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# A study to establish the rationale for a National Rivers Authority (NRA) river rehabilitation programme to further conservation, improve fisheries and promote recreation

ECON and Pond Action

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**A study to establish the rationale for a National Rivers Authority (NRA) river rehabilitation programme to further conservation, improve fisheries and promote recreation**


## SUMMARY

This report describes a rationale for an NRA river rehabilitation programme to further conservation, improve fisheries and promote recreation.

The report looks at:
- the environmental and financial benefits of undertaking rehabilitation
- how sites should be prioritised for rehabilitation
- what broad opportunities there are to undertake rehabilitation

One of the most important justifications for undertaking river rehabilitation is that there are clear benefits to be gained.

## Environmental benefits:

- **Benefits for conservation.** Existing evidence suggests that rehabilitation methods could be of considerable benefit in protecting aquatic and wetland biodiversity through the protection and extension of critical habitats. Floodplain wetlands are at particular risk, and rehabilitation is likely to be of great benefit where it restores river-floodplain links and habitats.

- **Evidence of clear benefits for fisheries.** Rehabilitation for fisheries has a proven record of success in improving the existing resource, i.e. both species composition and biomass.

- **Benefits for amenity and recreation.** Existing studies in both Britain and continental Europe indicate that there is a strong public preferences for natural river landscapes. River rehabilitation can therefore (i) provide an amenity and recreation resource in its own right (ii) give a good basis for the development of other river-based activities such as pleasure boating, and fishing.

## Financial benefits

- The financial benefits of river rehabilitation are most evident when considered from the perspective of integrated catchment management. The great strength of rehabilitation is that, as an holistic method, it is particularly effective at reconciling the demands of the different user groups identified within CMPs.

  Financial savings resulting from the use of rehabilitation methods are possible in the following areas:

  - **Water quality** improvement (including the potential to permanently reduce the concentrations of pollutants like nitrates).

  - **Routine Maintenance** (for example reducing the frequency of dredging by allowing deposition of sediments on floodplains).

  - **Flood defence** (including the possibility of using the floodplain to intercept storm-runoff, store floodwater and reduce erosion.

  - Amelioration of **low flows** through storage and slow release of water from floodplain areas.

## Prioritising sites for rehabilitation

A methods for selecting rehabilitation sites is reccomended, useing the Catchment Management Plan framework.

- It is recomended that a strategic approach to rehabilitation is adopted, which operates at a catchment level but considers wider (ie national) objectives.

- It is suggested that the national objectives of conservation and fisheries rehabilitation should be to preserve biodiversity through the protection and rehabilitation of critical aqautic habitats. The broad objectives of recreation should be to benefit the greatest number of people.

## Opportunities for rehabilitation

Recent changes in the planning framework, in land-use and in peoples attitudes may now make river rehabilitation a much more feasible option than it has been previously. The most important changes include:

- Trends towards **extensification of agriculture**, backed by finantial insentives such as ESA & Countryside Stewardship. This may increasingly provide opportunities to 'regain' active floodplain.

- The recognition of **integrated catchment processes** and the resulting framework of Catchment Management Plans (CMP) which have the potential to aid implementation of rehabilitation schemes, and enshrines the principle of 'working with the river rather than against it'.

- Recognition of **'natural recovery'** and the possibilities of 'recovery enhancement', as potential rehabilitation techniques which require low financial investments.

- Scope for **reduction of maintenance levels**, (particularly where dredging now exceeds the required level of service), which will allow greater natural river recovery as well as finantial savings.

The most important of these opportunities is the potential for landuse change. It is changing land-use, above all else, that is now offering the space for channel restoration and the chance to reinstate areas of fully functional floodplain with all its attendant environmental and financial benefits.

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# 1. INTRODUCTION

## 1.1 Aims of the project

This report describes the results of a feasibility study undertaken for the National Rivers Authority (NRA) Head Office. The main aim of the study was to establish the rationale for a programme of river rehabilitation works which could be undertaken by the NRA in England and Wales. The report is divided into five main sections:

1. Definition of terms used to describe river improvement works (restoration, rehabilitation, enhancement, creation, mitigation).
2. A review of the extent, reasons for and chronology of the physical degradation of rivers in England and Wales.
3. The development of a rationale for the rehabilitation of rivers.
4. An outline of the criteria for selecting sites for rehabilitation.
5. A review of rehabilitation works currently being undertaken by the NRA and a discussion of the opportunities for river rehabilitation in England and Wales.

## 1.2 Background

In its broadest sense river rehabilitation includes measures to control pollution, provide near natural flows *and* re-establish natural channel and floodplain structures (NRC, 1992). However, this feasibility study is concerned only with the **physical aspects of rehabilitation**. Other aspects of rehabilitation, particularly the problems of water quality degradation and low flows, are being dealt with by the NRA in a wide range of specific investigations and routine regulation and monitoring work.

This study forms the first of a three-part initiative to assess the potential for physical river rehabilitation works. The three stages of this initiative are:

1. The development of a rationale for river rehabilitation (this report). The rationale describes the need for rehabilitation and the benefits to be derived from rehabilitating rivers. The Project Leader for the project is Dr Paul Raven (NRA Head Office).
2. A review of river rehabilitation techniques, including the preparation of a manual of methods. This project is a national R&D project led John Pygott (NRA Yorkshire Region).
3. A review of the organisation of rehabilitation projects. The complexities and cost of rehabilitation ensures that it will often require a multi-agency approach. This project is intended to identify the institutional framework for rehabilitation and is being prepared by Richard Vivash (NRA Anglian Region).

## 1.3 Sources of information for the report

The main sources of information used to prepare this report are outlined below.

### 1.3.1 Technical and scientific literature

Literature used to undertake this study was obtained through a computerised search using GEOBASE, (through Geo Abstracts) and an internal search system at the University of East Anglia (BIDS). In both cases, references were gathered where they related to rivers and river terms, including: restoration, rehabilitation, engineering and habitat. The literature search drew on appropriate material already obtained in the course of the Phase 1 Feasibility Study for the River Restoration Project.

### 1.3.2 Questionnaire to NRA Conservation Officers

A questionnaire requesting information about the extent of rehabilitation works on rivers in each NRA Region was circulated to all NRA Conservation Officers. A copy of the questionnaire is given in Appendix 1.

### 1.3.3 Discussions with practitioners

Discussions were held with a wide range of people actively involved in river management and rehabilitation in Britain and abroad. A workshop to discuss the Draft Final Report was held in London on 9 February 1993. The workshop was attended by NRA staff representing a wide range of functions throughout the Regions and a representative from English Nature.

# 2. WHAT IS RIVER REHABILITATION?

## 2.1 Introduction

A wide range of terms and definitions have been used to describe both rivers and river improvement techniques. The terms used for river improvements (e.g. rehabilitation, restoration, enhancement) have frequently been confused and can be misleading. For clarity a series of definition of the main terms used in this report are given below.

## 2.2 The river and its riparian zone or floodplain

**River.** The term river is used here to include both the river channel and its riparian zone and/or flood-plain. In natural river systems these are often intimately linked so that they essentially function as one unit. This unit has been termed the **'Riverine-Riparian Ecosystem'** by some ecologists (NRC, 1992).

**Riparian zone.** The border or banks of a stream or river. Although this term is sometimes used interchangeably with floodplain, the riparian zone is generally regarded as relatively narrow compared to the floodplain. The duration of flooding is generally much shorter, and the timing less predictable, in the riparian zone than in the floodplain (NRC, 1992).

**Floodplain.** Defined by hydrologists as the areas flooded at the recurrence interval of once in 100 years. Ecologists define floodplains as areas that are periodically inundated by rivers and to which river ecosystem processes and communities are adapted. The main functional relationship between river channels and their floodplains is summarized in Figure 2.1 below.

**Figure 2.1 Relationships between the river channel and floodplain**

**River channel** ↔ **Riparian zone or floodplain**

**water**
**sediment**
**organic matter**
**nutrients**
**aquatic production**

Note: in small streams, the channel will be the major recipient of sediment, nutrient etc. Large rivers will be a major donor of water, sediments etc to the floodplain. Modified from NRC (1992) and Junk *et al.*, (1989).

## 2.3 Terms used for river improvement

The variety of terms are used to describe works which improve or maintain the quality of rivers include: **restoration, rehabilitation, renovation, enhancement, creation** and **mitigation**. Definitions of each of these terms are given in this section. The relationship between terms is summarised in Figure 2.2.

### 2.3.1 Restoration

Restoration is **'the complete structural and functional return to a pre-disturbance state'** (modified from Cairns, 1982, 1991; NRC 1992).

Restoration is generally considered to be the most desirable option for the environment, in that it should be completely self-maintaining. However, it is also likely to require the maximum commitment and is likely to conflict with many of the uses to which rivers are put (e.g. abstraction, navigation, land drainage). This definition can make restoration appear impossibly idealistic, and there are of course many practical and scientific difficulties in defining 'pre-disturbance' states. However, full restoration remains an important target which, even if not achieved, can act as a long term guide.

### 2.3.2 Rehabilitation (or renovation)

Rehabilitation is **'the partial structural and functional return to a pre-disturbance state'** (Cairns, 1982).

Rehabilitation typically involves selection of desirable features (Cairns, 1982) whether or not some of these were present prior to disturbance. A large-scale approach is implied. For river managers with a variety of duties and functions, rehabilitation is the pragmatic alternative to restoration. A rehabilitated river should be self-maintaining, but is more likely to require managing in some way.

Rehabilitation (and potentially restoration) may be facilitated by river **recovery**, whereby natural river processes (particularly erosion and deposition) act to change a structurally modified channel into one which is hydrodynamically stable under the prevailing conditions. The natural recovery process may be **aided** by removing inhibiting stresses (e.g. providing land to give a river 'room to move'). This approach has been termed **recovery enhancement.**

### 2.3.3 Enhancement

Enhancement is '**any improvement of a structural or functional attribute**' (NRC, 1992).

By implication, enhancement is usually undertaken on a relatively small scale and does not refer to the pre-disturbance condition. Rather, desirable features are put into place to expand any basic riverine attribute. Artificial structures, such as deflectors and groynes, which may mimic natural dynamics, are frequently used.

### 2.3.4 Creation

Creation is '**the establishment of a new ecosystem that previously did not exist at the site**' (NRC, 1992).

The concept of creation is not usually applied to rivers themselves (which are rarely created from scratch), but it is often relevant to river associated habitats, such as wetlands.

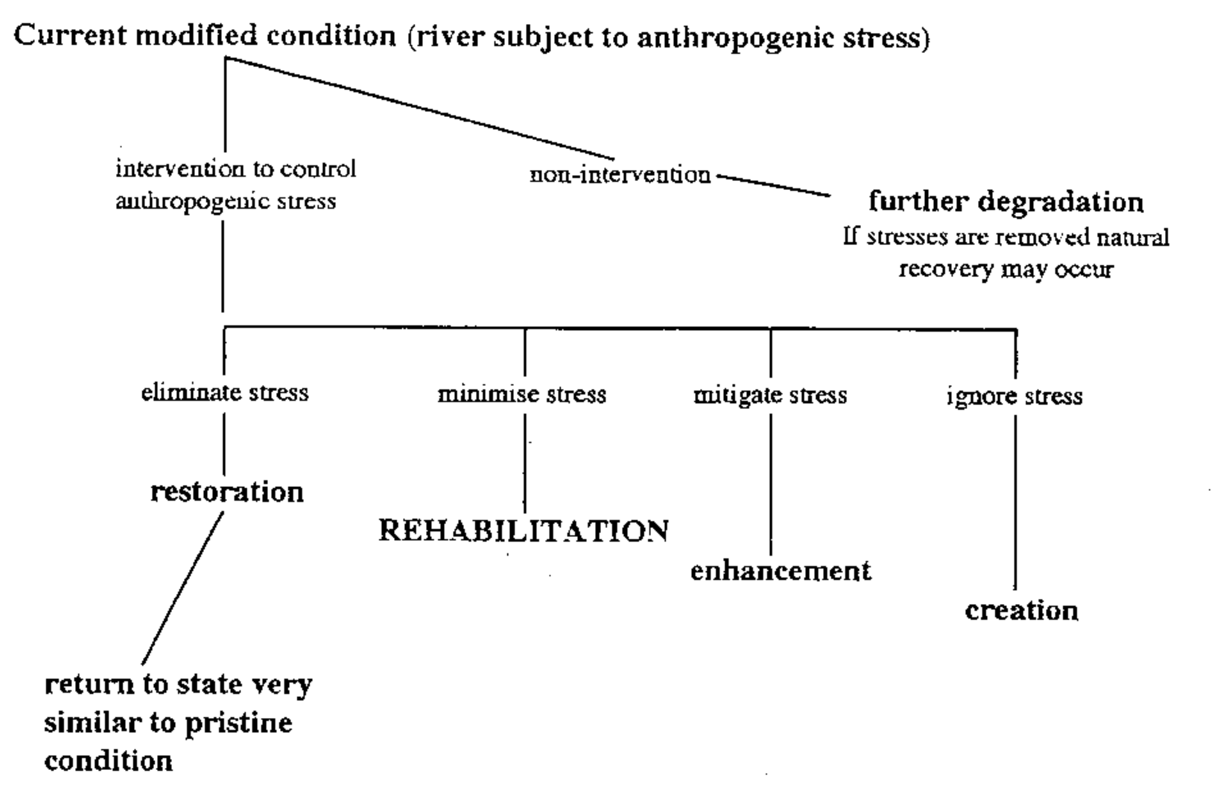
### 2.3.5 Mitigation

Mitigation involves '**actions taken to avoid, reduce or compensate for effects of environmental damage (potential or real)**' (NRC 1992).

Amongst the possible actions that may be taken are those that simply reduce environmental losses or those that make environmental gain on the original condition (before the scheme is implemented).

The practice of 'sensitive river engineering' (Newbold *et al.*, 1983; Purseglove, 1989) is a common form of mitigation. Here, the utilitarian goals of transmitting water from A to B as quickly and efficiently as possible are achieved, but the manner in which they are conducted may be less environmentally damaging than more 'traditional' engineering solutions.

**Figure 2.2 Schematic plan of the options available for improving degraded rivers.**



# 3. THE PHYSICAL DEGRADATION OF RIVERS IN ENGLAND AND WALES: EXTENT, REASONS FOR AND CHRONOLOGY OF DEGRADATION

## 3.1 The extent of physical degradation of rivers in England and Wales

### 3.1.1 Information sources

There is very little information available about the extent of physical degradation of rivers in England and Wales. Only one major study has attempted to make a quantitiative estimate of the national and regional impact of river engineering (Brookes *et al*, 1983), and this study dealt only with Main River maintained by the NRA. There is no consistent data available on the extent of physical modification of the remaining non-Main River channels.

Similarly there is only one main source of information about the impact of land-use change in river valleys, the 'Changing River Landscapes' project (Countryside Commission, 1987). However this study almost certainly underestimated the extent of change, since the case study rivers were chosen to be amongst the least polluted *and* the least affected by engineering work in England and Wales.

Although lack of information makes it very difficult to provide **estimates** of the **amount** of physical degradation, evidence from a variety of more indirect sources indicates that almost all river systems in England and Wales have been physically modified in some way. This evidence is discussed below in terms of: (i) modification to the river channel (ii) modifications to the floodplain/riparian zone.

### 3.1.2 Modification of river channels

Physical alteration of river channels occurs mainly as a result of channelisation or regulation of river flow.

#### Channelisation

Channelisation encompasses straightening, widening, deepening and removal of obstructions from river channels. It is one of the most obvious forms of river degradation and its extent is relatively well documented. **Of the 35,500 km of river maintained as Main River, about 24% (8500km) has been channelised** (Brookes *et al.* 1983).

However, the extent of channelisation on non-Main River (the majority of stream length) is unknown. Since many streams and smaller rivers are routinely dredged for land drainage purposes the length of channelised stream is likely to be high. In addition, as Brookes (1988) has noted, many small streams have been physically realigned to run parallel with fences, either for the convenience of cultivation or to act as boundaries.

The requirements of lowland drainage and the need to defend low-lying land and urban areas from flooding is mirrored by the regional pattern of channelisation in England and Wales. Thus channelisation is **most prevalent in East Anglia and in the London area** (Brookes *et al.*, 1983). Over 2000 km of Main River has been channelised in NRA Anglian Region (about 33% of the total) with about 41% channelised in London. The density and proportion of channelised Main River in each of these NRA regions is shown in Figures 3.1 and 3.2.

Channelisation is generally less widespread in upland areas (apart from the urban centres in the lower-lying land near the coast such as Merseyside). Correspondingly, the proportion of Main River channelised in NRA South-West, North West and Northumbrian Regions is relatively low (Brookes *et al*, 1983). In contrast however, rivers in upland areas are likely to suffer relatively more from the impacts of regulation (see below).

### River regulation

River regulation has been shown to cause distinct changes in the physical structure of river channels (e.g. changes in channel width and substrate type). Petts (1988) suggested that **around 89% of rivers in the UK are regulated.** However his definition of regulation was very general (i.e. all rivers subject to some form of abstraction or discharge).

More detailed information about the cause or scale of regulation is not generally available. However the extent of regulation impacts below impounding reservoirs can, to some extent, be judged from information about the distribution of dams. Of 450 large dams in the UK, 80% are in upland situations (Petts, 1988), suggesting that physical degradation due to impoundments is likely to be concentrated in the north and west of England and in Wales.

## 3.1.3 Modification of river floodplains

There is no published data about the extent of floodplain modification or about the total extent of floodplain which is still functionally connected to river channels. The best information is indirect evidence drawn from general land use changes in Britain. Overall these imply that well in excess of 95% of total floodplain area must be modified in some way.

The main impacts that have affected floodplains are:

(i) clearance of the original floodplain wildwood (which began at least 5000 years ago), and subsequent re-afforestation.
(ii) development of floodplains for agriculture
(iii) urbanisation of floodplains

## Floodplain woodland

In the pristine, post-glacial environment the majority of Britain's river floodplains would have been wooded (although clearings would have existed where soils were wet enough to prevent tree growth). This original 'wildwood' cover has been almost entirely removed in Britain. Indeed, Britain is now one of the least wooded countries in Europe (Johnston and Gardiner, 1991), with only 5% of land covered by broadleaved species. Floodplains are unlikely to be an exception to this, since river floodplains have been recognised as prime agricultural land for many centuries. In areas where broadleaved floodplain woodlands are extensive (e.g. the Norfolk Broads) they are mainly of relatively recent origin.

In addition to relatively low densities of floodplain woodland, many areas have experienced recent losses of trees in the floodplain. For example, in eastern England up to 70% of river-bank trees were removed between 1879 and 1970 (Mason 1981). In a national sample of rivers surveyed by Countryside Commission (1987), where river valley hedgerow densities varied between 51m/ha and 99m/ha, all areas had seen a decline in the density of hedges, and there was an overall decline of two-thirds in the number of specimen trees.

In contrast to broadleaved woods, plantation woodlands have increased rapidly in the past 50 years (Johnston and Gardiner, 1991) and around 10% of Britain is now covered by conifer plantation. The physical impacts of this afforestation (e.g. changes in bank structure and sediment type, Ormerod *et al.* 1993) are inevitably heavily weighted to smaller (particularly headwater) streams.

