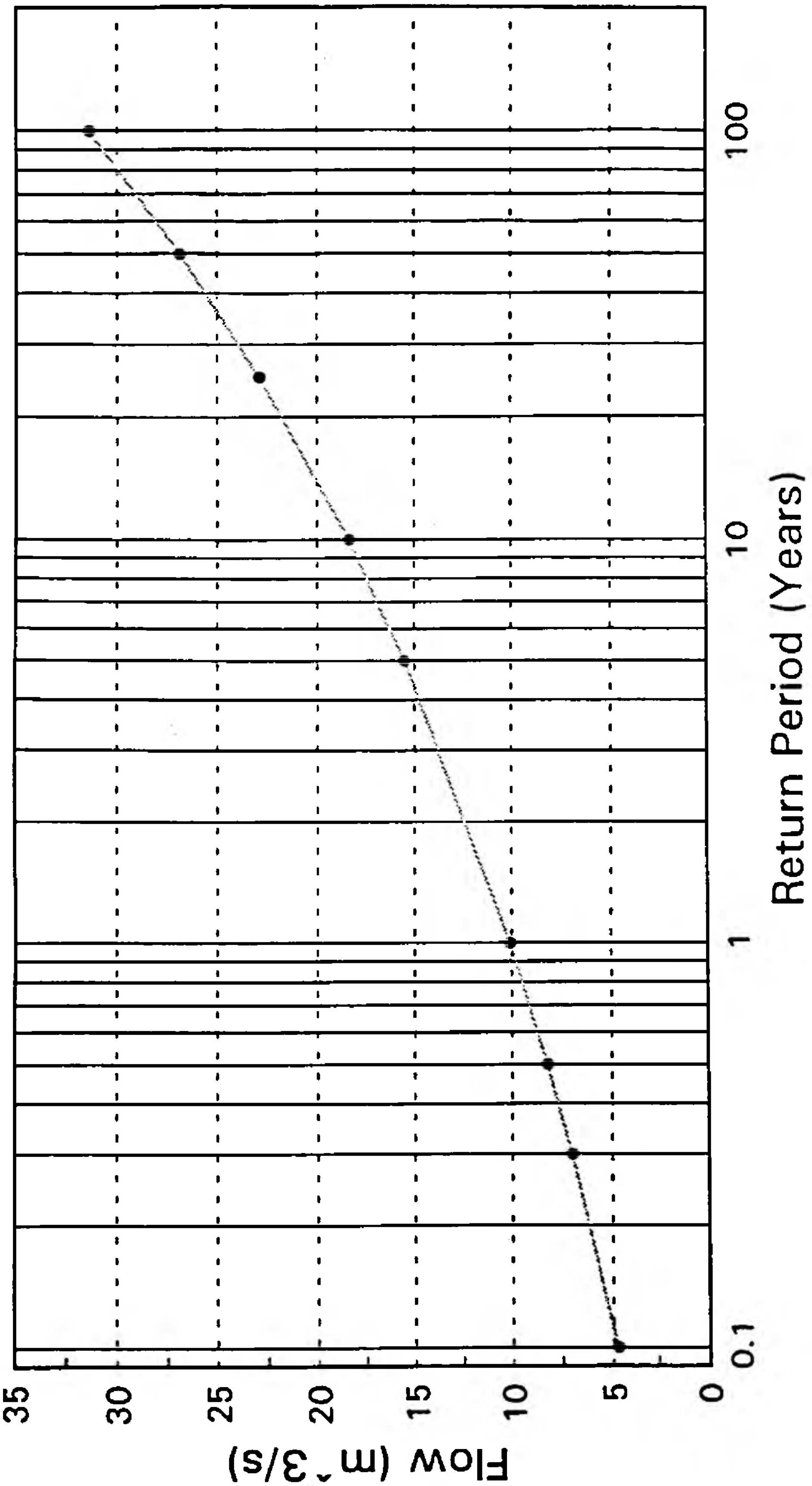
Throughout the period of study (1992 to 1995) river water level information was collected on a regular basis from two gauge boards which were installed within the study reach.

Information regarding frequency, duration and magnitude of flood flows has been collected from interviews with local farmers and NRA staff. Flood return period curves for the River Sence have been compiled from this information, using the methodology contained within the Flood Studies Report (NERC, 1975). The frequency of floods of different magnitudes can be estimated from this flood return period curves (Figure 4).

The flood return period for each block which floods and associated flooded areas are shown in Table 3.2. The 'without' maintenance return period is estimated by the farmer, the 'with' maintenance value is a modelled estimate using the cross-section information and Manning's n coefficient. It is assumed that the flooded area remains unchanged following maintenance.