## Development of floodplains for agriculture

The proportion of Britain covered by arable and pasture land has remained relatively static over the last 50 years (approximately 45% and 25% respectively). However this inevitably masks many local and regional variations. For example, the Countryside Commission (1987) suggested that in most lowland river valleys there was a 10-20% increase in cultivated land between 1940 and 1980 (see Figure 3.3). In contrast, the area of cultivated land decreased on all four upland rivers surveyed by Countryside Commission, reflecting the retreat of arable agriculture from the uplands after the second

World War.

### Urbanisation

As with other land-use changes the extent of urbanisation on river floodplains can only be indicated from general statistics about growth in urban development. Urban areas currently represent over 11% of the total land use of England and Wales, and are increasing at around 10% per decade (Best, 1981; Parry, 1991).

The Countryside Commission (1987) noted a **doubling in the area of urban land in river valleys between 1940 and 1980**. However this increase only gives an indication of urbanisation outside towns, since urban rivers were not include in the survey.

## 3.2 Reasons for the physical degradation of rivers in England and Wales

### 3.2.1 Introduction

The principle reasons for physical modification and degradation of rivers are much more readily identified than the extent of degradation and can be summarised under the following seven headings:

- catchment land use changes (for agriculture and urbanisation)
- drainage of floodplains
- river flood defence and erosion control
- demands for water supplies
- navigation improvements
- leisure and recreational pressures
- road and bridge building ('transport links')

### 3.2.2 Catchment land use change

One of the main reasons that rivers have been physically modified or degraded from their 'natural state' is because of land use changes in their catchments. The transition from what would originally have been predominantly wooded catchments to agricultural or urban catchments causes four main types of change/degradation. These are:

- an increase in flood peaks and the frequency of flooding
- an increase in channel capacity due to increased erosion (as a result of more rapid runoff)

Fig. 3.1 Density (km/km$^{-2}$) of channelized main river in each region. No distinction is made between one or both banks. (After Brookes *et al.*, 1983)

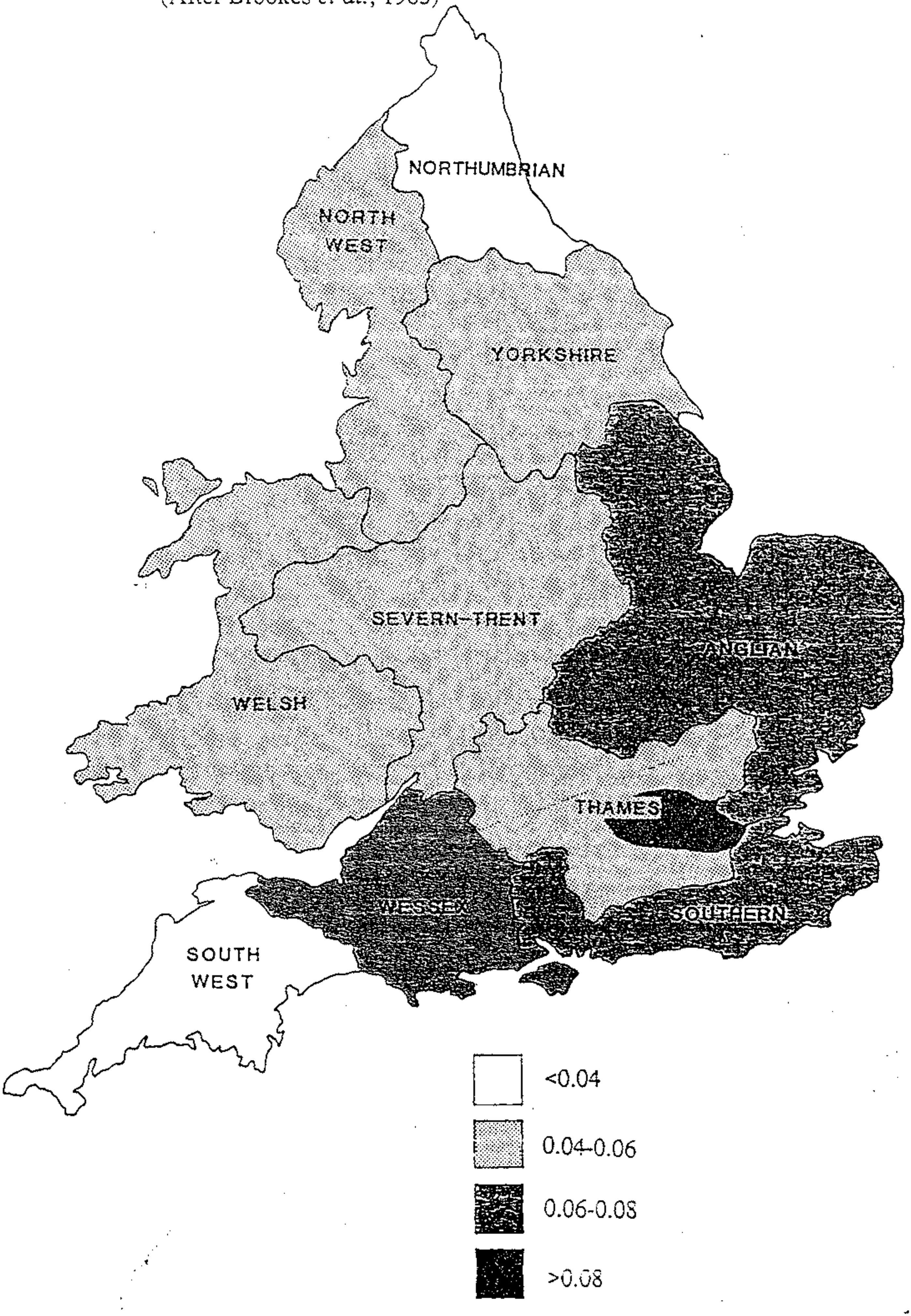


Fig.3.2 Proportion (%) of channelized main river in each region.
No distinction is made between one or both banks.
(After Brookes *et al.*, 1983)

- lowering of groundwater levels (as increased rate of runoff reduces opportunities for infiltration)
- increased sediment loads (as a result of more rapid runoff)

## Rural land use change

Woodland clearance took place at an early period in the English and Welsh landscape. By Domesday, the pattern of broadleaved woodland was established for the next 500-600 years (see Section 3.3). The clearance of wooded catchments, and their conversion to agriculture, must have resulted in increased water yields as runoff became more rapid (the result of less transpiration and interception by trees). Modern afforestation has begun to increase tree cover once again, however it has brought further problems of increased runoff, erosion and sedimentation during planting and felling periods.

The intensification of agriculture during the second half of the 20th century has also had a number of physical effects on rivers and their floodplains. These have included:

- increases in sediment inputs associated with arable agriculture.
- Increased volumes/velocities of water from field drainage which have necessitated regrading and widening of river beds (Brookes, 1988).
- Physical loss of wetlands, with associated biological impacts

In many areas of the lowlands drainage improvements have permitted farmers to convert from pastoral to arable systems, increasing the intensity of agriculture. Increasing intensity of livestock farming also has impacts on rivers. High densities of livestock can lead to the elimination of streamside vegetation and breaking down of river banks. This in turn can cause channel widening, channel degradation, lowering of the watertable and decline in water quality downstream (due to increased turbidity, sedimentation and animal waste).

## Urban development

Urban surfaces are predominantly impermeable, so that as the extent of urban areas increases, so too does surface run-off, with associated increases in water volumes, velocities and sediments. As a result urbanisation generally acts to increase the flood peaks and may increase the frequency of flooding by up to four times (Sears & Newson, 1991). In terms of physical stream degradation urbanisation leads to:

- wider shallower streams, especially on small water courses.
- impoundments of streams by onstream balancing ponds.

- lowering of ground
  infiltration)
- increased sediment

## Rural land use change

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- erosion, leading to increase in channel capacity of up to 50%, with sediment loads increased by up to ten times (Sears and Newson 1991).
- lowering of local and regional groundwater levels with consequent impacts on riverine wetlands, standing waterbodies and streams.
- increased volumes/velocities of water from urban outfalls which may necessitate regrading and widening of river beds (Brookes, 1988).
- culverting beneath urban areas e.g. the 'lost London rivers', Hermitage stream (Havant, Hampshire).

Increased sediment loads often consist of fine material from surface runoff, much of which may be derived from bare surfaces during construction work. Water quality is inevitably a problem in urban areas. Note that point sources of pollutants, like sewage treatment works, also contribute sediments.

### 3.2.3 Floodplain drainage

Floodplain drainage has profoundly modified the hydrology of riverine wetland ecosystems with the most significant historical losses resulting from agricultural drainage. Lowering of soil water levels has several desirable effects for cultivation, including increased soil oxygen content and increased temperatures.

The main effects of floodplain drainage are:

- loss of floodplain habitats.
- deepening of rivers, leading to lowering of adjacent floodplain water tables.
- relocation or channelisation of small streams.
- greater sediment inputs to rivers and streams.
- greater and more rapid runoff.

Channels alone can control the water levels in the adjacent land if the substrate is reasonably permeable. These channels, in unprotected banks, have traditionally been created to be trapezoidal in section.

In much British arable land, especially on floodplains, the alluvial soils are relatively impermeable and so underdrainage is required as an addition. Underdrainage increases the intensity of agricultural management (Williams & Bowers, 1987), which exacerbates sediment, as well as water quality problems.

### 3.2.4 River flood defence and erosion control

The main aims of flood defence are to protect property and agricultural land from flood damage. For agricultural land, it has usually been particularly important to protect crops from economically damaging summer flooding.

Water that would normally flow onto the floodplain in periods of high flow is contained and transmitted downstream as quickly and efficiently as possible. The way in which this is achieved has a considerable impact on the natural shape, hydrology and functions of the river and its floodplain. The main impacts include increasing channel capacity, increasing the rate of run-off, protection against scour and slip and removal of snags.

Land drainage for flood defence is likely to be the main cause of physical modification of rivers. This is born out by the results of a questionnaire sent to NRA regions during the production of this report (see Chapter 6), which indicated that flood defence is perceived as being one of the main reasons for river engineering in England and Wales (see Figure 3.4).

The main physical changes associated with flood defence works on rivers are increasing channel capacity, increased rate of runoff, the construction of groynes, dykes or hardened banks and removal of snags.

#### Increasing channel capacity

To contain flows, river channels are widened and/or deepened to increase channel capacity. Channel capacity can also be increased by raising adjacent banks and creating two-stage channels. Increasing channel capacity also lowers water tables and aids drainage of the floodplain

#### Increased rate of run-off

To increase the rate of run-off, channels are straightened (to increase channel slope) and dredged to a trapezoidal shape to reduce friction. In areas of high risk and/or flows, banks are often protected by artificial means such as rip-rap or gabions, with concrete channels often being used in urban areas.

#### Protection against scour and bank slip

To protect against the effects of scour or bank slip, which could obstruct flow and exacerbate flooding, groynes, dykes or spurs which are built in the channel, tranverse to the river flow, to deflect currents where appropriate. Revetments may also be included to armour the bank e.g. stone gabions, riprap,

| Table 4.5. | Ways in which river rehabilitation may alleviate sediment problems and the need for dredging |
|---|---|
| **Channel** | |
| Natural form (meandering,riffle/pool) | Re establishes river equilibrium and decreases river energy at high stage. Therefore reduces bank erosion and sediment deposition down stream. |
| Natural width/depth ratio | Prevents nick-point erosion in the channel and adjacent tributaries reducing sediment production. Increases low-flow energy and decreases sediment storage in the channel during these periods (Brookes, 1992). |
| Natural armoring | Prevents down-cutting and sediment release in naturally armoured channels. |
| Debris dams | Mixed benefits: may increase increase flooding and sediment deposition on the floodplain, but may also and increase local bank erosion, |
| Bankside vegetation | Increases flood hydraulic resistance, decreases flow and potential for sediment erosion and channel widening. Also reduces erosion by stabilising banks and bars (vegetation may increase bank strength and reduce bank erosion by 80-90%, Sears & Newson, 1989) |
| Note:: sediment problems in rivers are exacerbated by the process of dredging itself through resuspension of silt and by removing bankside vegetation and stable sediment bars (Brookes 1988) | |
| **Floodplain** | |
| Active flooding | Allows extensive sediment deposition and storage on the floodplain (up to 54% of suspended channel sediments (Sears & Newson, 1989)). |
| Semi-natural buffer | Reduces sediment erosion from the riparian zone and floodplain. (eg Wilkin and Hebel (1982) found that sediment **settled** in forested floodplains and stream borders at the rate of 10-20 tons per acre per year. Where the floodplain had been cleared for agriculture, sediment was being **eroded** from the floodplain at a rate of 15-60 tons per acre per year) Intercepts silt eroding from adjacent areas. (eg in Germany headwater erosion due to forest clearence for agriculture, has been so severe in some locations that deposition on downstream flood plains may be as much as several meters thick in places (Kern 1992). |

fish and aquatic invertebrates.

River rehabilitation which creates more hydrodynamically stable channels may thus be of considerable benefit in decreasing allocthonous sediment inputs and reducing the pollutants associated with them.

## The buffering capacity of riparian strips and/or floodplain

Buffer strips may reduce river pollution in two main ways. Firstly, since they are maintained under low intensity land use buffer strips do not release the quantities of sediments and other pollutants characteristic of lands which are regularly disturbed by ploughing and pest control (eg nitrogen released from disturbance of grassland soils may be as much as 50-200 kg/ha per annum). Secondly buffer zones may act to intercept water-borne and sediment-borne pollutants arriving from adjacent lands.
The 'ideal' size and composition of buffer zones is under much discussion and experimentation (Large & Petts 1992). Buffers as narrow as 8m have been shown to reduce phosphorus concentrations by up to 90% (Petersen *et al.* 1992), but it is unclear weather these effects will be sustainable in the long term.

In general it is likely that buffer zones will be most beneficial where they are relatively large and diverse, allowing maximum biodegradation or removal of pollutants (see below).

## Increase sedimentation and storage of nutrients and other river pollutants on the floodplain.

Just as sediments are deposited on the floodplain during flood events, so too are water-born and sediment-born pollutants (include the nutrients which make floodplains so fertile and desirable for agriculture).

Some of these 'pollutants' are permanently buried as floodplain sediments and accumulate, whereas others are used during plant growth. Where riparian zones or floodplains are used for low intensity agriculture (eg grazing, hay-cutting) some of these pollutants may be removed from the floodplain. Alternatively the creation of riparian forest may lead to long-term storage in above-ground biomass.

(ii) Most benefit is likely to come from the rehabilitation of active floodplains:

- Riparian zones and floodplains intercept storm run-off and increase water retention capacity for slow release later (this is most likely to be beneficial in areas of wet organic soils).
- Active flooding recharges aquifers and increases groundwater table levels (Brookes 1988).

### 4.6.4 Water quality: potential benefits of river rehabilitation

The concept that natural rivers are 'self cleansing' is widely recognised. Channelisation and loss of natural river floodplains both reduce this ability by: (i) moving water very rapidly through the system and (ii) facilitating high sediment inputs into channels.

By putting back the features which are known to be important in the pollution regulation of natural rivers, rehabilitation has the potential to considerably improve existing river water quality. The characteristics of rehabilitated rivers which are most likely to impove water quality are the:

- creation of a more stable channel morphology resulting in lower rates of bank erosion and reduced inputs of sediment-born pollutants.
- increased buffering capacity from riparian zones and/or the floodplain which intercept pollutants from adjacent lands
- the availability of floodplain for deposition of sediments, nutrients, organics and other potential channel pollutants.
- the potential for enhanced degradation of pollutants in natural channel-forms and in floodplain soils eg denitrification, oxidation.

These are discussed briefly below. A summary for each of the main pollutant groups is given in Table 4.6.

**More stable channel morphology leading to decreased erosion**

Sediment is an important river pollutant, increasing turbidity and transporting other pollutants (eg phosphate, non-soluble heavy metals, organics). Channelisation frequently entails high rates of channel and bank erosion and this can, in turn, considerably increase the amount of pollutants load of a river. For example, Roseboom (1987) showed that bank erosion yielded as much as half of the total phosphate, ammonia and nitrogen in a channelised stream in central Illinois. Other studies have demonstrated that the oxygen demand from organic rich sediments is sometimes sufficient to endanger

**Floodplain** rehabilitation is potentially important for sediment control in providing:

- a sediment storage facility
- buffer zones (i.e. semi-natural riparian zone or area of floodplain) to intercept silt from adjacent areas.
- buffer strips that prevent sediment eroding into the channel from agricultural areas at its margin.

The cumulative effects of rehabilitation in reducing sediment loads therefore reduces the need for maintenance dredging .

**Weed cutting and debris removal**

The presence of actively used riparian zones and/or floodplains may offer several opportunities to reduce the levels of routine maintenance operations such as weed cutting and debris removal by:

- creation of riparian zones next to the river which reduce aquatic plant growth by shading.
- allowing acceptable local flooding, so reducing requirement for flood protection maintenance

It should be noted, however, that where obstructions are not desirable within the river channel, creation of riparian strips may lead to the need for periodic removal of woody debris from the river.

### 4.6.3 Low flows: potential benefits of river rehabilitation

The problems of low channel flows and low groundwater and aquifer levels are likely to become of increasing future concern with increased demands for water consumption and the threat of climatic change. Within the framework of integrated catchment management and available land it may be possible to keep water back in the catchment rather than to encourage drainage and channelisation which funnels water off the land as rapidly as possible.

Rehabilitation of rivers and floodplain may help to ameliorate low land and river water levels in a number of ways:

(i) Some limited benefits may accrue from channel modifications (eg meanders and instream features, like debris dams and water plants) which may slow down drainage or perhaps increase flooding (see below).

### 4.6.2 Maintenance: potential financial benefits of river rehabilitation

Rehabilitation has the potential to provide three main cost savings in river maintenance:

- increased channel stability and therefore reduced requirements for capital maintenance such as bank protection.
- considerably reduced sediment production, leading to lower dredging requirements.
- locally reduced requirements for 'weed-cutting debris removal

**Channel stability and capital maintenance**

One of the benefits of river rehabilitation is that it may involve replacing highly engineered channels with more stable natural river forms. These are in essence self-sustaining with a more stable hydrological regime. This is in contrast to many channelised rivers (Brookes, 1988). Given the necessary room to move across their flood plain, natural channels need little maintenance. Channelised rivers on the other hand require high-cost maintenance (Sears and Newson, 1989), perhaps over 50 years or more (Brookes, 1988) to maintain their efficiency.

**Sedimentation and dredging**

One of the most obvious benefits of extensive river and floodplain rehabilitation is that it is likely to result in a considerable decrease in sediment production, and a concurrent decrease in the requirements for maintenance dredging.

Sediment production is the end-result of a wide variety of channelisation processes and human landuse modifications, including bank erosion, channel entrenchment, nick-point migration, drainage and urbanisation: and is most pronounced during storm and flood events, when rivers are at high stage and there is extensive surface run-off.

Deposition occurs in reaches of lower velocity thus decreasing channel capacity and often requiring extensive and expensive maintenance in the form of rolling dredging programmes.

Rehabilitation of rivers (and particularly the flood plain) may have considerable benefits in terms of the reduction of silt inputs. These are summarised in Table 4.5. **Channel** rehabilitation helps both by decreasing erosion at high stage (i.e. particularly due to increased hydraulic resistance) and by decreasing the potential for excessive sedimentation during low stage. It is thus especially suitable for high energy rivers where the bed or upstream substrates are unconsolidated.

flooding agricultural soils is still largely unknown, and their water storage capacity may be very different from the original floodplain lands (J.Treweek, pers. comm), although studies are currently underway which may help to solve some of these problem (eg joint ADAS, IOH, ITE and NRA on the R.Ray in Oxfordshire).

**Flood conveyance and erosion**

Floodplains may also act as extended channels to transport flood flows downstream. In natural river systems this water flow occurs as low-energy sheet-floods which spread out across the floodplain. In channelised rivers the flow is contained and river energy is thus much greater. This can result in considerable erosion of both river banks and the channel base.

The provision of floodplain, especially in high enegy rivers and those that have unconsolidated substrates, may reduce flood erosion of channels and potential damage to land and property (Brookes, 1987) and the expensive mitigation of sediment deposition .

The geomorphological and hydrological conditions under which such erosion is likely to occur are largely predictable (eg Brookes 1990, 1992), and the provision of adequate floodplain to contain flood flows may be the most economically viable solution.

**BOX 3. CASE STUDY: The rehabilitation of the River Danube to alleviate urban flooding**

In Germany plans have been made for the rehabilitation of the River Danube to reduce the impact of flooding caused by channelisation (H. Loffler pers. comm). The upper 70 km of the river suffered a 30% reduction in channel length over the period from 1895-1989, as a result of straightening. Much erosion resulted. In addition, there was a 20 fold increase in the amount of human settlement in the former inundation regions. In recent years, these areas, particularly the town of Riedingen, have suffered extensive flooding problems. The plan is now to re-construct former inundation regimes and give the river space to improve it's flood retention capacity. This project has been started but will take about 20 years to complete at a cost of around 100 million marks.

Together these functions may be used to enhance or supplement existing flood prevention schemes. Ultimately, as in the current scheme for the rehabilitation of the German Danube (see Box 3), they could potentially replace them.

**Opportunities for water interception**

It is widely recognised that land-use changes, such as woodland clearance (Webster et al., 1992, Brookes 1988) can have significant effects on the amount of water (and sediment) entering streams.

Rehabilitation of river catchments may provide opportunities to reverse this process by intercepting rainwater (particularly storm runoff) and ameliorating flood peaks. Interception is most useful high in the catchment where both runoff and erosion rates are potentially high, with the most effective interception provided by:

- woodland , which has very high interception of runoff and high evapotranspiration rates (Brookes 1988, NRC 1992).
- permanent wetlands (like swamps and bogs) which have a high proportion of organic soils, of high storage capacity (Brookes 1988).

**Flood storage areas**

River floodplains can have a major flood storage function. They achieve this by slowing water movement and by absorbing floodwater into their substrates and sediments.

Efficiency of storage is linked to substrate type: organic substrates (especially peat) are of particularly high value as they have high absorption and retention abilities whereas sandstones and gravels have a high storage capacity but low retention on account of their high porosity. Alluvium or clay substrates saturate quickly and are therefore susceptible to high rates of surface runoff, but they are relatively impermeable, and will store water where under-drainage is absent. Large wetland areas with organic sediments thus have great storage potential. In the US, the purchase of wetlands has been used as a more cost-effective alternative to building flood control systems (NRC, 1992).

There are some difficulties in using rehabilitated floodplains for flood storage. Firstly accurate hydrological models are needed to predict where it is an advantage to use flood storage areas to hold water back in part of a catchment (and therefore delay tributary flood peaks), or to take water off rapidly. Secondly, quantifying the storage capacity of flood lands may be difficult, as relatively unpredictable factors may have great influence (e.g.. cattle poaching of wet ground can considerably reduce the storage capacities of clay substrates (G. Harris, pers.comm)). Furthermore, the effect of re-

Existing studies on the public uses and desires from rivers indicates that there is a strong public preference for natural river landscapes that are rich in wildlife and form attractive landscapes (House Sangster ,1991; Green and Tunstall, 1992 and see Chapter 6 of this report).

The implication from this is that river rehabilitation which restores natural features and has a high wil value is a highly desirable option from an amenity and recreation point of view. It suggests that rehabilitation of rivers can provide an amenity and recreation resource in its own right. In addition it a good basis for the development of other river based activities e.g. pleasure boating, fishing.

The main exception to this , is likely to be in central urban areas where semi-formal landscaping of th riparian zone may be desirable particularly where aspects such as safety and access are important considerations (D. Vickers pers. comm.)

## 4.6 The potential financial benefits of river rehabilitation

River rehabilitation may, in addition to environmental benefits, bring financial benefits in areas such a

- Flood prevention (water interception, flood storage and flood conveyance)
- Maintenance (capital works e.g. bank reinforcement, dredging, cutting and snagging)
- Low flows
- Water quality

### 4.6.1 Flood prevention: potential financial benefits of river rehabilitation

Engineered flood prevention schemes have generally been very successful in achieving their aims of removing water quickly and efficiently from the land whilst preventing downstream flood damage to urban areas or farmland. However these capital schemes are expensive to construct and maintain (especially when costs such as sediment dredging are taken into account). Although often demanding of land, rehabilitation offers several less expensive 'softer' options:

- water interception in catchments (i.e. before water reaches the river).
- additional flood storage on the floodplain (e.g. by the creation of flood woodlands, floodways or washes), which also reduces erosion and some intensive maintenance requirements (e.g. bank protection, dredging)
- additional water storage and energy dissipation in the channel through reinstatement of natural river forms (e.g. meanders, riffle-pool characteristics)

## 4.5 Rehabilitation of rivers for recreation and amenity

Rivers are a natural magnet for people in leisure time and are widely regarded as landscape features of the highest value. River floodplains can also be areas of great landscape diversity and beauty, and they contribute towards provision of open space for recreational and visual enjoyment. In most situations conservation objectives and public perceptions closely agree suggesting that rehabilitation of both channel (especially of channel edge habitats which soften visual images) and floodplain is likely to be desirable

Justification for any type of river rehabilitation on landscape, amenity and recreation grounds may be made on three counts:

- rehabilitation increases public **enjoyment** of the river site either because of the provision of better facilities or improved landscape.
- rehabilitation will encourage greater **use** of the river site for recreation.
- visitor pressure or recreational demands are eased at **other** popular river sites.

### 4.5.1 Rivers as recreation and amenity areas

Studies of the public use and perception of river corridors suggests that rivers are generally highly valued and popular. In urban areas, for example, rivers have been shown to be more frequently visited, and to draw people from a wider area, than parks and other open areas (Green and Tunstall, 1992). In addition, several of the most popular recreational activities are conducted within the bounds of rivers and their floodplains including:

- angling, both in the river itself and within innumerable river valley ponds and gravel pits.
- boating, sailing and canoeing, the former especially on large rivers such as the Thames and Bure and the latter on a wide variety of fast and slow waters
- birdwatching and other forms of wildlife appreciation

River rehabilitation for recreation or amenity purposes may take many forms. It can range from what should strictly be termed enhancements (rovision of waterside paths, seats, toilets, car parking, fishing platforms, picnic sites and boat moorings) through to landscape improvements such as tree planting.

At its most extreme, rehabilitation for recreation has the potential to include major works such as restoring straightened and channelized rivers to a more attractive natural form, and to include full floodplain rehabilitation, providing areas which serve informal recreation and amenity needs.

| Table 4.3 | The negative effects of physical river modifications on fish diversity and biomass. |
|---|---|
| Loss of channel and bankside vegetation | Removes sites for spawning, shelter, food and temperature regulation. |
| Increased turbidity and suspended solids | Reduces oxygen concentrations and blocks gills. |
| Increased sedimentation | Smothers spawning gravels and reduces food diversity. |
| Alteration of stream flow patterns | Increased flow may increase energy expenditure |
| Changes in nutrient dynamics | Modifies stream |
| Loss of backwaters | Provide shelter in floods as well as over wintering sites and extra feeding and spawning habitats. |
| Loss of floodplain | Loss of spwning and nursery areas |

Sources include: Elser (1968), Hansen (1971), Hooton & Reid (1975), Groen & Schmulbach (1978) Chapman & Knudsen (1980), Milner *et al.* (1981), Swales (1982ab), Kennedy *et al.* (1983), Takahashi & Higashi (1984), McCarthy, (1985), Rivier & Seguier (1985), Regier *et al.* (1989).

**Table 4.4 Rehabilitation methods known to provide benefits for fish**

Reinstatement of natural features:

- riffles and pools
- reconnecting backwaters and oxbows
- replacement of instream debris and bouders
- removal of artifical structures such as weirs
- reinstatement of spawning substrate
- riparian zone restoration- through livestock removal or planting

Artificial structures which mimic natural features:

- deflectors
- dams, sills and weirs
- pools
- direct cover structures
- off-river supplementation units

Sources include: Tarzewell (1937), Warner & Porter (1960), Gard (1961), White (1975), Hunt (1976), Coulston & Maughan (1983), Hermansen & Krog (1984), Lewis & Williams (1984), Platts & Rhinne (1985), Rosgen & Fittante (1986), Cooper & Knights (1987), Jutila (1992).

extinction of the burbot (*Lota lota*) (Marlborough, 1970), whilst in America, Hansen (1971) reported the loss of 14 out of 40 species from the Little Sioux River was the result of wholesale channelisation.

In addition, fish **biomass** may also be significantly impaired by river modification. For example, in the River Soar, the standing crop was reduced from 39g/m$^2$ to 9.6g/m$^2$ after drainage works (Swales, 1982). Indeed, on a similar stretch of the same river larger fish of angling interest remained absent for a period of 5 years after land drainage operations had modified the channel and reduced physical habitat variability (Cowx *et al.*, 1986)

Some of the main causes of this degradation in fisheries stock are summarised in Table 4.3.

### 4.4.2 The potential benefits of rehabilitation for fish and fisheries:

There is clear evidence, that for fisheries, rehabilitation measures can be successful in ameliorating many of the detrimental effects of river channelisation and wetland drainage (NRC, 1992). The success of rehabilitation schemes is attested to by a wide variety of scientific and popular literature, particularly in the US (NRC 1992).

A variety of techniques have been used in species-centred rehabilitation projects, particularly in the US, and some of these are documented in Table 4.4. Many studies have concentrated on the use of artificial structures which mimic natural river features, often targeting benthic macroinvertebrates (Tarzewell, 1937; Spillet *et al.* 1984) which often constitute the basis of fish diet.

The bulk of studies are concerned with salmonids which often show strong positive relationships with habitat complexity, partly as an expression of their territoriality (Boussu, 1954; Gorman & Karr, 1978; Krog & Hermansen, 1985; Bray, 1988). This has lead to the development of habitat evaluation models (Fajens & Wehnes, 1981; Platts *et al.*, 1983) including the Instream Flow Incremental Methodology (IFIM) (NRC, 1992).

Studies of the habitat requirements of British freshwater fish, especially the dominant cyprinids, are scarce and are effectively limited to chub (*Leuciscus cephalus*) (Smith, 1989). However recent research at the Institute of Hydrology has worked on applying the IFIM to selected British cyprinids (MAFF, 1992). In the future this may allow species-specific recommendations to be made for river rehabilitation.

**BOX 2. Case Study: Pinkhill Meadow Nature Reserve**

In Oxfordshire, a 2ha mosaic of ponds and wet meadow habitats has been created as a joint initative between NRA(Thames) and Thames Water Utilities. The project is currently being monitored as part of a n NRA R&D project. Results so far suggest that after 3 years the site now supports 84 macro invertebrate speciesof which 14 are local and and 1 is rare (the water beetle *Coelambus nigrolineatus* ). In addition 49 species of wetland plant colonised the site of which 5 species were local. 34 species of wetland birds (16 waders) were also recorded including more uncommon species such as Temminck's stint and Garganey. Little Ringed Plover Tufted Duck and Lapwing all bred and reared young.

pools). A wide variety of plant and animal species have evolved to use these associations and therefore depend on more than one habitat during their lifetime (Stubbs & Falk, 1983; Underhill-Day, 1985; Schiemer & Waidbacher 1992;).

As a result, rehabilitation of a mosaic of semi-natural river habitats may have **cumulative** benefits for wetland wildlife diversity where the value of the whole is greater than the sum of the parts.

## 4.4 Rehabilitation of rivers for fisheries

Habitat enhancement for fisheries has been successful in increasing species diversity and biomass. This can bring three main benefits:

- an improved recreational resource (eg more and larger specimens)
- increased fisheries income (through rod licences etc).
- indirect benefits for conservation (increased macroinvertebrate abundance and diversity as result of habitat rehabilitation).

### 4.4.1 Causes of damage to fish communities:

There is considerable evidence that both channelization and loss of the floodplains have caused damage to fish **diversity**, with a large number of documented losses from both Europe and the USA. In Britain, for example, land drainage is reported to be one of the main causes of the probable

**Riparian zone and floodplain.**

It has long been known that the riparian zone and floodplain can exert considerable influence on the character of the river channel and increase its suitability for wildlife. For example floodplains or riparian zones can:

- diversify the channel margins (e.g. providing tree-roots and undercut bank habitats for aquatic invertebrates)
- provide a source of plant and animal material which falls into the river and adds to the food and habitat resource (e.g. leaf material and terrestrial invertebrates (Mason and Macdonald, 1982).
- buffer the channel from inputs of pollutants

Perhaps even more importantly floodplains support very valuable communities in their own right (see Table 4.2). Riparian zones also form important corridors linking patches of habitat which may be exploited by a wide variety of species (Hobbs, 1992).

Riparian rehabilitation is widespread in the US where it has been shown to bring benefits to plants, birds and mammals (Anderson & Ohmart, 1985; Burgess, 1985; Baird, 1989). In Britain riparian rehabilitation has mainly focused on the otter *(Lutra lutra)* (Lewis &Williams, 1984; Driver pers. comm.), and there is much scope to undertake more holistic rehabilitation.

Natural floodplains form a complex mosaic of associated habitats (Amoros *et. al.*, 1987,1992) and are consequently abundantly rich in wildlife each dependent on particular habitat types. For example, several Red Data bird species, such as Bewick's Swan, Ruff and Black-tailed Godwit, are all dependent on extensive areas of wet grassland (Batten *et al.*, 1990, Williams & Bowers, 1987), whereas species such as Marsh Harrier, Bearded Tit, Bittern, Savi's Warbler and Cetti's Warbler are dependent on habitats dominated by reed (Bibby & Lunn , 1982).

One of the greatest challenges in river rehabilitation for wildlife is the reinstatement of fully functioning semi-natural floodplains. Where it is successful this is likely to bring some of the greatest conservation benefits. To date the rehabilitation of functioning floodplain wetlands has hardly begun in Britain. However evidence from current river floodplain enhancements can begin to give an idea of the potential benefits (Box 2).

Finally rehabilitation of a number of adjacent semi-natural river habitats may have cumulative benefits for wildlife diversity. It is important to recognise that wetland habitats do not usually exist in isolation, and many habitats frequently occur as associations (e.g. fen and carr, rivers and marginal temporary

### 4.2.2 The conservation benefits of river rehabilitation

The conservation benefits of river rehabilitation come mainly from replacing the simplified environments of channelized rivers and non-functional floodplains with the much more complex habitats which are characteristic of natural river systems. This section briefly considers some of the more important characteristics of these natural habitats.

**Channel and bank habitats**

Natural river channels are highly diverse and productive areas, providing mosaics of different habitats. Channel edge habitats are especially important because they provide habitats both for aquatic and semi-aquatic species. Channel edges may support a very wide variety of invertebrates, many of which are river dependent (Stubbs & Chandler 1978, Kirby 1992).

In general terms rehabilitation should aim to increase habitat diversity (including flow diversity), since this will increases species diversity. The relationship between habitat and species diversity is particularly well documented for aquatic invertebrates (Jenkins *et al.,* 1984; O'Connor 1991), with the presence of a diverse aquatic flora being an important component of this relationship (Jenkins *et al.,* 1984; Harper *et al, 1992)*. Aquatic plant communities also respond to variations in water chemistry and substrate type (Bornette & Amoros, 1991). The benefits of habitat rehabilitation are sdescribed for a specific sites in the Case Study given in Box 1.

**BOX 1. Case Study: the Gelså River, Denmark**

Reinstatement of a natural flow and sediment regime through the reinstatement of meanders, natural cross-sections and substrate on the River Gelså in southern Jutland in Denmark, had beneficial effects on plant and invertebrate communities. In total 13 new species of aquatic macrophyte have been recorded bringing the total to 31 aquatic and semi-aquatic species. The new reach also has greater invertebrate species diversity than reference reaches. Of the extra thirteen species, several such as the mayfly (*Heptagenia sulphurea*), caddisfly (*Hydropsyche siltalai*) and midge (*Rheotanytarsus* sp.) are particularly common as a result of the stable bed.

| Table 4.2 | Potential wildlife benefits of river channel and riparian zone rehabilitation |
|---|---|
| **Channel** | |
| Bare Cliffs | An important habitat for insects like wasps and bees which nest in sandy cliffs. Also a nesting site for sand martin and kingfisher. |
| Low vegetated banks | A hugely varied and diverse area with a wide variety of water regimes and many microhabitats. Vegetated banks support many damp ground plants eg sedges, watercress, water parsnip, yellowcress, speedwells, purple loosestrife. It is a very important (and currently under-valued) habitat for many semi-terrestrial insects including larval hoverflies and other Diptera, as well as wetland snails, spiders etc. Also used as a burrow site by water vole. |
| Sediment and shingle bars | A distinctive habitat which supports a number of rare and uncommon semi-terrestrial species of insects. May provide a nesting site for Little Ringed Plovers. |
| Shallow mud and stones | Used by many insects, and particularly valuable for diptera such as dance-flies, crane-flies, shore-flies. Stoney areas may be inhabited by crayfish. |
| Shallow gravelly riffles | Important for aquatic species of mayfly, riffle beetles, caddisfly larvae, sponges, stonefly. A feeding site for fish (especially trout and salmon parr) and spawning site for salmonids. Also a feeding site for Dipper and Grey wagtail. Used by well adapted plants such as water buttercup, river water-dropwort. |
| Silty pools | Used by aquatic invertebrates, especially those well adapted to silty conditions eg club-tailed dragonfly, mayflies eg *Ephemera danica*, some caddisfly. Plants may include broad-leaved pondweed, water milfoils and waterlily. |
| Emergent vegetation | Stands of watercress, water-mint, reed, clubrush provide a habitat for invertebrates such as white-legged damselfly, water snails, freshwater leeches, flatworms, limpets, freshwater shrimp, many species of water beetle. |
| Submerged vegetation | Stands of species such as water crowfoot, arrowhead and water starwort are inhabited by aquatic animals such as water boatmen, water snails and caddisfly larvae. |
| Shaded water | Many flowing water animal species benefit from the presence of shade or the presence of trees along at least part of the margin. Leaves and invertebrates falling in the water from overhanging trees provide a valuable food resource for fish (especially trout and chub) and aquatic insects. Some aquatic invertebrates live preferentially or exclusively on submerged tree roots or logs eg the caddisfly *Limnephilus extractus*. |
| **Riparian zone** | |
| Wooded and undercut banks | Holt sites for otter, damp sheltered, shady, muddy conditions for damp-ground insects eg giant lace-wing, crane fly and owl midges. Some adult insects with aquatic larvae spend much of their adult life high in trees bordering or overhanging water eg the spongefly *Sisyra terminalis*. Other aquatic larvae emerge from water and pupate in crevices in tree bark. Invertebrates such as crayfish , and fish such as pike preferentially shelter beneath undercut banks. |
| Pollards | Nesting sites for Barn and Little Owl. Habitat for many invertebrates such as the musk beetle (*Aromia moschata* ). |
| Marginal herb and scrub | A varied habitat used by a wide variety of small mammals, especially harvest mouse and water shrew. Can support a wide variety of birds, insects and plants. |
| Back channels | Back channels can be very important habitat for overwintering fish (especially cyprinids), as well as providing fish spawning sites and safe havens during floods. A favoured habitat for nesting grebes, moorhen, coot etc. Feeding area for otter. Rich habitat for macroinvertebrates and plants. |
| Riverside ponds and pools | Used by a wide variety of still-water animals and plants including frogs, toads and newts, plants such as water horsetail, floating sweet-grass, spike rush. Very many invertebrate animal species. Can be important fishing site for otter. Temporary pools adjacent to rivers may support very specialised invertebrate animal communities, including a variety of uncommon species. |

## Table 4.1 Documented examples of the damaging effects of river modification on wildlife

**Drainage and destruction of floodplain habitats**

**Floodplains:** national loss of wetland habitats, often associated with floodplain drainage (eg flood meadow, fen, marsh, wet flushes, wet woodland) (Newbold 1977, Williams & Bowers 1987). Associated loss or decline of many species of bird (Williams & Bowers 1987, Williams and Hall 1987, Smith 1983), invertebrates (Shirt 1987, Foster 1991), wetland plants (Newbold 1977) and amphibians (Cooke& Ferguson 1976). Many of these wetland species are now rare and threatened (Shirt 1987, Newbold 1977, Williams & Bowers 1987). Loss of aquatic floodplain habitats eg ponds (particularly temporary pools), with consequential damage to vulnerable aquatic invertebrate and wetland plant species (Shirt 1987).