**Table 3.2 Flood return periods**

| Block No. | Block Size (ha) | Flooded Area (ha) | Flood Return Period (Years) Without Maintenance | Flood Return Period (Years) With Maintenance |
|---|---|---|---|---|
| 101 | 4.21 | 1.9 | 0.3 | 1.1 |
| 201 | 1.80 | 0.9 | 0.3 | 1.1 |
| 202 | 3.11 | 1.2 | 0.3 | 1.1 |
| 203 | 3.31 | 3.3 | 0.3 | 1.1 |
| 204 | 4.50 | 4.5 | 0.3 | 1.0 |
| 205 | 9.10 | 9.1 | 0.3 | 1.1 |
| 302 | 13.18 | 8.5 | 0.3 | 0.7 |
| 303 | 5.56 | 4.4 | 0.3 | 0.7 |
| 401 | 4.10 | 2.5 | 0.3 | 0.7 |
| 402 | 2.60 | 1.3 | 0.3 | 0.7 |
| 501 | 7.32 | 4.3 | 0.2 | 0.6 |
| 502 | 2.95 | 1.4 | 0.2 | 0.6 |
| 503 | 4.98 | 2.5 | 0.3 | 0.7 |
| 505 | 8.40 | 1.2 | 0.2 | 0.6 |




NB: Flood Studies Report methodology

**Figure 4** **Flood return period curve**

# 4 LAND DRAINAGE

## 4.1 Field Drainage Status

Through an extensive literature and farmer survey, drainage status of the land has been classified into three bands according to watertable depth. These watertable bands have been identified as > 0.5 m from the surface, between 0.3 and 0.5 m from the surface and < 0.3 m from the surface. According to the time the watertable lies within these bands, the drainage standard is classed as good (G, no limitations on land use), bad (B, some restrictions on agriculture) or very bad (VB, severe limitations to agriculture). Further details are presented in the R&D Note 456, Section 3.5.2.

The drainage status of land within the benefit area has been determined on a seasonal basis using a non-steady state watertable model which relates infield watertable levels (and hence drainage conditions) to observed water levels in the river and ditch system (see R&D Note 456, Section 3.5.2 for further details). The model has been run using river water levels for the 'with' and 'without' maintenance scenario and the same climatic data in order to isolate the impact of maintenance on drainage status. An example of the input and output data of the watertable model is shown in Appendix I.

The results of the watertable model and the assessment of drainage status made by farmers are shown in Table 4.1. In some cases, there may be a change in the number of weeks that the watertable lies within the good, bad and very bad drainage bands following maintenance. However, these changes may not be of sufficient magnitude to change the drainage status classification. Where a sufficient change in drainage status has occurred due to maintenance, the changes appear in bold print in Table 4.1.

These assessments confirm that the drainage status in the benefit area with maintenance is generally good under dry climatic conditions, bad under average conditions and very bad under wet climatic conditions. If maintenance were not performed, drainage conditions would deteriorate towards very bad in a wet season and average season and towards bad under dry conditions.

**Table 4.1 Drainage status for wet, average and dry seasons, without/with maintenance**

| Block No | | Wet Season * | | Average Season * | | Dry Season * | | Farmer Assessment With Maintenance | | | Farmer Assessment Without |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Without | With | Without | With | Without | With | Wet | Average | Dry | |
| 101 | N | VB | VB | **VB** | **B** | **B** | **G** | *B* | B | G | B |
| 102 | N | VB | VB | VB | VB | B | B | VB | VB | B | VB |
| 201 | Y | VB | VB | B | B | **B** | **G** | VB | *VB* | G | VB |
| 202 | Y | VB | VB | B | B | **B** | **G** | VB | *VB* | G | VB |
| 203 | Y | VB | VB | B | B | **B** | **G** | VB | *VB* | G | VB |
| 204 | Y | VB | VB | B | B | **B** | **G** | VB | *VB* | G | VB |
| 205 | Y | VB | VB | B | B | **B** | **G** | VB | *VB* | G | VB |
| 301 | N | VB | VB | VB | VB | B | B | *B* | *B* | *G* | B |
| 302 | N | VB | VB | VB | VB | B | B | *B* | *B* | *G* | VB |
| 303 | N | VB | VB | VB | VB | B | B | *B* | *B* | *G* | VB |
| 401 | N | VB | VB | VB | VB | **VB** | **B** | VB | VB | B | VB |
| 402 | N | VB | VB | VB | VB | **VB** | **B** | VB | VB | B | VB |
| 501 | Y | VB | VB | **VB** | **B** | G | G | VB | *VB* | G | VB |
| 502 | Y | VB | VB | **VB** | **B** | G | G | VB | *VB* | G | VB |
| 503 | Y | VB | VB | **B** | **G** | G | G | VB | G | G | B |
| 504 | Y | VB | VB | B | B | G | G | VB | B | G | B |
| 505 | Y | VB | VB | **B** | **G** | G | G | VB | G | G | B |

NB : * Modelled results
Y or N refers to the presence or absence of field drainage
Bold type indicates a change in drainage status due to maintenance
Italics indicate a difference in farmer and modelled assessment of drainage status with maintenance

The output from the watertable model is generally consistent with the farmers assessment of drainage status under wet, dry and average climatic conditions for the 'with' maintenance situation. Under conditions of no maintenance, farmers perceive the drainage condition to be worse in an average season, than the model predicts. The discrepancy appears to be in the distinction between bad and very bad drainage by farmers. Under average weather conditions, there is 41 % agreement between the farmers' assessment and modelled assessment of drainage conditions. Under wet and dry conditions there is 76 % and 82 % agreement respectively.

River maintenance results in the prevention of a deterioration of drainage status on five blocks of land in an average season and on eight blocks in a dry season.

- In an average season maintenance prevents deterioration from :

  B to VB over 14 ha (15 % of BA)
  G to B over 13 ha (14 % of BA)

- In a dry season maintenance prevents deterioration from :

  B to VB over 7 ha (7 % of BA)
  G to B over 26 ha (28 % of BA)

The farmer assessment of field drainage conditions in an average season, suggest a deterioration in drainage condition from good to bad over 14 % (13 ha) and from bad to very bad over 20 % (19 ha) of the benefit area, in the absence of maintenance.

The analysis and farmer assessment suggest that maintenance has a limited impact on drainage conditions. Farmers accommodate the generally poor drainage conditions within their farming practice.

# 5 SCHEME APPRAISAL

## 5.1 Benefit Assessment

For each block of land, agricultural production scenarios were created which reflect different levels of field management under conditions of good, bad and very bad drainage (see R&D Note 456 Section 3.5.4). These scenarios are based on discussions with farmers in the benefit area over the period 1992-1994.

Changes in field drainage status as a result of maintenance under dry, average and wet climatic conditions have been identified. Changes in flood risk due to maintenance have also been determined. Estimates have been derived of the monetary value of changes in field management and productivity associated with changes in the standards of drainage service.

Two perspectives have been used to value agricultural performance. The first perspective is that of financial analysis which uses the prices paid and received by farmers to estimate the added-value associated with drainage. Financial analysis shows the benefits of maintenance to farmers in the benefit area.

The second perspective is that of economic analysis which modifies the financial analysis to make allowance for the direct and indirect subsidies paid to farmers by Government. In accordance with the MAFF Project Appraisal Guidance Notes on Flood Defence (PAGN, 1993), these modifications involve reductions in the financial value of output (including subsidies) by 10 % in the case of cereals, oil seeds and grain legumes, 35 % for beef and 25 % for sheep. Commodities subject to quota such as potatoes, sugar beet and milk are treated as winter wheat. The set aside areas are also treated as wheat. The reasons for these adjustments are discussed in the R&D Note 456 Section 2.7.2.

Using the results of watertable modelling, Table 5.1 shows the financial net returns (1995/96 prices) for each block of land within the benefit area under conditions of good, bad and very bad drainage. Changes in net returns relating to a change in drainage status are also shown. Table 5.2 presents similar data using economic prices. Table 5.3 shows the flood costs for each block of land assuming with and without maintenance and specified field drainage conditions. It is assumed that there is no difference between financial and economic values in the case of flood damage to standing crops.

**Table 5.1 Financial net returns**

| Block | Area (ha) | Net Returns (£/ha) | | | Change in Net Returns (£/ha) | | |
|---|---|---|---|---|---|---|---|
| | | Good | Bad | Very Bad | Good to Bad | Bad to Very Bad | Good to Very Bad |
| 101 | 4.21 | 638 | 478 | 294 | 160 | 184 | 344 |
| 102 | 6.70 | 313 | 269 | 226 | 44 | 43 | 87 |
| 201 | 1.80 | 243 | 195 | 118 | 48 | 77 | 125 |
| 202 | 3.11 | 132 | 127 | 71 | 4 | 56 | 61 |
| 203 | 3.31 | 445 | 350 | 280 | 95 | 70 | 165 |
| 204 | 4.50 | 406 | 318 | 254 | 87 | 64 | 152 |
| 205 | 9.10 | 437 | 357 | 232 | 79 | 125 | 204 |
| 301 | 6.76 | 515 | 400 | 292 | 114 | 108 | 223 |
| 302 | 13.18 | 432 | 326 | 258 | 106 | 68 | 174 |
| 303 | 5.56 | 136 | 127 | 72 | 9 | 56 | 64 |
| 401 | 4.10 | 474 | 402 | 300 | 72 | 102 | 174 |
| 402 | 2.60 | 311 | 271 | 238 | 41 | 33 | 73 |
| 501 | 7.32 | 399 | 338 | 222 | 62 | 116 | 177 |
| 502 | 2.95 | 393 | 338 | 217 | 56 | 121 | 176 |
| 503 | 4.98 | 404 | 341 | 224 | 62 | 117 | 179 |
| 504 | 4.80 | 419 | 351 | 237 | 69 | 114 | 183 |
| 505 | 8.40 | 425 | 358 | 238 | 67 | 121 | 187 |