**Drainage and destruction of the riparian zone:** loss of riparian habitats (eg fringing woodland (Mason 1981) with concurrent loss of general habitats for birds (Possardt & Dodge 1978) and small mammals (Perrow *et al.* 1992). Loss of marginal aquatic habitats and stream invertebrate diversity (Ormerod et al. 1993). Loss of stream buffering capacity (Newbold *et al.* 1980). Loss of buffering zone with detriment to wildlife (Newbold et al. 1980). Loss of overhanging vegetation (especially bankside trees, Mason 1981) providing otter holt sites (Macdonald & Mason 1983).

**River channelization**

**Widening and deepening of channels:** loss of riffle and pool structures with consequential damage to fish spawning and feeding grounds (Cooper & Knight 1987, Hooton & Reid 1975, NRC 1992).
**Straightening:** loss of meanders and associated flow diversity important in maintaining diverse habitats for wildlife eg fish (McCarthy 1985, Swales 1982). This habitat degradation may have lead to the extinction of the burbot (Marlborough 1970).
**Loss of backwaters and associated habitats** important for fish spawning,, flood escape and overwintering (Schiemer & Waidbacher 1992, NRC 1992).
**Trapezoidal or vertical bank profiles:** associated loss of a varied habitat for aquatic and semi-terrestrial wildlife eg, fish (Gorman & Karr 1978) and nesting birds (Campbell 1988).

**River maintenance**

**Dredging:** removal of plants, animals and habitats causing loss of wildlife diversity eg plants, invertebrates, (Pearson & Jones 1975 fish, birds etc. (Campbell 1988). Increase in suspended material causing damage to fish (Rivier & Seguier 1985).
**Plant cutting:** removal of plant species, plant biomass and aquatic invertebrate habitats (McCarthy 1985)
**Removal of debris-dams and overhanging vegetation:** reduction of flow variation creating pools and fast runs and upstream sediment bars (Shields & Smith 1992). Consequential reduction in habitat variety for fish and invertebrates (Coulston & Maughan 1983) .

**Others**

**Sediment deposition:** excess sediment is a result of many alterations to floodplain and channelization (eg channel down cutting, bank erosion, intensive floodplain agriculture, urbanisation). This results in physical swamping of plants (Brookes 1986). Decrease in river-bed substrate diversity (eg loss of gravel and sand) with consequential damage to fish spawning grounds (Hermansen & Krog, 1984), invertebrate habitats (Tarzewell, 1937, Bravard *et al.* 1986, Chutter 1969). Also lower water quality eg suspended sediment reducing oxygen levels and foraging efficiency (Hansen 1971, Riviers & Seguier 1985, McCarthy 1985).

# 4. THE RATIONALE FOR RIVER REHABILITATION

## 4.1 Introduction

This chapter describes a rationale for river rehabilitation in terms of the **need** for rehabilitation and the **benefits** that rehabilitation is likely to bring.

The environmental needs and benefits for nature conservation, fisheries and recreation are reviewed in Sections 4.2 to 4.5, respectively. These are likely to be of particular relevance to NRA conservation, fisheries and recreation functions. Potential financial benefits of rehabilitation, (e.g. pollution control, flood storage potential) are described in Section 4.6. These are likely to be of most relevance to NRA water resources, pollution control and flood defence functions. A summary of the rationale is given in Section 4.7.

## 4.2 Rehabilitation of rivers for nature conservation

### 4.2.1 The case for rehabilitation

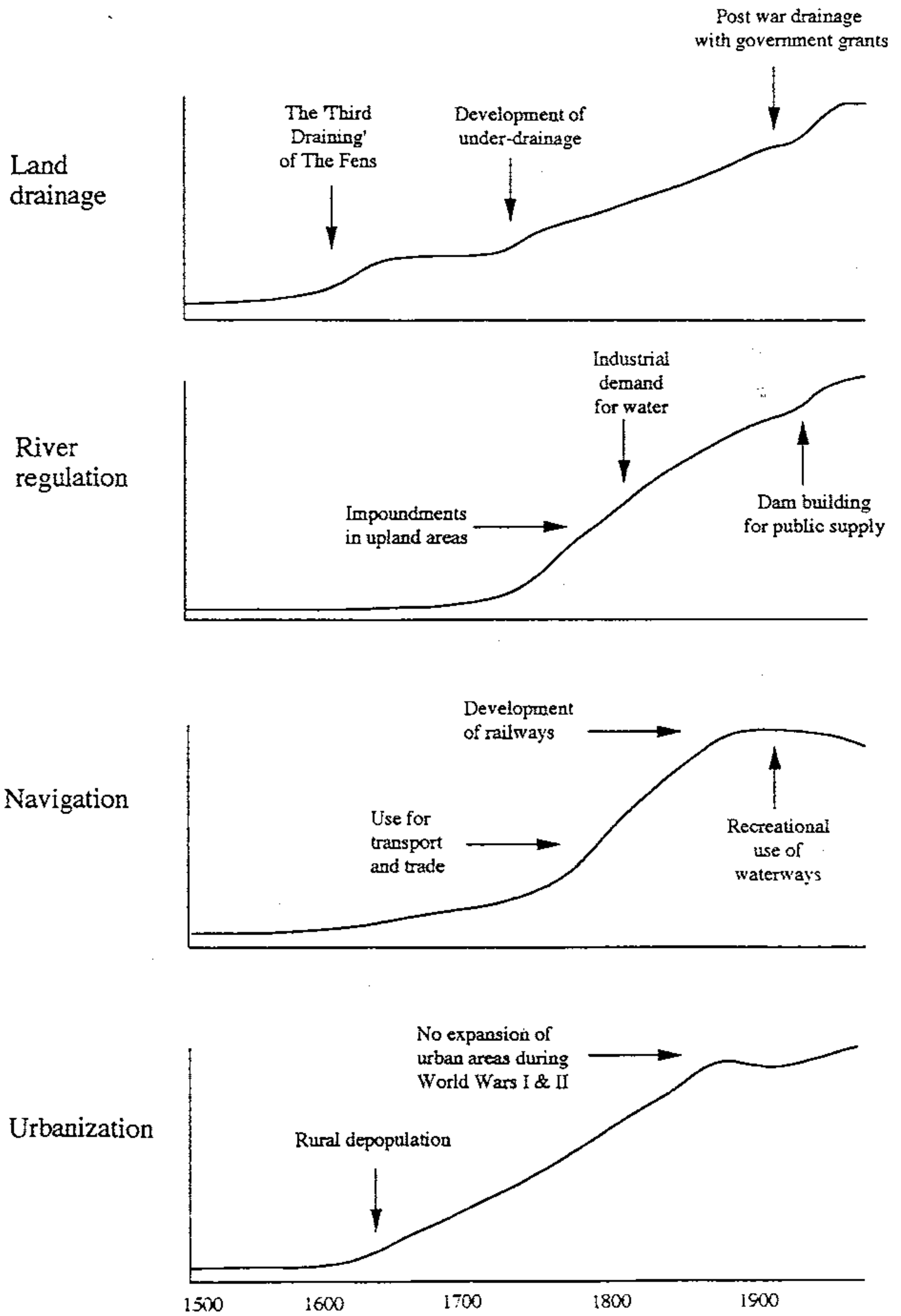
The case for undertaking river rehabilitation for nature conservation is very strong. There has been considerable physical degradation of river ecosystems (see Section 3) which, although difficult to quantify, appears to have affected a very large proportion of water courses.

There is clear evidence that the physical degradation of rivers has exposed river plant and animal communities to a very wide variety of damaging impacts. Table 4.1 list some of the studies which have documented these impacts, highlighting the range of impacts that have been investigated.

Equally it is clear that rehabilitation can at least ameliorate, and in some cases eliminate, many of these damaging impacts. Table 4.2 summarises the range of plants and animals dependant on different physical features which could be reintroduced or strengthened in rehabilitation projects. The evidence suggest that rehabilitation can provide a very effective environmental management tool.

The following section reviews in more detail the benefits of rehabilitation for plants, invertebrates, birds and mammals. The benefits for fish communities are described separately in Section 4.4 (fisheries).

**Figure 3.5 The chronology of river degradation, 1500-2000. Vertical axes not to scale.**



The availability, from 1800 onwards, of clay tile drains marked the beginning of large scale under-drainage (Purseglove, 1989). Between 1830 and 1890, 1,200,000 acres (480,000ha) were drained with the assistance of government loans (Trafford, 1970), about 46% of the agricultural land in England and Wales. The peak of land drainage activity was in the 1850s when up to 100,000ha were drained per annum.

The maintenance of land drains lapsed between the end of the 19th century and World War II, during the long agricultural depression of this era, and many river valleys must have become wetter at this time. However, by the 1950's land drainage was again attracting significant Government support and 40,000ha were being mole drained annually (Trafford 1970), increasing to 83,000ha. per annum between 1971 and 1980 (Purseglove 1989).

During this period (1940-1981) land drainage schemes were undertaken on about 20,000km of river with support from MAFF funds (Williams & Bowers, 1987). The effects of this work, which occurred long before more recent study of the effects of river engineering can only be guessed at.

### 3.3.8 Regulation of rivers

River regulation has a long history in Britain, with records from as early as 762 AD of mill races operating to provide power to grind corn. The early effects of river regulation (for example the 6000 impoundments noted in the Domesday Book, Sheail, 1988) were likely to be piecemeal. However, it is reasonable to assume that the main impacts of river regulations began with the construction of major dams in the late 19th Century (see Figure 3.5).

This phase of large dam-building peaked in the 1960's (Petts, 1984). After a dry summer in 1959 and flooding in 1960, the Water Resources Act 1963 came into being and established the control of the River Authorities along with the advisory Water Resources Board. Since then the emphasis has been on direct river regulation, with large reservoirs, groundwater abstraction and interbasin transfer providing the basis of the integrated management of water resources. However, the impacts of regulation currently show little sign of declining. Indeed in 1993, Thames Water Utilities Ltd has announced plans to build a large new flow augmentation reservoir on the Thames, a river which is already one of the most regulated in the world.

### 3.3.9 20th century intensification of river engineering

The second half of the 20th Century has seen river engineering reach its peak intensity, primarily for flood defence. Although little data is available to assess the impacts even of this most recent of developments in Britain, there is little doubt that its intensity and extent has partly prompted the moves now developing to rehabilitate rivers.

Industrial Revolution. Since then Britain has become increasingly urbanised and by 1971 11.0% of the land of England and Wales was classed as urban (Best, 1981). In some areas urbanisation of river valleys has been particularly rapid during the 20th century. Of the 12 rivers surveyed for the Countryside Commissions 'Changing River Landscapes' project, 9 showed increases in urban development of more than 50% between 1940 and 1980 (Countryside Commission, 1987). None of the rivers were in designated urban areas.

Although no quantitative data exists, it can be assumed that most watercourses within urban areas have been physically modified to a greater or lesser extent. Urbanisation has also led to loss of large areas of river floodplain.

### 3.3.6 Navigation

Engineering of rivers for navigation began in the Middle Ages, and by about 1600, there were around 700 miles of navigable river (Willan, 1936). Early attempts to improve navigation on rivers involved cutting back of inside bends, dredging shoals and shallows, piling where banks were weak, and weed-cutting (Rolt, 1969). The technique of 'ballasting' where material was removed from the bottom of the bed was used on the Upper Thames.

The length of navigable river in Britain had increased to 1300 miles by around 1760. Only isolated portions of Wales, the Midlands and north of Leeds had no navigable river links. With the advent of the Industrial Revolution, trade continued to expand with a corresponding increase for the need for internal transport. Many miles of river were improved throughout Yorkshire during this period, with further river engineering including the deepening of the Ouse to York by contracting its bed and increasing the scouring action of the current.

Since this time, the requirement for additional river modifications to facilitate industrial river traffic has declined. However what would otherwise have been a marked decline in navigable river has been in part halted by the needs of recreational boating, especially on some large rivers. The Broadland area, for example, has over 1600 cabin craft for hire, the largest fleet in Europe.

### 3.3.7 Drainage of the claylands

In contrast to fen and marsh drainage, the drainage of claylands was a much later development, with techniques for underdraining not developed until the 16th Century (and even then not widely applied for at least another 150 years). Although estimates of the area of land drained are available , the scale of these impacts on rivers remain unquantified.

### 3.3.3 Deforestation of river valleys and the extension of agriculture onto river floodplains

Following the end of the last glaciation some 11,000 years ago, river floodplains developed extensive woodland over most of Britain, probably interspersed with open wetland areas where trees were unable to grow. Clearance of floodplain forest began very early in England and Wales. On the floodplains of rivers like the Thames, Nene and Ouse (where there is some of the earliest evidence of human activity in Britain) there is evidence of systematic clearance of this floodplain wildwood' from at least 2000 BC (Robinson, 1992).

By the late Bronze Age most alder woodland is thought to have been cleared from the larger floodplains and replaced by an open grassland environment, with poplars and willows. By the Iron Age, there is evidence that, in many river valleys, the environment was similar to that of today. Pollen and insect remains from the Thames, for example, suggest huge areas of treeless pasture, very much like the current landscape of the Upper Thames.

The first evidence of hay meadows in Britain comes from the Roman period and there seems little doubt that hay meadows established on the river floodplains at this time persisted into Saxon and mediaeval periods. It is likely that, in many areas, the landscape described in the Domesday Book changed relatively little until the second half of the 20th century.

### 3.3.4 Drainage of floodplain wetlands (particularly lowland peatlands)

Following the deforestation of the river valleys, the next major impact on river environments was the drainage of river valley wetlands like those of the East Anglian Fenland rivers, the Somerset Levels and other inland systems (e.g. Otmoor, Oxfordshire). The drainage of these areas was started by the Romans, who were highly skilled drainage engineers (undertaking the 'First Draining' of the East Anglian Fens for example) and continued until the 'Third Draining' (Rackham, 1986) in the 17th century.

The drainage of the lowland wetlands affected many thousands of kilometres of river and stream; but although historians and paleoecologists have documented these changes, the impacts on river systems are poorly understood.

### 3.3.5 The growth of urban area from the mid 18th Century onwards

Urbanisation has probably affected rivers on a small scale for a thousand years or more. However extensive impacts due to urbanisation date mainly from the mid 18th Century and the beginning of the

FLOOD DEFENCE

LAND DRAINAGE

EROSION CONTROL

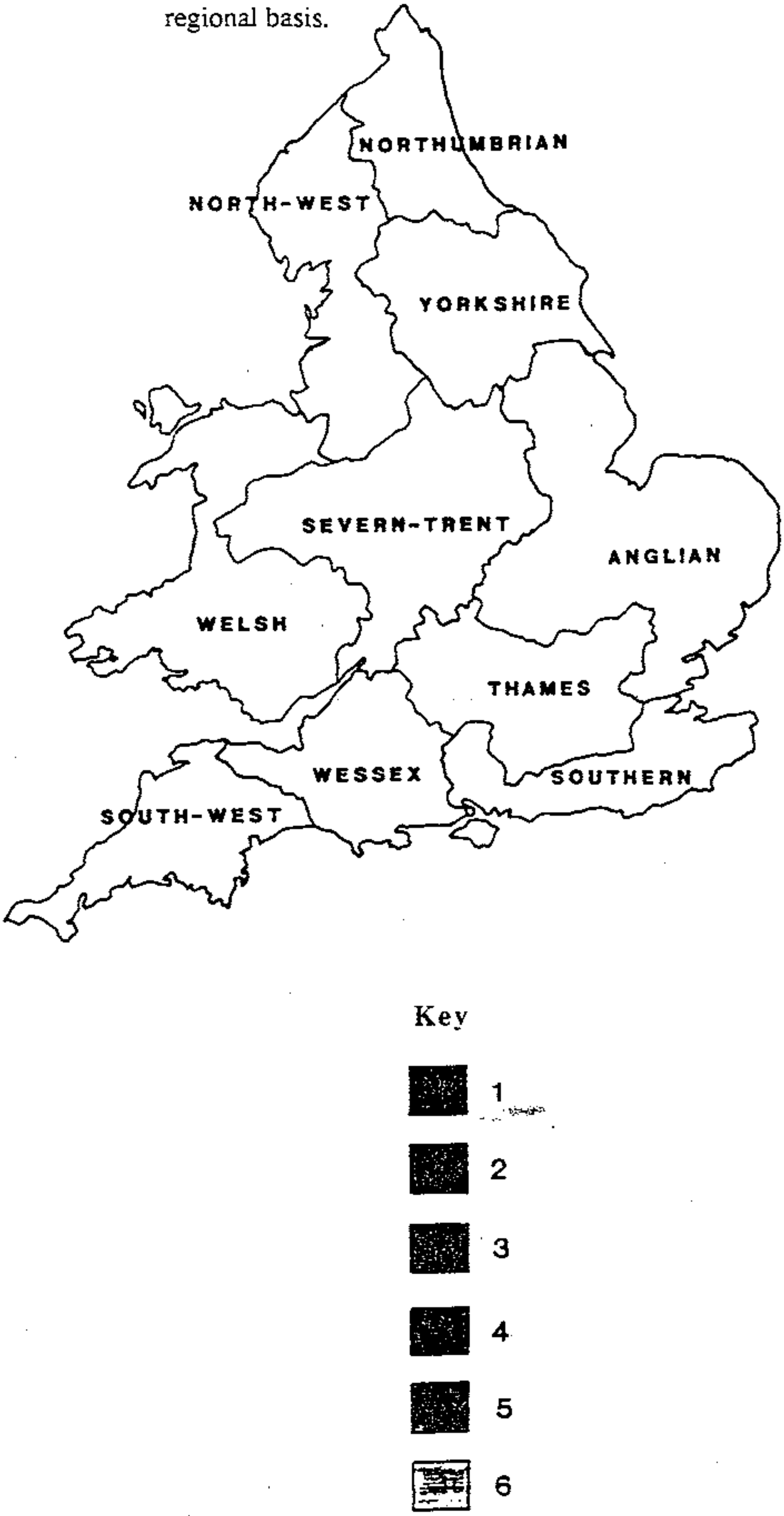
NAVIGATION

TRANSPORT LINKS

OTHER

Figure 3.4 The relative importance of the reasons for river engineering as perceived by NRA personnel.