**Table 5.2 Economic net returns**

| Block | Area (ha) | Net Returns (£/ha) | | | Change in Net Returns (£/ha) | | |
|---|---|---|---|---|---|---|---|
| | | Good | Bad | Very Bad | Good to Bad | Bad to Very Bad | Good to Very Bad |
| 101 | 4.21 | 26 | 7 | -10 | 19 | 16 | 35 |
| 102 | 6.70 | 92 | 68 | 47 | 24 | 21 | 45 |
| 201 | 1.80 | 146 | 108 | 43 | 38 | 65 | 103 |
| 202 | 3.11 | -39 | -36 | -36 | -3 | 0 | -3 |
| 203 | 3.31 | 106 | 74 | 56 | 33 | 17 | 50 |
| 204 | 4.50 | 76 | 49 | 36 | 27 | 13 | 40 |
| 205 | 9.10 | 251 | 197 | 105 | 54 | 92 | 147 |
| 301 | 6.76 | 201 | 148 | 84 | 53 | 64 | 117 |
| 302 | 13.18 | 98 | 62 | 47 | 36 | 16 | 52 |
| 303 | 5.56 | -42 | -36 | -38 | -7 | 2 | -4 |
| 401 | 4.10 | 410 | 340 | 232 | 70 | 109 | 179 |
| 402 | 2.60 | 91 | 70 | 59 | 20 | 11 | 31 |
| 501 | 7.32 | 339 | 277 | 154 | 62 | 123 | 185 |
| 502 | 2.95 | 330 | 277 | 148 | 53 | 129 | 183 |
| 503 | 4.98 | 343 | 280 | 157 | 63 | 123 | 186 |
| 504 | 4.80 | 360 | 292 | 174 | 68 | 118 | 186 |
| 505 | 8.40 | 365 | 298 | 172 | 67 | 126 | 194 |

**Table 5.3 Flood costs**

| | | | GOOD DRAINAGE | | BAD DRAINAGE | | VERY BAD DRAINAGE | | | | | CHANGE IN FLOOD COSTS | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Block Number | Without maintenance return period | With maintenance return period | Without maintenance flood cost | With maintenance flood cost | Without maintenance flood cost | With maintenance flood cost | Without maintenance flood cost | With maintenance flood cost | GOOD Without -with | BAD Without -with | VERY BAD Without -with | GOOD TO BAD Without -with | BAD TO ERY BAD Without -with | GOOD TO ERY BAD Without -with |
| 101 | 0.30 | 1.10 | 28.20 | 7.69 | 21.71 | 5.92 | 13.97 | 3.81 | 24.39 | 15.79 | 10.16 | 17.90 | 8.05 | 10.16 |
| 201 | 0.30 | 1.10 | 46.13 | 12.58 | 39.86 | 10.87 | 31.57 | 8.61 | 37.52 | 28.99 | 22.96 | 31.25 | 20.70 | 22.96 |
| 202 | 0.30 | 1.10 | 18.59 | 5.07 | 16.13 | 4.40 | 10.60 | 2.89 | 15.70 | 11.73 | 7.71 | 13.24 | 6.20 | 7.71 |
| 203 | 0.30 | 1.10 | 22.59 | 6.16 | 18.92 | 5.16 | 15.80 | 4.31 | 18.28 | 13.76 | 11.49 | 14.61 | 10.64 | 11.49 |
| 204 | 0.70 | 1.00 | 10.19 | 7.13 | 8.54 | 5.98 | 7.13 | 4.99 | 5.20 | 2.56 | 2.14 | 3.55 | 1.15 | 2.14 |
| 302 | 0.30 | 0.70 | 16.64 | 7.13 | 13.25 | 5.68 | 10.71 | 4.59 | 12.05 | 7.57 | 6.12 | 8.66 | 5.03 | 6.12 |
| 401 | 0.30 | 0.70 | 411.18 | 176.22 | 344.35 | 147.58 | 253.52 | 108.65 | 302.53 | 196.77 | 144.87 | 235.70 | 105.94 | 144.87 |
| 402 | 0.30 | 0.70 | 9.26 | 3.97 | 8.54 | 3.66 | 7.77 | 3.33 | 5.93 | 4.88 | 4.44 | 5.21 | 4.11 | 4.44 |
| 501 | 0.20 | 0.60 | 216.93 | 72.31 | 193.92 | 64.64 | 142.14 | 47.38 | 169.55 | 129.28 | 94.76 | 146.54 | 77.50 | 94.76 |
| 502 | 0.20 | 0.60 | 179.25 | 59.75 | 161.61 | 53.87 | 116.49 | 38.83 | 140.42 | 107.74 | 77.66 | 122.78 | 62.62 | 77.66 |
| 205 | 0.30 | 1.10 | 141.53 | 38.60 | 121.70 | 33.19 | 99.18 | 27.05 | 114.48 | 88.51 | 72.13 | 94.65 | 65.99 | 72.13 |
| 303 | 0.30 | 0.70 | 41.93 | 17.97 | 34.74 | 14.89 | 23.45 | 10.05 | 31.88 | 19.85 | 13.40 | 24.69 | 8.56 | 13.40 |
| 503 | 0.30 | 0.70 | 107.24 | 45.96 | 96.25 | 41.25 | 72.40 | 31.03 | 76.21 | 55.00 | 41.37 | 65.22 | 31.15 | 41.37 |
| 505 | 0.20 | 0.60 | 80.73 | 26.91 | 69.93 | 23.31 | 51.36 | 17.12 | 63.61 | 46.62 | 34.24 | 52.81 | 28.05 | 34.24 |

Table 5.4 combines data on changes in drainage status, flood risk and financial performance to determine the financial benefits and change in financial net returns due to maintenance for wet, average and dry weather conditions for each block of land in the benefit area. These benefits are the avoidance of losses which would occur in the absence of maintenance. Benefits, weighted by field size for wet, average and dry seasons are multiplied by the relative probability of the occurrence of the season to give an average expected annual benefit. These are summed for the benefit area as a whole.