Reasons are ranked on a scale of 1-6 in decreasing order of priority on a regional basis.



## 3.3 A preliminary chronology of the physical degradation of rivers in England and Wales

### 3.3.1 Introduction

In contrast to other semi-natural ecosystems in Britain (like ancient woodland), historians have paid little attention to the history of river management and the changes it has caused. However it is possible to establish a broad chronology for the physical degradation of rivers, by identifying periods of great change in river environments. Inevitably this chronology relies heavily on indirect evidence including archaeological studies of river valleys, the history of land-drainage, the history of inland navigation and recent studies of changes in river valley land-use.

One important practical consequence of a general lack of historical information is that our understanding of river ecology and river management has very little historical perspective. Indeed only rarely is it possible to describe aspects of the river environment even 100 years ago (see for example Mason, 1981). Studies of rivers with a longer timescale are exceptionally uncommon (for example the work of the International Centre for Landscape Ecology, ICOLE (Large and Petts, 1992) on the Trent).

### 3.3.2 The history of river management

There have been at least seven major stages in the physical management of rivers in England and Wales which have led to important periods of physical change, and usually degradation. In roughly chronological order these are:

- Deforestation of river floodplains and the extension of agriculture on river floodplains
- Drainage of floodplain wetlands
- The growth of urban areas
- Modification of rivers for navigation
- Drainage of the claylands
- Regulation of rivers
- 20th century intensification of river engineering

The timing of the principal impacts over the past 500 years is indicated in Figure 3.5. However, in the absence of detailed historical studies of human impacts on river environments, the extent of change must be regarded as provisional.

bends) since journey-time are not critical for pleasure craft.

### 3.2.7 Recreational activities

The two main recreational activities affecting rivers are angling and recreational boating.

#### Angling

Several aspects of angling modify the physical environment of rivers but the scale of the impacts have received relatively little attention. Debris dams may be removed from rivers to facilitate upstream migration of salmonids (for example in the New Forest) with consequential detrimental effects on stream width and potentially also on degree of flooding. Fishing platforms and embayments may also have minor effects on erosion/sediment loads. On many rivers, water plants are regularly removed to create fishable swims.

#### Recreational boating

Problems associated with recreational boating tend to be localised (for example in the Broadland rivers) and are mainly concerned with erosion of river banks which may require stabilisation. In addition, water displacement, propeller wash, and wakes from boats resuspend bottom sediments and can disorient or injure sensitive aquatic species.

### 3.2.8 Improvement of transport links

Rivers are often relocated or channelised in the course of constructing road crossings (in the past this also occurred in the course of railway construction).

concrete blocks, sheet pile

**Removal of snags**

Snags are removed to smooth the through-flow of water and decrease bed or bank friction/roughness. Work can include the removal of vegetation which also helps to reduce summer flooding. Removal of woody debris also reduces the risk of flooding.

### 3.2.5 Regulation for water supply

There are several ways of regulating rivers, which may be defined as either direct or indirect controls.

Direct methods include:

- on river impoundments e.g. dams, onstream balancing ponds
- pumped storage reservoirs

Indirect methods include:

- groundwater abstractions
- interbasin water transfer

Dams are the most conspicuous element of river regulation. They serve not only as a barrier to migrating fish (and other animals) within the river but also as sediment barriers and as obstructions to the flooding of riparian areas. Because of this they prevent the return of nutrients and sediments to the land (NRC 1992). Dams also alter water quality and initiate long-term changes in downstream channel structure, riparian zones and floodplain.

### 3.2.6 Navigation

Navigation improvements have affected a relatively small number of rivers in England and Wales like the Thames,Trent, Wey (Surrey), Kennet (Berkshire, Wiltshire), Itchen (Hampshire) and Welland (Leicestershire/Northamptonshire, Lincolnshire) (Hadfield, 1969). These rivers were straightened by creating cuts or canals across the bends, although deepening by dredging is also used to allows the free passage of boat traffic. Locks were originally constructed to reduce flows and negotiate inclines.

With decline of rivers for industrial transport canalised rivers are increasingly used for leisure (see below). This has made some of the original modifications to the rivers redundant (e.g. straightened

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## 6.4 Additional reccomendations and conclusions

Three additional reccommendations and conclusions to come out of the report are:

1. River rehabilitation aims should be incorporated within Catchment Management Planning guidelines (as well as the Plans themselves). As far as possible, guidelines should also recommend a strategic approach to rehabilitation. This is particularly important for conservation, where there are likely to be considerable benefits from recognising, protecting and extending key sites of national and regional value.

2. In general, rehabilitation for wildlife and fisheries should not be undertaken in areas of poor water quality. This does not prohibit rehabilitation for recreation and amenity in low water quality areas, but recognises that the benefits of rehabilitation for conservation or fisheries **alone**, are unlikely to justify the costs involved.

3. Where possible there should be a proactive approach to restoration which reinstates natural flooding regimes and floodplain habitats, because:

    - it is likely to yield considerable conservation benefits (in terms of protecting and enhancing wetland habitats which are nationally threatened in Britain).

    - it considerably extends the range and scope of channel modifications which are feasible either by technical modification (e.g. reinstatement of meanders), or by natural means (e.g. recovery enhancement in high energy channels).

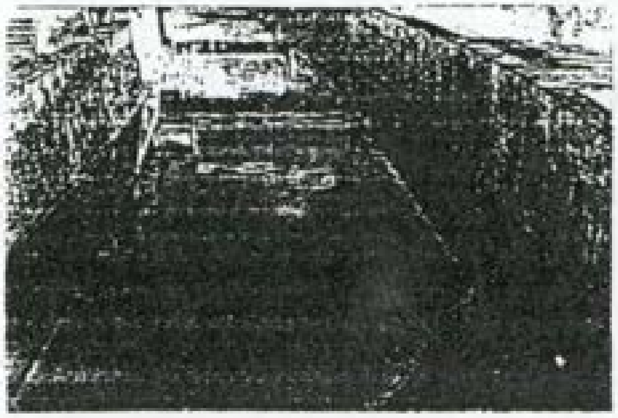
    - most of the potential financial benefits associated with river rehabilitation depend on reinstatement of the riparian zone and preferably, the floodplain (eg water quality improvements, stormwater interception & flood storage, pollutant interception and degradation, sediment input reductions etc).

# After

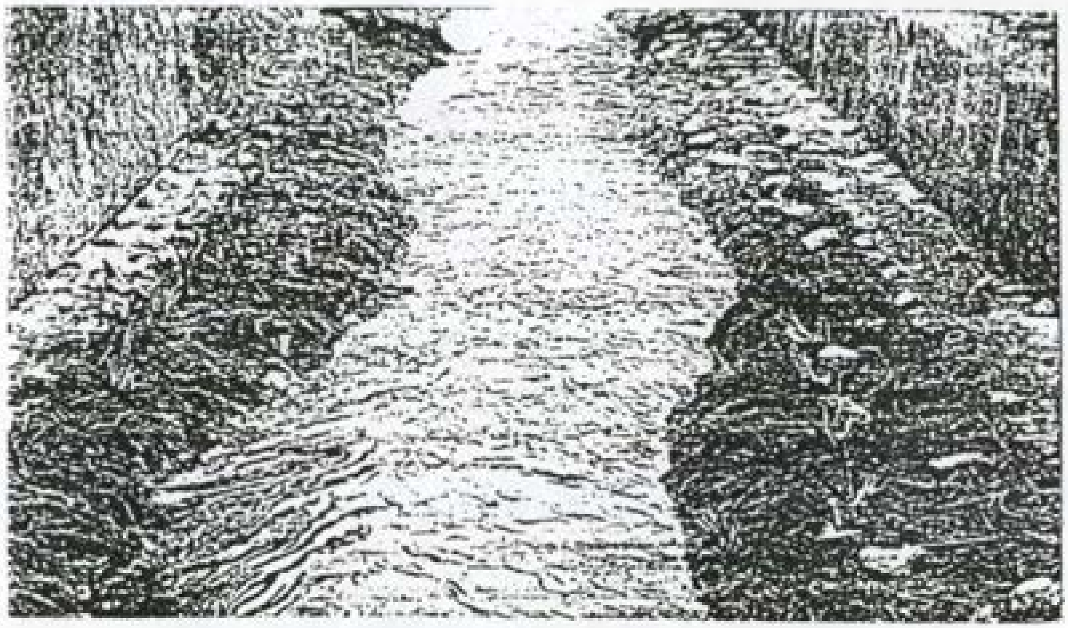
*Mitte September ist die Trockenphase uberstanden*
*(Jahr 2. 302)*

# River Metter

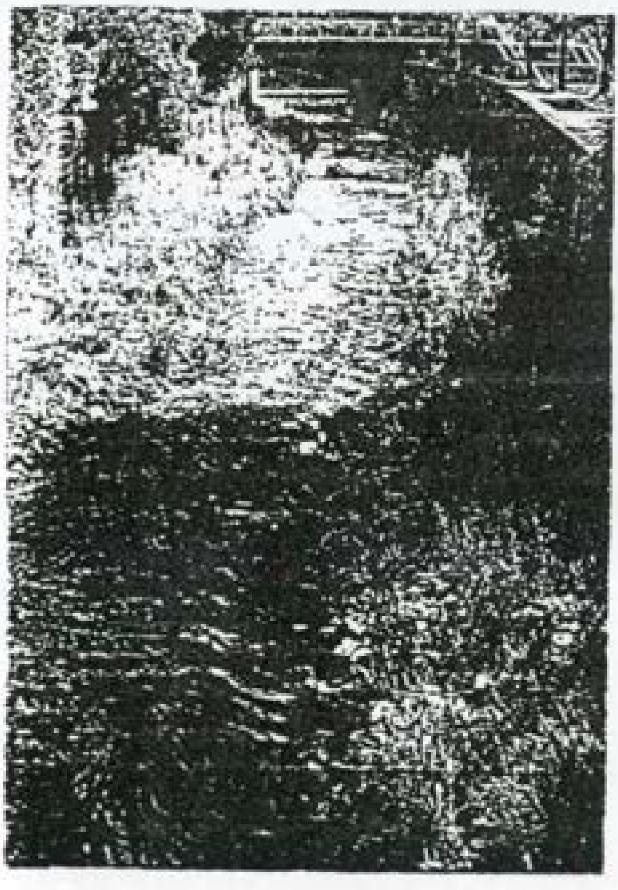
The River Metter flows through Bietingheim, Baden Wurrtemberg, Germany and joins the River Enz. A 100m stretch of this small, urban river was redesigned in 1988 to eliminate the problems of low oxygen content, generally poor water quality, and slow currents. The channel was reduced to that of low flow width and the slope resulting from two weirs was reduced. Gravel and stone placement created variation on the bed, and natural bank stabilization methods provided a base for an extensive planting programme. The cost was £75 000.



**Before**



**During the scheme**

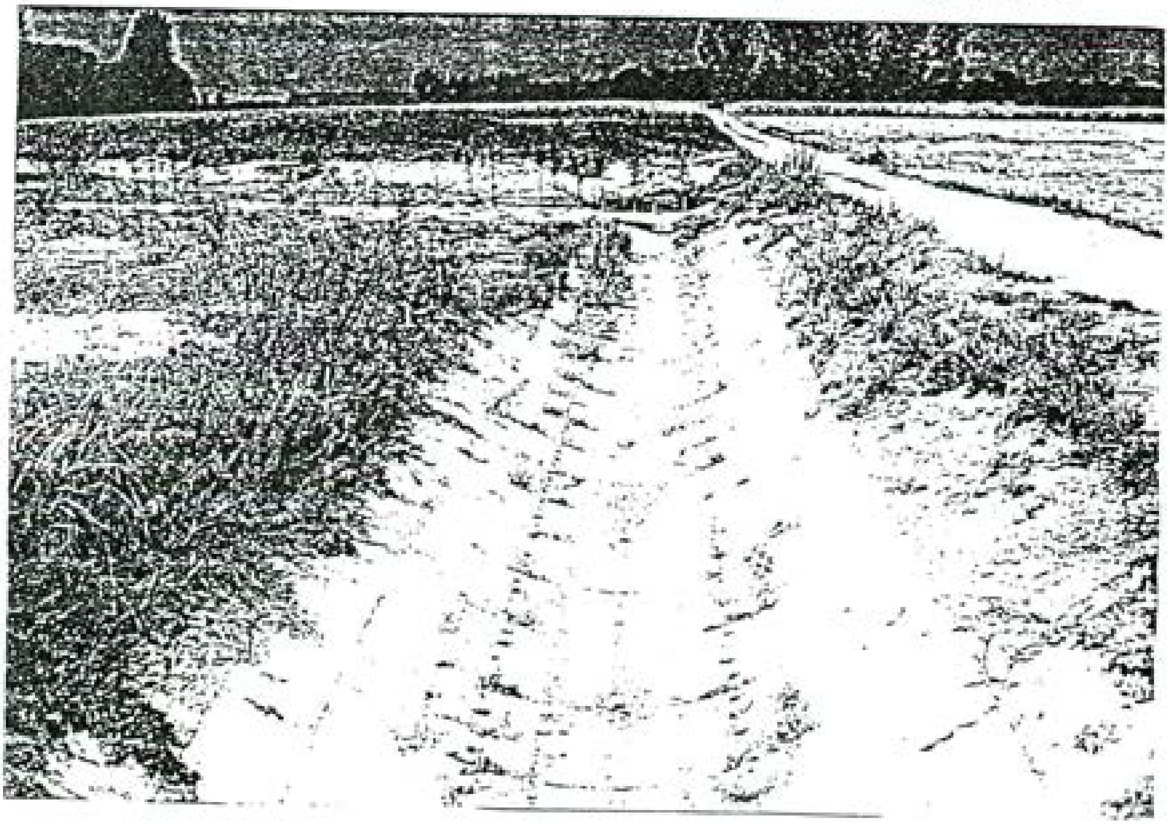


**After completion**

Reference:
Kern *et al.* (1992)

# Rungsbachle & Kleines Sulzbachle Stream

The Rungsbachle/Kleines Sulzbachle is situated in Buhl, Baden Wurrtemberg, Germany and flows through a predominantly residential and industrial area, which also has some recreational and agricultural land. Some of the river is contained within a pipe, whereas other sections have concrete tiles and still other sections have mixed gravel and sand sediments. The high ecological value of the area, which supports rare amphibia, a rare mollusc, and valuable insect and plant communities, initiated the need for a scheme to create a natural floodplain which included the surrounding meadows, eliminated the need for a pipe by re-diverting it around a sportsfield, narrowed the upper reaches of the channel and widened the lower reaches of the floodplain by up to 50m.
Initial plans were not considered to be ecologically appropriate for the waterway so a small pilot scheme (475m) was set up to test the options. Structures placed in the river have been kept to minimum in the hope that the river would readjust naturally, although it became evident that further reinforcement would be necessary in the future. Substrate reinstatement was carried out using varying sizes of gravel. Bushes and trees endemic to the area have been planted on the banks. The total cost of the project was £184 583 of which £45 000 was spent on land purchase.



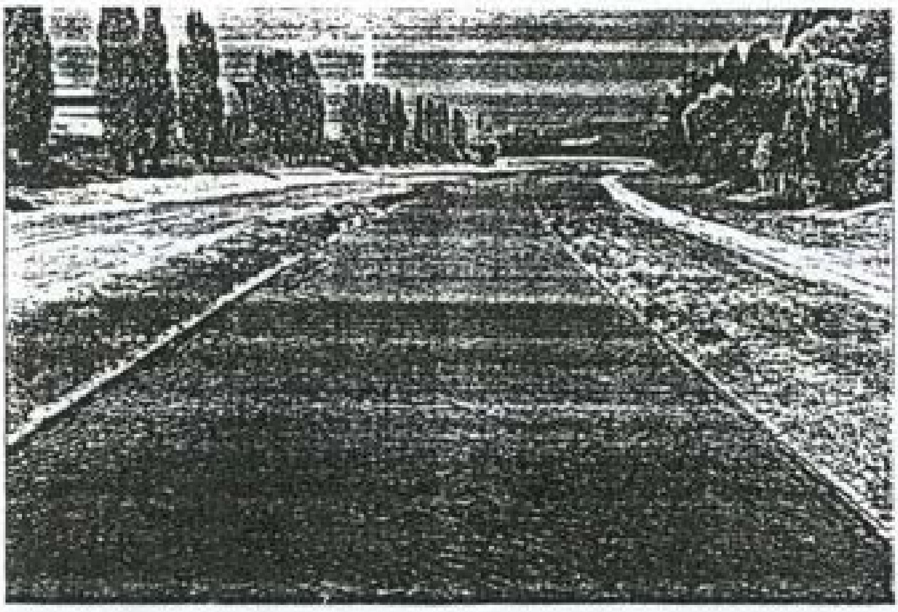
**Before**

Reference: Kern et al. (1992)

# River Enz

This fairly large urban river (width 90m, max. depth 1.6m) flows through Pforzheim, Baden-Wurrtemberg, Germany. In 1990, a scheme was undertaken predominantly for flood protection but also to improve the appearance of the area before a National Garden Festival. As there were also many important additional factors to be considered, such as the avoidance of gas, water and electricity pipes, the maintenance of a water source for factories nearby, and the retention of a levee, a detailed scale model of the 1500m stretch was constructed to help predict the effects of any scheme on flows and flooding regime. The river bed substrate was manipulated to create a more natural channel shape, three islands were created, and bank protection measures included the placement of local stone, willow piling, reed cylinders, grass turf and the sowing of grass seed. The scheme cost £1 542 000 (£1041 per metre).

Reference: Kern *et al.* (1992).



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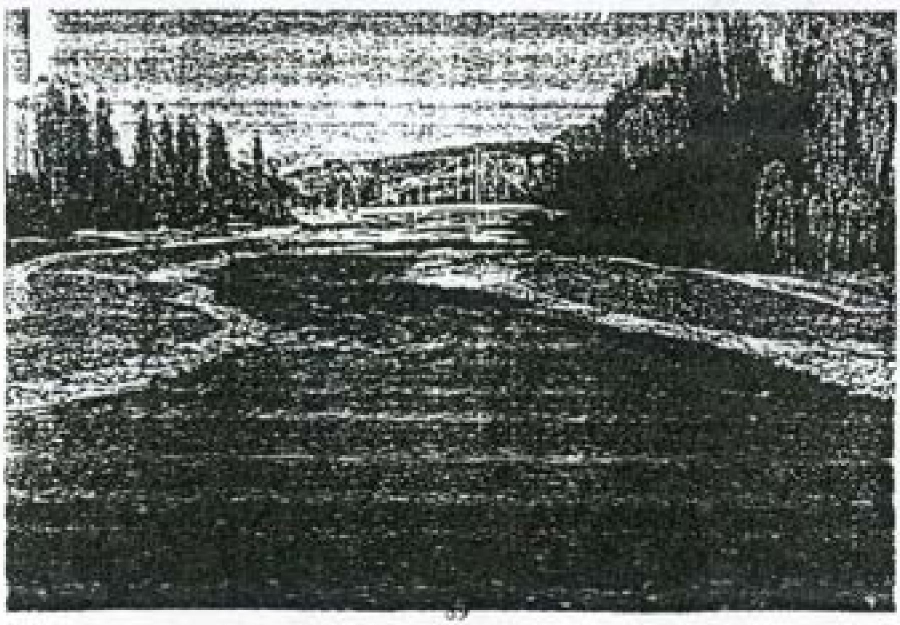
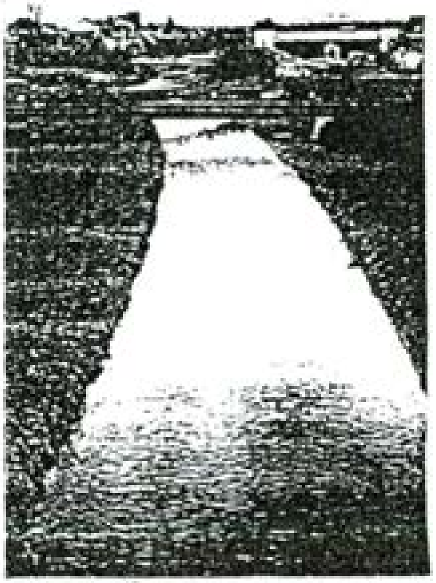


**After**

# River Alb

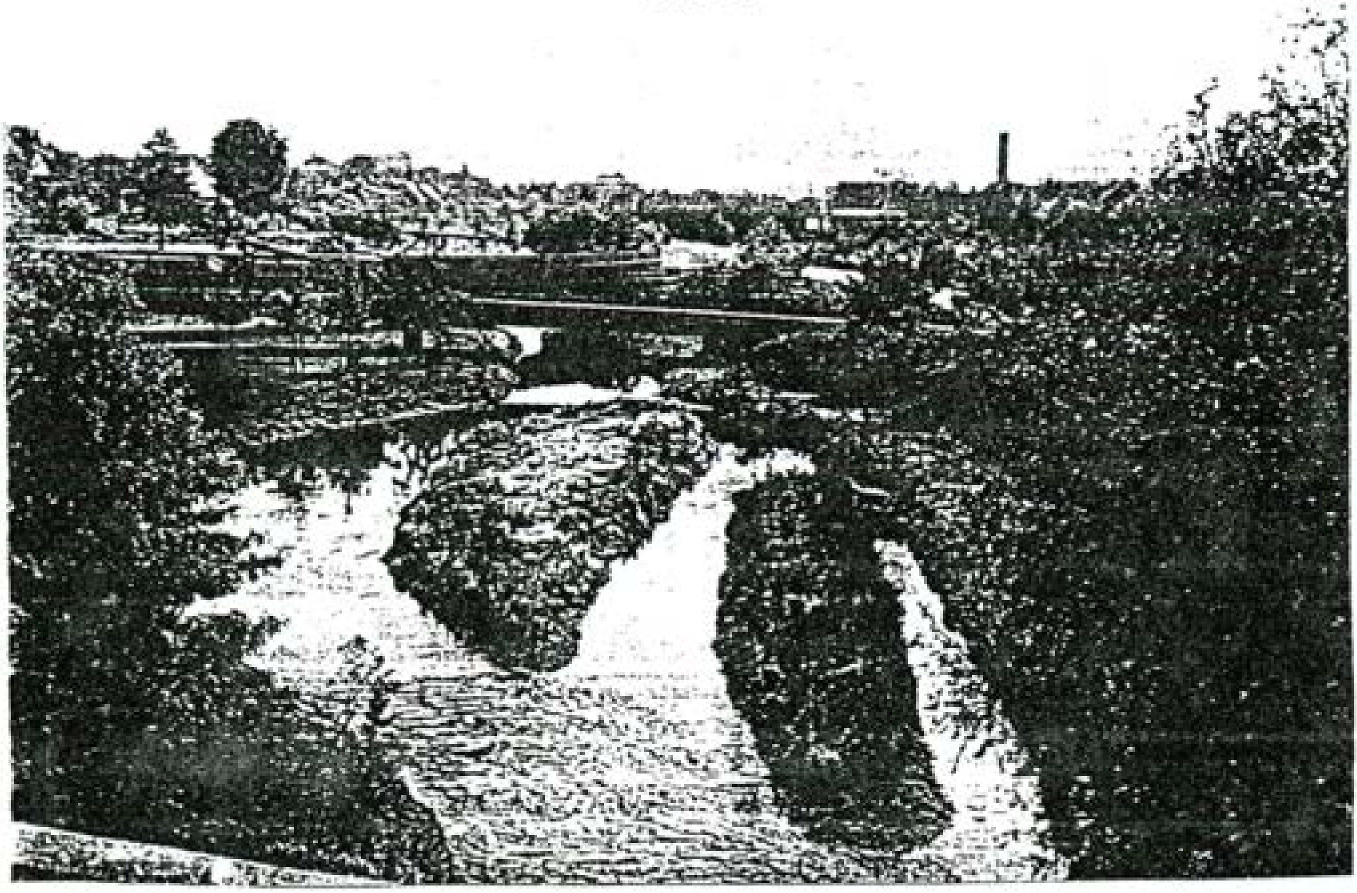
The Alb near Bierthe, Baden-Wurttemberg in Germany, is a medium sized river (width 14.5m, depth 1.3m). It formed an important 'green space' for the nearby town, even when it was channelized. The 1988 scheme improved a 500m stretch of the river by removing concrete revetments, creating islands, widening the stream bed, protecting and regrading shore and banks with coarse gravel and rip-rap, creating greater flow diversity in the middle sections and planting the banks extensively. The post-project evaluation showed that the scheme had proved hydrologically sound after a flood event, new islands were forming naturally, invertebrate species diversity had increased, trees had colonised the banks naturally, and more public use was being made of the area. The total cost was £109 583 (£216 per metre).



**Before**

Reference: Kern *et al.* (1992).

**After**



# River Surbæk

This river in southern Jutland Denmark had been used as an experimental site to test the effects o different maintenance regimes in 1982.

The site was then left alone for ten years. A natural flow width and natural variations in depth were recovered and plants and associated fish became more prolific. This increase in channel vegetation increased water level. Trees colonised and provided some shading of the channel naturally regulating plant growth.

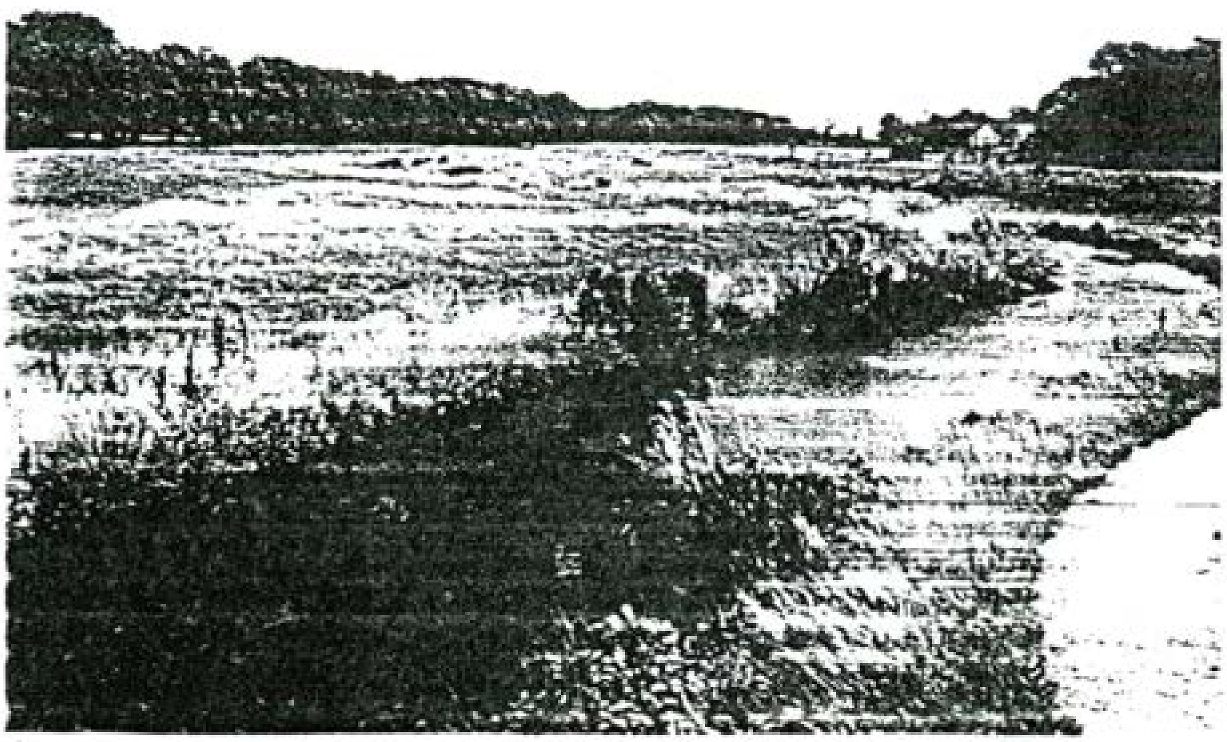
# River Gelså

The River Gelså near Bevtoft, Southern Jutland, Denmark, is a lowland rural river (width 6-8m, depth 1.5m) running through grazing meadows, which was channelized in 1952. In 1989, it was proposed that the river and its riparian zone be restored for both ecological (particularly for fish) and aesthetic reasons. The project was undertaken by Sønderjyllands amt (County council) who designed, funded and carried it out with the co-operation of the local residents and landowners. The works undertaken on the 1340m reach included:

- the restoration of sixteen meanders increasing the length of the reach by 38% to 1850m
- reinstatement of natural gravels to provide suitable substrate and raise bed levels so that flooding takes place every two years
- riffle & pool sequence creation and flow diversity enhancement with boulder placement
- bank re-profiling with natural stone
- sediment trap installation downstream of the site
- removal of a weir

The post project appraisal and monitoring indicated that there had been a great improvement in the aesthetic quality of the area, 13 new plant species had been recorded and the number of invertebrate species had increased from 62 to 75. The cost of the scheme was $ 220 000.

Reference: Nielsen *et al.* (1990).

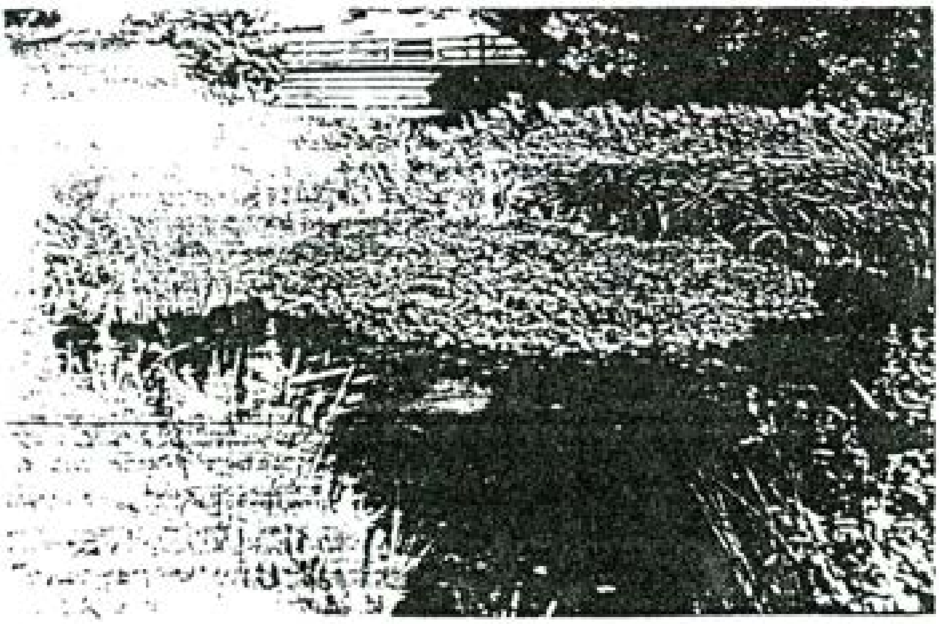


# Sapiston Brook

The Sapiston Brook is a low energy (6m wide) rural river that is part of the Suffolk River Valley ESA scheme, (Anglian Region), within which the development of traditional grazing meadows through raising of water levels is encouraged and landowner cooperation is a valuable asset. Although the Sapiston had retained a sinuous course, previous management practices had resulted in the depletion of gravel substrate and riffles. The project was undertaken between February and April 1992, and involved the reinforcement of each of the 6 original riffles in the 1.5km stretch with about 20 tons of gravel rejects. The ramps that were produced had the desired effect of increasing river level and backing up of meadow dykes which ultimately raised the water table on the adjacent land. Additional meanders with riffles and pools were also created. The project cost around £5 000 and was funded from the conservation (80%) and flood defence budgets (20%) of the NRA.

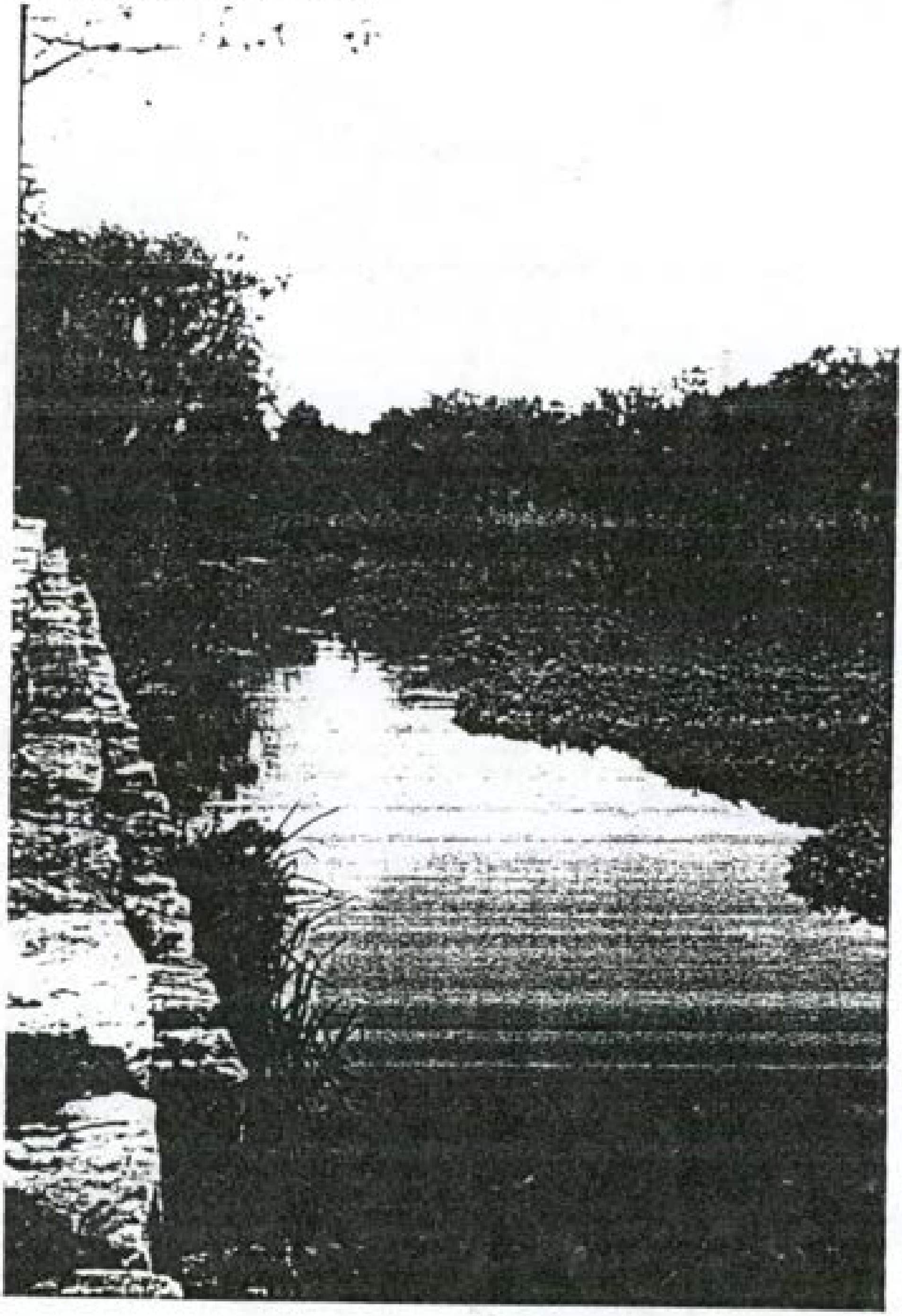
# River Leen

The Leen is a small (4m wide) urban river (in Nottingham) in the Severn-Trent region. Collaboration with local authorities (who contributed 50% of the funding) and wildlife trusts was instrumental in the development of the project, which began in 1988. Works include emplacement of small weirs, widening to develop marginal fringe features and embayments in some concrete sections. The project will continue under the Leen Management Plan approved by local authorities. About 15 km of the river has so far been improved at a cost of £80 000.



# Wraysbury River

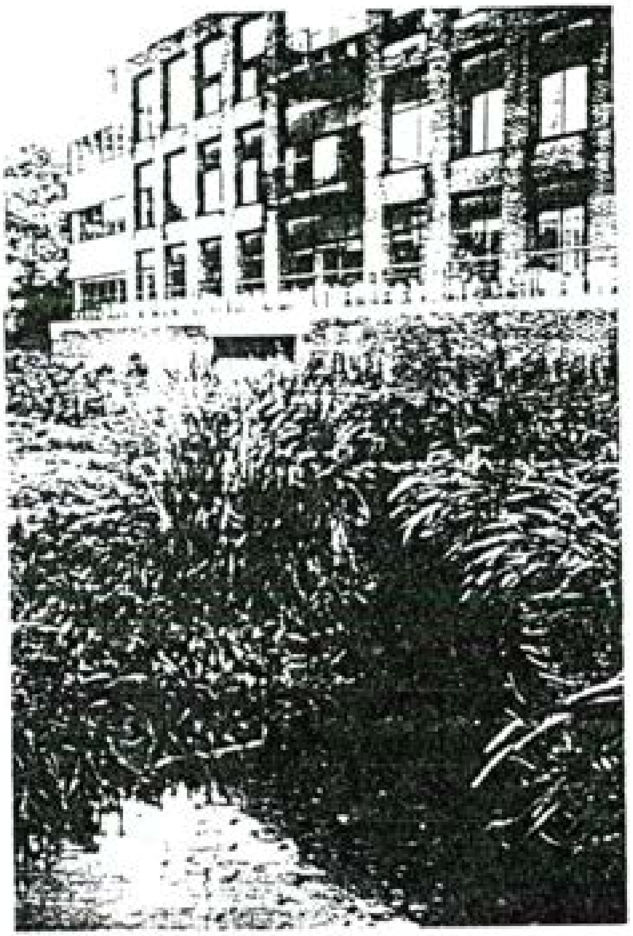
The Wraysbury River, flows through an industrial area at Poyle (Thames Region). A flood alleviation scheme sought to use biotechnical alternatives to hard engineering methods. Large limestone blocks, willow spiling, and nicospan, rather than steel piling and concrete revetments, were used to stabilise banks.



Although channel capacity was maintained, a natural low flow width was created by the use of current deflectors to initiate the formation of berms, which were colonized by a variety of marginal plant species. An island and an extra high-flow channel were also incorporated to add further to the high instream diversity. As the area improved in appearance, it was increasingly utilized as an amenity area by the factory workers.