Table 5.4 estimates a total expected annual benefit of £ 5342 in 1995 financial prices, equivalent to about £ 57/ha per year. The majority of this benefit is associated with avoidance of flood damage to standing crops flood rather than those associated with reduced waterlogging. Maintenance benefits are greatest in dry seasons. This reflects the fact that in other seasons maintenance has limited impact on field watertable levels. Table 5.5 shows the benefits attributable to maintenance using economic prices based on the current MAFF Project Appraisal Guidance Notes. Total average expected annual benefits are about £ 5052 in economic prices for the benefit area, equivalent to £ 54/ha. On this basis, the benefit to the national economy is 94 % of the benefits which accrue to farmers. This difference reflects the adjustments required by MAFF to remove government subsidy from the assessment of benefits.

**Table 5.4 Changes in net returns due to maintenance and climate, 1995/96 financial prices**

| | | Wet Season | | | Average Season | | | Dry Season | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Block | Area (ha) | Benefit due to drainage (£/ha/yr) | Benefits of flood alleviation (£/ha) | Change in net return due to maintenance | Benefit due to drainage (£/ha/yr) | Benefits of flood alleviation (£/ha) | Change in net return due to maintenance | Benefit due to drainage (£/ha/yr) | Benefits of flood alleviation (£/ha) | Change in net return due to maintenance | Total Change (£/yr) |
| 101 | 4.21 | 0 | 10.16 | 10 | 43 | 8.05 | 51 | 160 | 17.90 | 178 | 290 |
| 102 | 6.70 | 0 | 0.00 | 0 | 0 | 0.00 | 0 | 0 | 0.00 | 0 | 0 |
| 201 | 1.80 | 0 | 22.96 | 23 | 0 | 28.99 | 29 | 48 | 31.25 | 79 | 68 |
| 202 | 3.11 | 0 | 7.71 | 8 | 0 | 11.73 | 12 | 4 | 13.24 | 17 | 38 |
| 203 | 3.31 | 0 | 11.49 | 11 | 0 | 13.76 | 14 | 95 | 14.61 | 109 | 107 |
| 204 | 4.50 | 0 | 2.14 | 2 | 0 | 2.56 | 3 | 87 | 3.55 | 91 | 91 |
| 205 | 9.10 | 0 | 72.13 | 72 | 0 | 88.51 | 89 | 79 | 94.65 | 174 | 933 |
| 301 | 6.76 | 0 | 0.00 | 0 | 0 | 0.00 | 0 | 0 | 0.00 | 0 | 0 |
| 302 | 13.18 | 0 | 6.12 | 6 | 0 | 6.12 | 6 | 0 | 7.57 | 8 | 84 |
| 303 | 5.56 | 0 | 13.40 | 13 | 0 | 13.40 | 13 | 0 | 19.85 | 20 | 82 |
| 401 | 4.10 | 0 | 144.87 | 145 | 0 | 144.87 | 145 | 102 | 105.94 | 208 | 646 |
| 402 | 2.60 | 0 | 4.44 | 4 | 0 | 4.44 | 4 | 33 | 4.11 | 37 | 28 |
| 501 | 7.32 | 0 | 94.76 | 95 | 116 | 77.50 | 193 | 0 | 169.55 | 170 | 1243 |
| 502 | 2.95 | 0 | 77.66 | 78 | 121 | 62.62 | 183 | 0 | 140.42 | 140 | 456 |
| 503 | 4.98 | 0 | 41.37 | 41 | 62 | 65.22 | 128 | 0 | 76.21 | 76 | 503 |
| 504 | 4.80 | 0 | 0.00 | 0 | 0 | 0.00 | 0 | 0 | 0.00 | 0 | 0 |
| 505 | 8.40 | 0 | 34.24 | 34 | 67 | 52.81 | 119 | 0 | 63.61 | 64 | 773 |
| Total | 93 | | | | | | | | | Total | 5342 |
| Probability of : | | Wet season | | 0.19 | | | | | | Benefit (£/ha) | 57 |
| | | Average season | | 0.61 | | | | | | | |
| | | Dry season | | 0.20 | | | | | | | |

Table 5.5 Changes in net returns due to maintenance and climate, 1995/96 economic prices