# River Ash

The Ash is a regulated river in the Borough of Spelthorne, Thames Region. Much of the river had been straightened with excessive siltation. A six phase plan was developed in 1990, to improve wat and habitat quality over an 11.7 km stretch. Phase one of this is now complete and cost £200,000 with the bulk of these funds coming from external sources. The scheme aimed to ameliorate low flows, increase channel habitat and reduce silt loading through the reinstatement of gravel beds in which pools and riffles were formed. The placement of boulders enhanced flow and aeration. Beds emergent vegetation and a variety of habitats were created to increase conservation and fisheries valu and to promote the river as a amenity area to be enjoyed by the local community.



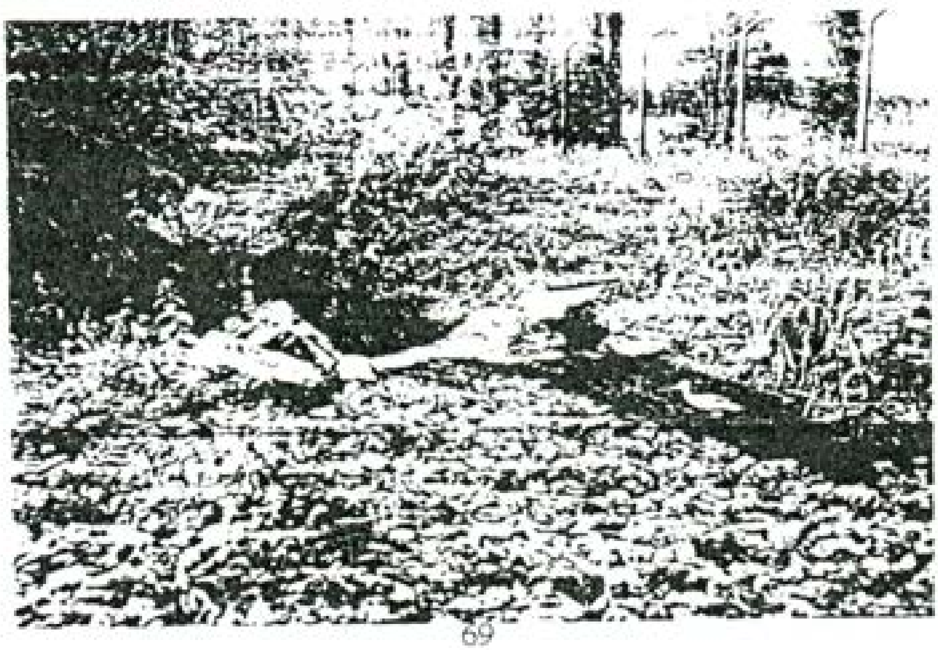


Figure 6.3 Some European schemes of widespread relevance

| | | |
|---|---|---|
| Denmark | - | River Surbæk |
| | - | River Gelså |
| Germany | - | River Alb |
| | - | River Enz |
| | - | River Metter |
| | - | Rungsbachle & Kleines Sulzbachle Stream |

stresses and lets the river recover naturally. The advantage of such a policy is that it ultimately produces a river in equilibrium with its channel and surroundings (an objective of rehabilitation) at minimal cost and with minimal understanding of the rate and pathways of recovery. The main requirement is likely to be land.

There are many examples of channels that have regained their original channel form and function in this way even where severe modification such as widening and straightening have been imposed (Brookes, 1988, 1992).

However not all rivers will recover naturally in relatively short time scales. High energy rivers with an abundant supply of sediment are likely to recover most rapidly. Low energy rivers with few silt inputs, may not return to a natural form in many centuries (Brookes 1992).

Since the conditions for recovery are relatively predictable, it is possible to predict which rivers are likely to benefit from recovery and therefore where it will be beneficial to encourage this process through enhanced recovery (ie simple removal of stresses such as regrading banks, breaking out stabilising materials etc). Enhanced recovery could potentially include relatively cheap and simple methods to reinstate floodplain such as removing flood protection structures such as dykes , levees and embankments, where these are no longer needed or cost-effective (NRC 1992).

### 6.2.9 Optimisation of maintenance as a means of rehabilitation

Where rivers with a good potential for recovery are regularly dredged, then a decrease in dredging frequency and/or extent may facilitate partial recovery (Brookes, 1992). This is particularly pertinent as requirements for agricultural flood defence and drainage decrease).

## 6.3 Lessons to be learnt from other countries

Several other European countries have already undertaken extensive river rehabilitation schemes, including Denmark, Germany, Hungary, the Netherlands and Switzerland. Before beginning extensive rehabilitation in Britain, we therefore have an opportunity to learn from their experiences.

Of the European schemes, those undertaken in Germany and Denmark are most relevant to Britain in terms of the type of sites which are encountered and the degree of their experience.
Examples of Danish and German schemes are illustrated in Figure 6.3. A summary of the factors which contribute to their success and failure is outlined in Table 6.3 over the page.

### 6.2.6 Increased interest and awareness of river rehabilitation

There is currently considerable interest in rehabilitation from a number of areas including:

- the River Restoration Project (RRP), an independent group seeking to undertake demonstration projects in Britain and Denmark to show the scope of full river restoration.
- large environemtnal organisations working in collaboration with the NRA (eg in NRA Thames the National Trust has a joint project to rehabilitate parts of the the River Windrush and its floodplain on the Oxfordshire and Gloucestershire border)..
- Local Authorities (eg Havant Borough Council which is promoting rehabilitation wirks on the urban Hermitage Stream ).
- Smaller bodies eg the Tweed Commissioners and the Norfolk Anglers Cooperative Association (NACA).

Some of the above offer potential co-funding opportunities, either in terms of money, land, time or expertise. In addition there will undoubtedly be continued interest from landowners seeking drainage consents, and probably increased interest from from developers as increased environmental standards and requirements from EC directives are implemented.

If Britain follows the American pattern, then the future may see the initiation of numerous public and private agencies and citizen organisations interested in initiating further stream and river rehabilitation projects (NRC 1992). These organisations, are likely to require proper guidance and advice, but their support may be a valuable impetus for effective aquatic ecosystem rehabilitation and, in some cases a valuable source of volunteer labour to accomplish those objectives (NRC 1992).

### 6.2.7 Greater scientific understanding

The sophistication of hydrological and geomorphological models geared to understanding catchment processes is increasing rapidly, especially in European countries such as Germany. This is likely to considerably improve the potential for testing and potentially implementing 'softer' engineering options (eg the Rivers Enz and Danube in Germany, which integrated use of wetlands and washlands for flood defence requirements with the rehabilitation of rivers for flood control).

### 6.2.8 Natural Recovery

Rivers and streams have an inherent ability to recover from even severe disturbance. This may be readily exploited by a policy of minimal intervention which simply reduces or removes the necessary

### 6.2.4 Financial incentives

The scope for the reinstatement of functional floodplains is also made greater by the number of financial incentives for example:

- MAFF set-aside, set up specifically to promote changing land use with no provision for habitat type or management and therefore of least value for riverine rehabilitation
- the Countryside Commissions' Countryside Premium scheme, currently available only in Anglian region but offering a range of wetland habitats (Countryside Commision, 1989).
- The Countryside Commissions' Countryside Stewardship scheme including waterside landscapes at £225/ha. (Countryside Commision, 1991).
- MAFF Environmentally Sensitive Areas (ESA's), offering a tiered system of payments depending on the wetness of the soil and the degree of change that the landowner is prepared to accept. So wheat to wet grassland grass qualifies for a higher payment than grassland to wet grassland. Payments are different or different schemes (eg Broadland or Suffolk River Valleys) but are in the range of £200/ha for the highest tier (MAFF, 1992).
- Woodland grants are available from the Forestry Commission for areas >0.25ha.

Currently all schemes, except the last, are of limited tenure, typically 10 years although recent CAP proposals suggest that it may increase (perhaps to 20 years). In addition, there are possibilities that set-aside may become compulsory, taking 15% of land on each farm. This could encourage wide spread introduction of riparian buffer zones and lead to river and floodplain rehabilitation.

### 6.2.5 Integrated Catchment Management

Rehabilitation is a holistic process which fits well in the strategic approach of Catchment Management Plans. Rehabilitation may benefit from the implementation of CMPs in a number of ways including:

- greater chances of developing large scale rehabilitation features within the CMP framework eg re-establishment of extensive rivers corridors.

- clear advantages for rehabilitation projects in cathment management planning because of the wide range of objectives which rehabilitation can help to fulfil..

- Considerably greater interest and co-funding opportunities from both the public and private sectors.
- The recognition that integrated catchment planning, and the framework provided by Catchment Management Plans (CMP), may help with the implementation of rehabilitation schemes.
- Increasingly sophisticatedof hydrological and geomorphological models which may identify areas where 'soft' and 'hard' engineering can be integrated (eg use of washlands to in flood relief schemes).
- Recognition of **natural recovery** and the possibilities of recovery enhancement, which require relatively low levels of financial investments
- Scope for reduction of maintenance levels, particularly where dredging exceeds the required level of service.

These points are discussed briefly below.

### 6.2.3 General trends towards extensification of land use.

As suggested by Brookes (1988) large scale rehabilitation of rivers and their floodplains is only really feasible if the channel and floodplain are no longer required to fulfil their previous land-use or engineering objectives.

One of the most important changes in recent years, has been the general trend towards extensification of agricultural land. This may increasingly provide major opportunities for river rehabilitation, because it simultaneously eases the pressure from two otherwise unavoidable stresses on streams and rivers: namely agricultural drainage and flood defence.

The potential for river rehabilitation that this provides is considerable and includes:

- the potential to reinstate areas of functional floodplain with a variety of habitats and all their associated benefits.
- increased space for channel modifications, including both 'technical' options (eg reinstatements of meanders), and 'natural', options (eg recovery enhancement in high energy channels).
- the possibility of decreasing the frequency of of maintenance dredging, and weed cutting which may increase the risk of flooding.

(Thames) and Pinkhill Meadows Wetland Enhancement Scheme where Thames Water Utilities are co-funding partners in the project.

Table 6.2 gives the details of 18 relatively large projects described in the questionnaire returns (see also Figures xx-xx). Information about these schemes suggests that the rivers selected for rehabilitation/enhancement are usually relatively small (ie less than 10m wide). However, the length of river which was modified was variable (between 400m and 15km). Financial input to each scheme also varied widely (between £5K-£200K for conservation funded schemes and over £1M for flood defence funded schemes with mitigation built in).

## 6.2 Constraints and future opportunities for river rehabilitation

### 6.2.1 Constraints

A wide variety of rehabilitation schemes have been implemented within NRA regions. However information from the questionnaires and from discussions with practitioners indicate a number of constraints on rehabilitation works (as opposed to enhancements). These are:

- uncertainty over the interpretation of the Water Resources Act (1991) and how much rehabilitation work is justified on conservation grounds.
- limited GIA funding to enable Conservation departments to pursue large (and therefore more expensive) rehabilitation schemes.
- too few staff, and in some regions insufficient technical expertise, available to effectively plan, design and execute large-scale rehabilitation schemes.

Some of the constraints identified above may be addressed by the River Environmental Development initiative, led by Richard Vivash, which is currently seeking to establish a framework whereby funding from external organisations could be combined with resources from the NRA.

### 6.2.2 Future opportunities

There are a number of important recent changes in planning framework, land-use and attitudes which may now make river rehabilitation a much more feasible option than it has been in the past. These include:

- Trends towards extensification of agriculture which may increasingly provide opportunities to 'regain' active floodplain (with potential benefits for conservation, flood relief, water quality, river maintenance etc.).

| Region | River | width | length of scheme | land use | reason | finances | ppa |
|---|---|---|---|---|---|---|---|
| Anglian | Harper's Brook | 4 | 2 km | rural | Cons | 20K | detailed visual |
| | Sapiston | 6 | 1.5km | rural | Cons | 5K | visual |
| Northumbrian | Lustrum | 5 | 0.5km | urban | Coms, FD | - | too early |
| | Leven | 15pre 6post | 0.4km | urban | Cons, Am. | 15K | ongoing |
| | Till | 20 | - | rural | Cons | - | monitoring otters |
| Severn-Trent | Leen | 4 | 15km | urban | Rec, Cons | 80K | visual |
| | Rea Brook | 3 | 5km | urban | Cons, Arch, Rec | 20K | visual |
| | Severn | 2500 | 5km | rural | Cons | 25K | visual |
| Southern | Cray | 1-2 | 3.5km | urban | FD | 700K | visual |
| Thames | Ash | 4 | 11.7km | urban | FD, Cons, Rec | 200K | ongoing |
| | Coln | - | - | rural | Fish | 31.5K | monitoring fish |
| | Windrush | 8 | 1.5 | rural | FD, Fish, Cons | 150K | ongoing monitoring |
| Welsh | Rhymney | - | 10 sites over 34km | urban | Cons | 11K | visual |
| | Cefni | 10 | 2km | rural | Cons | 9K | visual |
| | Gywrfai | 6 | 0.6km | rural | Fish | 28K | monitoring fish |
| Wessex | Brinkworth | 1-2 | 2km | rural | Con, Am, Fish | 100K (5 years) | too early |
| | Tone | 10 | 0.5km | rural | FD | >1M | visual |
| | Wellow Brook | 2-4 | 2km | rural | FD, Fish, Cons | - | visual |

Figure 6.2 <u>Some British schemes of widespread relevance</u>

| | | |
|---|---|---|
| Thames | - | River Ash |
| | - | Wraysbury River |
| Severn-Trent | - | River Leen |
| Anglian | - | Sapiston Brook |

Table 6.1 The status of improvement schemes undertaken in seven regions of the NRA

| | Anglian | Northumbrian | Severn-Trent | Southern | Thames | Welsh | Wessex |
|---|---|---|---|---|---|---|---|
| Improvements | | | | | | | |
| Rehabilitation | 25 | 2 | 19 | 4 | 300 | 1 | 5 |
| Rehabilitation inc. floodplain | 10 | 1 | 15 | 2 | 200 | 0 | 5 |
| Enhancements | * | 6 | 100 | 5 | 50 | 17 | 300 |
| Objectives satisfied % | | | | | | | |
| Rehabilitation | - | 100 | 100 | 75 | 90 | 100 | 80 |
| Enhancements | - | 80 | 95 | 60 | 90 | 94 | - |
| Primary internal funds | | | | | | | |
| Rehabilitation | Cons. | FD | Cons. | Cons. | FD | Cons. | Fish. |
| Enhancement | FD | FD | FD | Cons. | FD | Cons. | FD |
| Primary external funds | | | | | | | |
| Rehabilitation | ESA | LA | - | LA | All | CCW | - |
| Enhancement | - | LO | LA | LO | minor | OT & LO | PC |
| Conservation budget (K) | | | | | | | |
| '91/'92 | - | - | 580 | 8 | 650 | 44 | - |
| '92/'93 | - | - | 445 | 5.2 | 650 | 50 | - |
| '93/'94 | - | - | 450 | 3.2 | 800 | 56 | - |
| Desirable level of funding (K/pa) | 250 | 75/100 | 500 | 200 | 1M | 600 | 100 |

Key: Cons = Conservation; FD = Flood defence; Fish = Fisheries; ESA = Environmentally Sensitive Area; LA = Local Authority; LO = Land Owner; CCW = Countryside Council for Wales; OT = Otter Trust

Notes: * too numerous to quantify

# 6. CURRENT STATUS AND FUTURE TRENDS FOR REHABILITATION

This chapter summarises information about the current status of restoration sites in Britain, and identifies where future opportunities may lie. It is organised into the following sections:

- the current status of the river improvement schemes within the regions of the NRA
- constraints and future opportunities for rehabilitation in NRA regions
- lessons which can be learnt from rehabilitation schemes undertaken in Europe
- overall recommendations

## 6.1 Current status of river improvements in England and Wales

### 6.1.1 Information gathering

Information about the current nature and extent of river improvement projects (rehabilitation, enhancements and mitigation schemes) was collected by means of (i) a questionnaire distributed to the Conservation Officers in all NRA regions (Appendix 1) and (ii) site visits to a number of the larger projects in five NRA regions (Anglian, North-West, Severn-Trent, Southern and Thames).

### 6.1.2 Results

NRA conservation staff believed that physical damage to river environments (caused by low flows and channelisation) was more significant than the impacts of water pollution or losses of species (see Figure 6.1). However, it was clear from the questionnaire that the responses the regions were able to make to this impact varied greatly. As Table 6.1 shows there was a very large regional variation in the number of improvement schemes undertaken. This variation predominantly correlates with the extent of finances available to the conservation section within each region.

In all regions Flood Defence contributes a significant part of the funding for enhancements, often in association with flood alleviation schemes and other capital works. One region, Thames, undertkaes additional rehabilitation work in a collaboration between Flood Defence and Conservation. Overall the results suggest that most rehabilitation schemes have been conservation-driven

External collaboration with landowners is clearly an important part of the river improvement process. However, whilst there is active collaboration with many groups (eg EN, CCW, the Otter Trust, local authorities, private companies) there appears to be little external funding to support projects. The main exceptions noted were the Department of Transports involvement with the River Ash scheme

PHYSICAL

— HABITAT LOSS

CHANNELIZATION

WATER QUANTITY

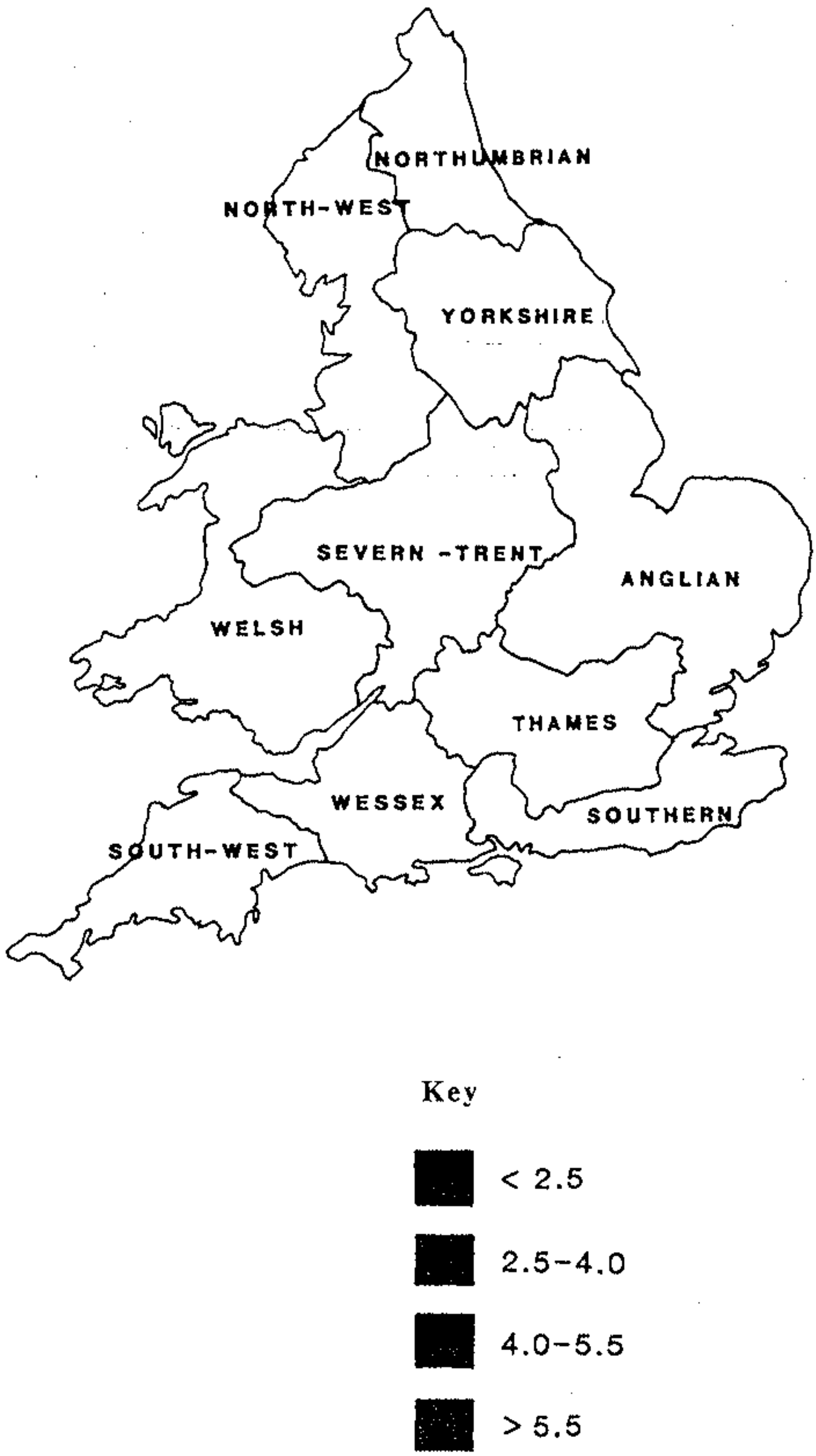
CHEMICAL

— WATER QUALITY

BIOLOGICAL

— SPECIES CHANGE

Figure 6.1 The relative importance of physical, biological and chemical factors in river degradation as perceived by NRA personnel. Mean ranks for each of the factors are shown.