| Block | Area (ha) | Wet Season: Benefit due to drainage (£/ha/yr) | Wet Season: Benefits of flood alleviation (£/ha) | Wet Season: Change in net return due to maintenance | Average Season: Benefit due to drainage (£/ha/yr) | Average Season: Benefits of flood alleviation (£/ha) | Average Season: Change in net return due to maintenance | Dry Season: Benefit due to drainage (£/ha/yr) | Dry Season: Benefits of flood alleviation (£/ha) | Dry Season: Change in net return due to maintenance | Total Change (£/yr) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 101 | 4.21 | 0 | 10.16 | 10 | 16 | 8.05 | 24 | 19 | 17.90 | 37 | 102 |
| 102 | 6.70 | 0 | 0.00 | 0 | 0 | 0.00 | 0 | 0 | 0.00 | 0 | 0 |
| 201 | 1.80 | 0 | 22.96 | 23 | 0 | 28.99 | 29 | 38 | 31.25 | 69 | 65 |
| 202 | 3.11 | 0 | 7.71 | 8 | 0 | 11.73 | 12 | -3 | 13.24 | 10 | 33 |
| 203 | 3.31 | 0 | 11.49 | 11 | 0 | 13.76 | 14 | 33 | 14.61 | 47 | 66 |
| 204 | 4.50 | 0 | 2.14 | 2 | 0 | 2.56 | 3 | 27 | 3.55 | 31 | 37 |
| 205 | 9.10 | 0 | 72.13 | 72 | 0 | 88.51 | 89 | 54 | 94.65 | 149 | 887 |
| 301 | 6.76 | 0 | 0.00 | 0 | 0 | 0.00 | 0 | 0 | 0.00 | 0 | 0 |
| 302 | 13.18 | 0 | 6.12 | 6 | 0 | 6.12 | 6 | 0 | 7.57 | 8 | 84 |
| 303 | 5.56 | 0 | 13.40 | 13 | 0 | 13.40 | 13 | 0 | 19.85 | 20 | 82 |
| 401 | 4.10 | 0 | 144.87 | 145 | 0 | 144.87 | 145 | 109 | 105.94 | 214 | 651 |
| 402 | 2.60 | 0 | 4.44 | 4 | 0 | 4.44 | 4 | 11 | 4.11 | 15 | 17 |
| 501 | 7.32 | 0 | 94.76 | 95 | 123 | 77.50 | 200 | 0 | 169.55 | 170 | 1275 |
| 502 | 2.95 | 0 | 77.66 | 78 | 129 | 62.62 | 192 | 0 | 140.42 | 140 | 472 |
| 503 | 4.98 | 0 | 41.37 | 41 | 63 | 65.22 | 128 | 0 | 76.21 | 76 | 504 |
| 504 | 4.80 | 0 | 0.00 | 0 | 0 | 0.00 | 0 | 0 | 0.00 | 0 | 0 |
| 505 | 8.40 | 0 | 34.24 | 34 | 67 | 52.81 | 120 | 0 | 63.61 | 64 | 777 |
| Total | 94 | | | | | | | | | Total | 5052 |
| Probability of : | | Wet season | | 0.19 | | | | | | Benefit (£/ha) | 54 |
| | | Average season | | 0.61 | | | | | | | |
| | | Dry season | | 0.20 | | | | | | | |

As an alternative estimate to that based on watertable modelling, Table 5.6 estimates the benefits due to maintenance which were perceived by farmers (earlier reported in Table 4.1) where they identified a change in drainage conditions between the 'with' and 'without' maintenance situations in an average, representative season. These estimates include the flood damage costs identified in Table 5.3 which were based on a combination of farmer and modelled data. Farmer assessment gave an average annual financial benefit of £ 7767 (£ 83/ha) and an economic benefit of £ 6922 (£ 74/ha) under average conditions.

**Table 5.6 Farmer asessment of maintenance benefits**

| Block | Area (ha) | Average Season Financial Prices: Benefit due to drainage (£/ha/yr) | Average Season Financial Prices: Benefits of flood alleviation (£/ha) | Average Season Financial Prices: Change in net return due to maintenance | Average Season Economic Prices: Benefit due to drainage (£/ha/yr) | Average Season Economic Prices: Benefits of flood alleviation (£/ha) | Average Season Economic Prices: Change in net return due to maintenance |
|---|---|---|---|---|---|---|---|
| 101 | 4.21 | 0 | 10.16 | 43 | 0 | 8.05 | 34 |
| 102 | 6.70 | 0 | 0.00 | 0 | 0 | 0.00 | 0 |
| 201 | 1.80 | 77 | 22.96 | 180 | 65 | 28.99 | 169 |
| 202 | 3.11 | 56 | 7.71 | 198 | 0 | 11.73 | 36 |
| 203 | 3.31 | 70 | 11.49 | 270 | 17 | 13.76 | 102 |
| 204 | 4.50 | 64 | 2.14 | 298 | 13 | 2.56 | 70 |
| 205 | 9.10 | 125 | 72.13 | 1794 | 92 | 88.51 | 1643 |
| 301 | 6.76 | 108 | 0.00 | 730 | 64 | 0.00 | 433 |
| 302 | 13.18 | 0 | 6.12 | 81 | 0 | 6.12 | 81 |
| 303 | 5.56 | 0 | 13.40 | 75 | 0 | 13.40 | 75 |
| 401 | 4.10 | 0 | 144.87 | 594 | 0 | 144.87 | 594 |
| 402 | 2.60 | 0 | 4.44 | 12 | 0 | 4.44 | 12 |
| 501 | 7.32 | 116 | 94.76 | 1543 | 123 | 77.50 | 1468 |
| 502 | 2.95 | 121 | 77.66 | 586 | 129 | 62.62 | 565 |
| 503 | 4.98 | 62 | 41.37 | 515 | 63 | 65.22 | 639 |
| 504 | 4.80 | 0 | 0.00 | 0 | 0 | 0.00 | 0 |
| 505 | 8.40 | 67 | 34.24 | 850 | 67 | 52.81 | 1003 |
| Total | 93 | | Total financial benefit (£) | 7767 | | Total economic benefit (£) | 6922 |
| | | | Benefit (£/ha) | 83 | | Benefit (£/ha) | 74 |

According to the criteria used, these financial and economic benefit estimates show the limits which farmers and the nation respectively could justifiably spend on maintenance. These estimates require cautious interpretation as explained in the R&D Note 456 Section 2.7.2.

## 5.2 Maintenance Costs

Maintenance activities on the Hilton Brook involved a programme of shoal removal, selected minor regrading, and tree and bush work. These were last carried out in 1990. The cost of these works was initially estimated at £ 25,000. The total expenditure on the study reach was eventually around £ 37,000 but this included some additional remedial works to the channel.

The latter cost is equivalent to a capital sum of £ 41,440 in 1995 prices or an annual charge of £ 4268, assuming a 15 year life for the maintenance activity. A 10 year life gives an annual charge of £ 5635.

## 5.3 Scheme Appraisal

The estimated benefits attributable to maintenance can be compared with estimated costs to determine the justification for expenditure. Because the main maintenance activity is performed annually, the appraisal involves a simple comparison of annual benefits and costs.

Table 5.7 shows that the existing maintenance scheme is not viable in financial and economic terms. The modelled results show that benefits to farmers and the economy do not appear to recover the costs of the scheme. Feasibility is very sensitive to the assumed life of the maintenance works. A 15 year life would generate benefit : cost ratios of 1.25 and 1.18 in financial and economic prices respectively, rendering the scheme profitable. Given the gravel substrate material, the interval between operations required to maintain standards is unlikely to exceed 10 years.

**Table 5.7 Maintenance scheme appraisal: Hilton Brook**

| Average Annual Benefit (£) | Average Annual Benefits (£) | Average Annual Costs (£) | Benefit: Cost Ratio |
|---|---|---|---|
| *Modelled Estimates* | | | |
| Financial Prices | 5342 | 5635 | 0.95 |
| Economic Prices | 5052 | 5635 | 0.90 |
| *Farmer Estimates* | | | |
| Financial Prices | 7767 | 5635 | 1.37 |
| Economic Prices | 6922 | 5635 | 1.22 |

The farmer based estimate shows that, based on benefits in an average year, the maintenance scheme not viable. The scheme generates an annual benefit : cost ratio of 1.37 and 1.22 in financial and economic terms respectively.

These conclusions must be interpreted cautiously as discussed in the R&D Note 456 Section 2.7.6.

# 6 ENVIRONMENT

## 6.1 Introduction

The environmental quality of the Hilton Brook is outlined in this chapter. Reference is made to river corridor surveys, public consultation and farmer assessment.

## 6.2 River Corridor Survey

A river corridor survey was completed for each 500 m section of the study reach pre- and post-maintenance in 1989. The survey methodology developed by the Nature Conservancy Council, (NCC, now English Nature, EN) was followed. A record card and sketch map was completed for each section. The maps and cards can be found in Appendix V of the RIMS Project Evaluation - Hilton Brook Report.

## 6.3 Farmer Assessment

Farmers interviewed along the study reach were asked if they were aware of any flora or fauna of environmental interest along this section. Most farmers thought the river to be of significant environmental interest in terms of fish. The Brook is stocked annually with trout.

## 6.4 Channel and Bank Quality

The environmental quality of the Hilton Brook has been determined by following the procedure outlined in the 'Guidelines for the Justification of River Maintenance' (R&D Note 511) produced within the framework of the NRA R&D Note 456 (River Maintenance Evaluation).

The quality of both the river channel and banks is classed as medium. At times of low flow there is a well developed transitional zone between the river and edge of the channel and sediments are exposed. Sediments are varied and pool - riffle sequences, interspersed with slack water are dominant. Submerged tree roots, overhanging and trailing branches provide minor habitats.

The banks are of simple structure, consisting of predominantly two or three vegetation types without large areas of trees or scrub. Bank width is typically 5 to 10 m. The bank structure is varied, comprising earth cliffs and slumped banks. Trees, scrub, grass and herbs comprise the bank vegetation. The tree and bush species are varied and interspersed with other vegetation.

# 7 CONCLUSIONS

## 7.1 Scheme Appraisal

The existing maintenance scheme is not viable in either financial or economic terms. The average annual economic benefit of maintenance in terms of its prevention in a deterioration in drainage status and increase in flooding is £ 5052. Average annual maintenance costs are £ 5635. The benefit : cost ratio is therefore 0.9.

## 7.2 Maintenance Best Practice

The 'best practice' vegetation maintenance methods for the Hilton Brook were determined using the Guidelines (R&D Note 511), produced as a result of the Environmental Impact Assessment Study.

**Channel**

Best practice maintenance operations for emergent weed are identified as :

- Biennial cutting;
- Cutting on a 3 to 5 year rotation; and,
- Desilting / raking at an interval of 2 to 7 years.

Best practice maintenance operations for floating and submerged weed are identified as :

- Annual cutting in the autumn;
- Biennial cutting; and,
- Cutting on a 3 to 5 year rotation.

All these maintenance operations should be selective, concentrating on those areas which are particularly choked by vegetation or areas in which the weed is liable to cause an obstruction, hazard or restriction to flow.

No channel maintenance has been performed on the Hilton Brook since the selective desilting, tree and bush scheme and selective regrading of 1990. As the Hilton Brook is predominantly a gravel bed channel, movement of the substrate during times of high flow inhibits the development of a lot of aquatic vegetation due to its inability to create a firm root hold.

Selective cutting of vegetation every few years may be sufficient to keep the vegetation under control. Selective desilting every seven years may be sufficient to enable the channel to provide the required standard of service. This is in accordance with the channel maintenance regime recommended as best practice in environmental terms.

**Bank**

Best practice maintenance operations for bank vegetation are identified as :

- Single bank mowing / flailing in spring / summer leaving a 1 m wide toe strip;
- Single bank mowing / flailing in autumn / winter leaving a toe strip > 0.25 m wide;
- Mowing / flailing every 3 - 5 years leaving a toe strip over 1 m wide or selective cutting (< 20 %); and,
- Light grazing.

Since 1990, the only bank maintenance performed has been the single flail mowing of two small areas. The majority of the banks are grazed lightly by sheep and or beef. This is in accordance with the bank maintenance regime recommended as best practice in environmental terms.

## 7.3 Recommendations

It is recommended that further research is carried to examine and quantify :-

- the impact of debris dams on flooding within the benefit area.

## 7.4 Epilogue

This report has assessed the impacts of the current maintenance regime on the study reach. It has been used along with other study sites to formulate guidelines on the appraisal of maintenance works and best environmental practice. These draft guidelines are summarised in Chapter 5 of the R&D Note 456 and presented in full under separate covers.

# 8 REFERENCES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NERC (1975). Flood Studies Report. NERC, London.

Nix, J (1994). Farm Management Pocket Book, 25th ed. 1994/95., MAFF, HMSO, London.

Sutherland, D.C and Morris, J. (1990). RIMS Project Evaluation - Baseline Report. Report submitted to the NRA Severn Trent Region, 1990.

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Map: Pathfinder 832. Derby and Etwall. 1: 25 000, Ordnance Survey Southampton (1988).

## APPENDIX I

Example of input and output data for the watertable model

Hilton Brook
Block Number 101
Cross-section 4

| | Input Data | Output Data |
|---|---|---|
| | River height (m AOD) | Watertable height (m AOD) |
| Week 1994 | | |
| 1 | 63.58 | 64.03 |
| 2 | 63.59 | 64.23 |
| 3 | 63.30 | 64.23 |
| 4 | 63.71 | 64.23 |
| 5 | 63.59 | 64.23 |
| 6 | 63.51 | 64.23 |
| 7 | 63.48 | 64.23 |
| 8 | 63.50 | 64.23 |
| 9 | 63.48 | 64.23 |
| 10 | 63.50 | 64.20 |
| 11 | 63.75 | 64.21 |
| 12 | 63.75 | 64.23 |
| 13 | 63.45 | 64.23 |
| 14 | 63.45 | 64.23 |
| 15 | 63.45 | 64.23 |
| 16 | 63.30 | 64.21 |
| 17 | 63.30 | 64.10 |
| 18 | 63.44 | 64.05 |
| 19 | 63.38 | 63.69 |
| 20 | 63.30 | 63.49 |
| 21 | 63.35 | 63.63 |
| 22 | 63.34 | 63.77 |
| 23 | 63.34 | 63.47 |
| 24 | 63.34 | 63.42 |
| 25 | 63.32 | 63.34 |
| 26 | 63.34 | 63.41 |
| 27 | 63.34 | 63.43 |
| 28 | 63.30 | 63.57 |
| 29 | 63.37 | 63.45 |

Example of drainage status classification, Hilton Brook

With maintenance

Block 101

| | Watertable depth (m) | Spring 1994 | No. of weeks |
|---|---|---|---|
| >0.5 | 65.39 | 65.39 | 3 |
| 0.3><0.5m | 65.59 | 65.59 | 1 |
| <0.3m | 65.89 | 65.89 | 9 |

Drainage status classification, according to time watertable is within the G, B, VB drainage bands — Very Bad

Without maintenance

| | Watertable depth (m) | Spring 1994 | No. of weeks |
|---|---|---|---|
| >0.5 | 65.39 | 65.39 | 3 |
| 0.3><0.5m | 65.59 | 65.59 | 0 |
| <0.3m | 65.89 | 65.89 | 10 |

Drainage status classification, according to time watertable is within the G, B, VB drainage bands — Very Bad

| Summer 1994 | No. of weeks |
|---|---|
| 65.39 | 12 |
| 65.59 | 1 |
| 65.89 | 0 |

Good

| Autumn 1994 | No. of weeks |
|---|---|
| 65.39 | 2 |
| 65.59 | 1 |
| 65.89 | 10 |

Very Bad

| Summer 1994 | No. of weeks |
|---|---|
| 65.39 | 10 |
| 65.59 | 3 |
| 65.89 | 0 |

Bad

| Autumn 1994 | No. of weeks |
|---|---|
| 65.39 | 1 |
| 65.59 | 1 |
| 65.89 | 11 |

Very Bad