## Table 5.4 Matrix showing the potential benefits of river rehabilitation

| RIVER FEATURES | Wildlife (excluding fish) | Fish | Recreation & amenity | Flood control | Low flow amelioration | Water quality | Channel Stability | Sediment (produced or deposited) | Weed clearance & removal of obstructions |
|---|---|---|---|---|---|---|---|---|---|
| **FEATURES OF STRUCTURALLY MODIFIED RIVERS:** | | | | | | | | | |
| Channelized river | -- | -- | -- | ++ | -- | -- | ++/- | -- | -- |
| Straightened river | -- | -- | -- | ++ | -- | -- | ++/- | -- | -- |
| Deepened/increased capacity | -- | -- | +/-- | ++ | -- | -- | ++/- | -- | + |
| High maintenance levels | --/- | -- | - | ++ | -- | - | ++/- | ++ | ++ |
| Non-functional floodplain | -- | - | -- | -- | 0 | -- | 0 | -- | -- |
| **FEATURES OF REHABILITATED RIVERS:** | | | | | | | | | |
| Natural river-riparian system | ++ | ++ | ++ | ++/-- | ++ | ++ | ++ | ++ | ++ |
| Meandering or sinuous channel | ++ | ++ | ++ | +/- | + | + | ++/-- | ++ | 0 |
| Riffle-pool structure | ++ | ++ | ++/- | 0 | + | + | ++/-- | ++ | - |
| Appropriate width/depth ratios | ++ | ++ | + | -- | + | + | ++ | ++ | 0 |
| Natural substrate | ++ | ++ | + | 0 | + | + | ++ | ++ | 0 |
| Channel vegetation | ++ | ++ | +/-- | -- | + | + | +/- | + | -- |
| Bankside vegetation | ++ | ++ | ++ | -- | + | ++ | ++ | ++ | - |
| Channel debris and debris-dams | ++ | ++/- | -- | -- | ++ | ++ | ++/--- | +/-- | -- |
| Riparian zone | ++ | ++ | ++ | ++/-- | ++ | ++ | ++ | ++ | -- |
| Floodplain (functional semi-nat) | ++ | ++ | ++ | ++/-- | ++ | ++ | ++ | ++ | -- |

## Table 5.4 continued

| RIVER FEATURES | Wildlife (excluding fish) | Fish | Recreation & amenity | Flood control | Low flow amelioration | Water quality | Channel Stability | Sediment (produced or deposited) | Weed clearance & removal of obstructions |
|---|---|---|---|---|---|---|---|---|---|
| **ENHANCEMENTS & PARTIAL REHABILITATIONS:** | | | | | | | | | |
| Flood storage areas | ++ | + | + | ++ | ++ | + | ++ | ++ | 0 |
| Multi-stage channels | + | + | + | ++ | ++ | + | + | + | -- |
| Flood diversion & by-pass channels | + | + | + | ++ | 0 | 0 | + | + | 0 |
| Embankments | -- | -- | -- | ++ | 0 | 0 | ++ | +/- | 0 |
| Buffer zone | ++ | ++ | ++ | +/- | + | ++ | ++ | ++ | - |
| Current deflectors | ++ | ++ | + | 0 | 0 | + | ++ | + | 0 |
| Dams/weirs/sills | + | +/-- | + | + | + | + | +/- | +/-- | -- |
| Direct cover structures | + | + | - | 0 | 0 | 0 | + | 0 | - |
| Berms | + | + | + | +/- | ++ | 0 | + | ? | -- |
| Gabions | - | - | - | ++ | 0 | 0 | ++ | ++ | 0 |
| Riprap | + | + | 0 | ++ | 0 | 0 | ++ | ++ | 0 |
| Geotextiles | + | + | 0 | ++ | 0 | 0 | ++ | ++ | 0 |
| Natural stabilisation materials | ++ | ++ | + | ++ | 0 | ++ | ++ | ++ | 0 |

KEY
- ++ strong known or presumed benefit
- \+ some known benefit
- +/- known benefits and disbenefits
- -- strong known or presumed disbenefit
- \- some known disbenefit
- 0 no known important effect

### 5.6.5 Identify the scope for rehabilitation and the most appropriate rehabilitation/enhancement techniques.

The final stage of planning the works that should be undertaken is to: (i) make the most of funding opportunities and (ii) most effectively integrate user needs (e.g. flood defence and conservation). Table 5.4 over page helps to clarify this by identifying the benefits of different rehabilitation and enhancement methods.

In general it is recommended that there should be a preference for adopting rehabilitation (rather than enhancement) techniques, since they are more likely to have a holistic effect (i.e. work for more than one function e.g. using bankside plants instead of direct cover structures solely for fish

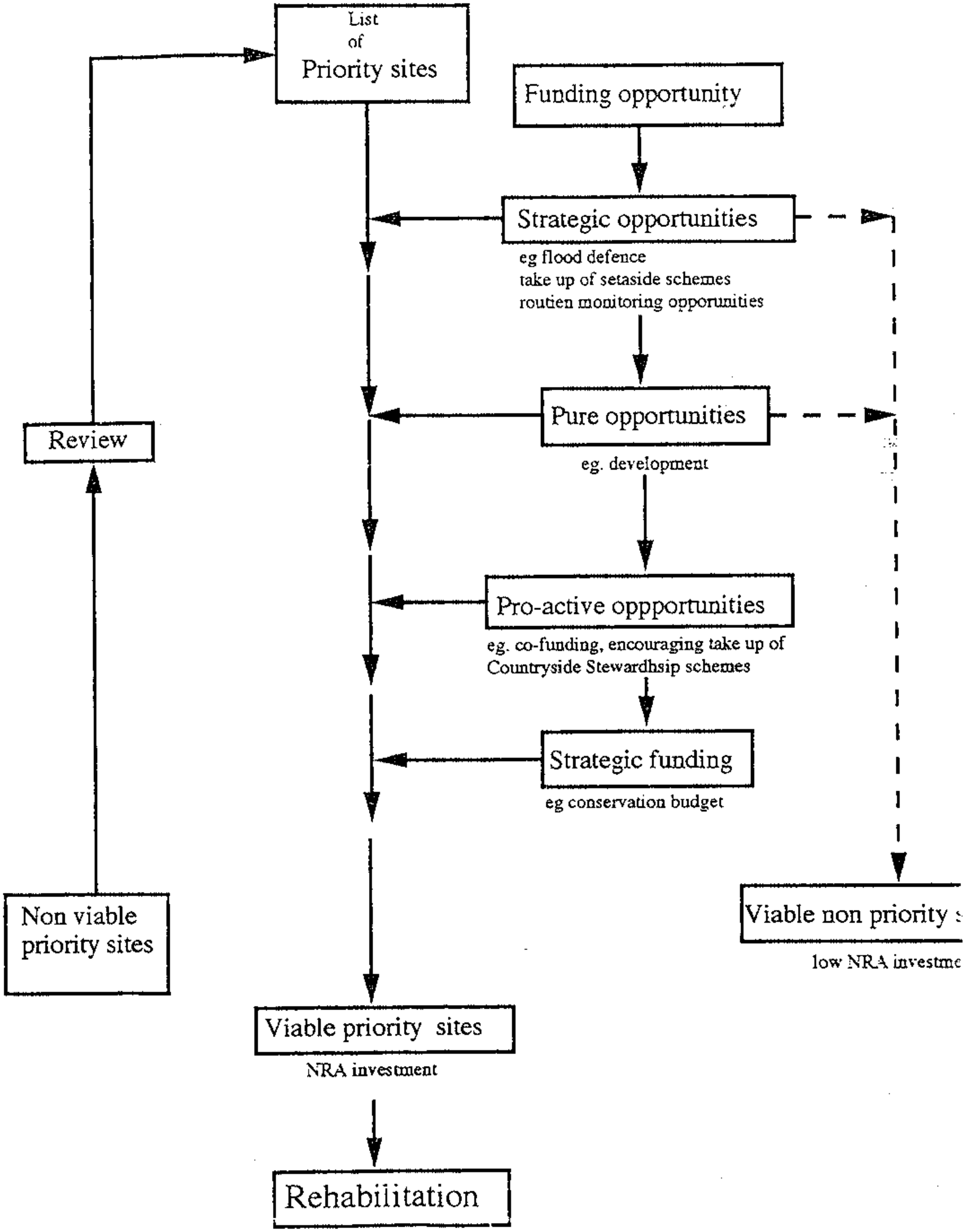
However it needs to be recognised where this is not possible (e.g. in urban sites) enhancement is often the best practical option. In many cases rehabilitation and enhancement may be integrated (e.g. flow deflectors to cause flow diversity, wetland plants to stabilise resultant sediment bars).

Finally a number of additional points are worth making:

- Once information about the rehabilitation sites has been gathered, and potential works have been identified, it is vital that a long term implementation strategy is drawn up to order and integrate the works. This is particularly important since work on the site may be long term and will inevitably often be piecemeal.

- Monitoring the effect of rehabilitation is essential to aid and increase our understanding of the costs and benefits. Detailed baseline surveys of both biological and physical parameters are therefore recommended from which the effects of the rehabilitation work can be monitored.

Figure 5.2 Opportunities for rehabilitation of priority sites.



### 5.4.3 Prioritising sites for recreation related rehabilitation

The priority sites for recreation related rehabilitation works are sites which give the greatest benefit to the greatest number of people. These may either be sites associated with the existing key sites identified above or they may be new or upgraded sites where there is the potential for high public use or benefit. As with conservation and fisheries priorities, rehabilitation associated with key sites should aim to improve and extend these areas.

Sites for recreation and navigation rehabilitation should have priority where they are:

- key sites of national or regional importance which can be improved or enhanced
- key sites of national or regional importance which can be extended.
- sites which help link together recreational areas to form 'green chains'.
- sites which have a potential for high recreation or amenity usage
- sites which take the pressure from other heavily used areas.
- sites where rehabilitation works can fulfil the objectives of more than one user group (e.g. conservation and fisheries).
- sites where financial benefits may result from rehabilitation works (i.e. increased interception of urban runoff)

## 5.5 Implementing river rehabilitation within the framework of Catchment Management Plans

The priority lists of rehabilitation sites for conservation, fisheries and recreation should all be identified in Catchment Management Plans, where these exist. If a CMP does not exist for the catchment, a priority list of sites for each river can be prepared.

A large number of sites are likely to be identified as key sites within any catchment. In order to work on priority sites, funding opportunities must be available. Funding opportunities may take a number of forms (i.e. opportunities within planned NRA works, potential co-funding with other organisations, chance offers from developer mitigations). The way in which these opportunities can be used to fund rehabilitations is summarised in Figure 5.2.

Where funding opportunities are available for priority sites, these become **viable sites** for rehabilitation. Ideally the list of viable sites should be reviewed regularly as new funding opportunities arise. All sites would potentially be valid as sites for rehabilitation, but they can be ranked according to the number of rehabilitation criteria they fulfil.

## 5.6 Deciding what to do at viable sites

### 5.6.1 Introduction

Having identified viable sites, the nature of appropriate rehabilitation works needs to be assessed. This involves:

(i) identifying the existing stresses (e.g. channelisation, regular dredging).

(ii) identifying the rehabilitation 'ideal' in the absence of constraints (e.g. full restoration).

(iii) identifying the constraints (e.g. funding, reconciling the needs of different river users).

(iv) choosing appropriate rehabilitation/enhancement techniques which most fulfil requirements (see Table 5.4).

### 5.6.2 Identifying the extent and type of existing stresses (e.g. channelisation)

All available information should be used to identify the causes of any damage or degradation within the site (e.g. historical and current land use, maintenance routine, previous capital schemes, water quality data).

This will indicate the nature of stresses on the river and the type of rehabilitation work which is likely to be needed.

### 5.6.3 Identify the 'ideal' for the site

Determine what full restoration of the site would entail (use available information from historical records, adjacent semi-natural sites etc to indicate this).

### 5.6.4 Identify the constraints on restoration or rehabilitation.

The constraints on restoration or rehabilitation may include:

- funding
- land availability,
- reconciling the needs of different river users (i.e. water supply, flood defence, recreation, conservation etc).

This may require extensive survey work (e.g. status and needs of wildlife, flood defence requirements etc).

### 5.4.2 Prioritising sites for conservation and fisheries rehabilitation

Sites should be given high priority for conservation and fisheries rehabilitation if they are:

- key sites where rehabilitation measures could protect or enhance their existing value (e.g. by creating buffer strips alongside rivers supporting rich fish or invertebrate communities; raising water levels in fens that have been damaged by deepening of river channels adjacent to them).

- areas that extend key sites (e.g. reinstatement of spawning gravels upstream and downstream of known salmonid spawning grounds).

- areas that provide greater habitat diversity adjacent to key sites (the building block approach, where the value of the whole is greater than the sum of the parts).

- areas that link two or more key sites to maximise the function of the riverine environment as a corridor (e.g. buffer zones).

- key sites (rivers or reaches) where there is scope to reinstate floodplain areas.

- key sites where it is possible to reinstate natural flow and flooding regimes.

In addition sites should be prioritised for rehabilitation if there are:

- opportunities to control water quality or land-use upstream of key sites, since rehabilitation works can easily be damaged by changes in the catchment, riparian zones or floodplain upstream (NRC, 1992).

- potential benefits for more than one user-group (e.g. conservation and/or fisheries and/or amenity), assuming that key sites will not be damaged by additional uses.

- potential financial benefits associated with the rehabilitation of key sites (e.g. increased stormwater interception from the creation of riparian zones).

## 5.4 A strategy for prioritising sites (rivers or reaches) for rehabilitation

In the previous section a simple, practical method for assessing the existing status of the river reaches in a catchment was outlined. The method allows all river reaches, for which standard CMP data is available, to be ranked in terms of the importance of their conservation, fisheries or recreation resources. The highest ranking sites are the **key sites** for conservation, fisheries and recreation re in each catchment. Key sites may be individual reaches (e.g. a length of river with adjacent fen habitat) or whole rivers (e.g. rivers which support plant community types uncommon in that region).

This section describes how the key sites are used to provide the focus for prioritising reaches and rivers where rehabilitation is likely to be most beneficial (see aims stated in Section 5.2). Ideally sites should be prioritised at catchment levels, making rehabilitation an integral part of the CMP. However, for catchments without CMPs the reaches of individual rivers can be prioritised in the same way.

Criteria for prioritising sites are outlined below. The approach to selecting sites for conservation or fisheries rehabilitation is broadly similar and the suggested criteria for prioritising sites are considered together. The criteria for prioritising rehabilitation sites for recreation are described in section 5.4.2.

### 5.4.1 Criteria used to prioritise sites for conservation and fisheries rehabilitation

The prioritisation of rivers or reaches for rehabilitation involves focusing on the **key sites** in each catchment (or river). The general aim of rehabilitation for conservation and fisheries should be protect and enhance the communities and functions that already exist at the key sites and create conditions which enable these communities and functions to extend outwards from the key sites. For species which are poor or slow colonists this increases the chances that they will extend their range. This approach is also likely to increase the chances of successfully reinstating river functions (e.g. floodplain-channel sediment interactions), many of which are physically, chemically and biologically complex.

If there are no key reaches within a catchment (or on a river) there is a choice either to (i) work in an alternative catchment or (ii) select the next-highest ranked reach/site. The former would be a more strategic choice but the latter is the best option if funds/opportunities are available only for work in that catchment/river.

| Table 5.3. Assessment of the recreational status of river reaches | Score |
|---|---|
| Criteria for recreation must include sites that have current and potential value.<br><br>Nationally important recreation resources<br><br>At a nationally important scale both landscape and recreational criteria are important:<br><br>**Scenic rivers in major tourist centres**<br>(eg Wye, National Park rivers) which must not be allowed to degrade through over-use, although rehabilitation works may improve recreational use.<br><br>**Nationally important informal recreation sites**<br>(eg Thames footpath).<br><br>**Nationally important formal recreation centres**<br>(eg National Canoeing Centre). | **10** |
| Regionally importanbt recreation resources<br><br>**Areas of maximum visitor usage alongside rivers; areas recognised in regional recreation strategies**<br>which may include both urban, suburban and more rural sites.<br><br>**Areas which make an important contribution to formal and informal recreation,**<br>particularly rivers which act as 'green chains'<br><br>**Areas of maximum landscape appeal**<br>(eg the open pollard willow landscapes of the Thames Valley; the wooded valleys of streams flowing off Dartmoor) | **5** |
| Locally important recreational resources<br><br>At first sight, the attributes associated with biodiversity (see Table 5.1) may seem of little relevance to rivers which may be selected on the basis of human usage and may include degraded urban areas. However, people do prefer reasonable water quality and more natural landscapes (House & Sangster, 1990; Green & Tunstall, 1992). In addition, much recreational use of riverine environments is based on interest in wildlife. Therefore, it is suggested that the environmental criteria used above for conservation (5.2.1) and fisheries (5.2.2) should also be used as criteria for recreational and amenity value. This will aid the separation of areas in which rehabilitation is more praticable and cost-effective (see below). | **Up to 2** |

| Table 5.2 Assessment of the fisheries status of river reaches | Score |
|---|---|
| In contrast to the conservation priorities, where river type is used as a rough guide to the species present, fisheries sites can be prioritised directly on the abundance and diversity of fish. It is possible that in the near future, priority could also be given on the basis of the genetic qualities of populations (e.g. for races of brown trout).<br><br>__Nationally important fisheries resources__<br><br>At a national scale, rehabilitation priorities should focus on rivers supporting oustanding fish communities and/or populations.<br><br>**High diversity fish communities**<br>(e.g. Hampshire Avon, 33spp., Great Ouse, 30spp., Severn, 39spp., River Thames, 35 spp. (after Maitland and Campbell, 1992))<br><br>**Populations of rare species**<br>(e.g. shad, smelt), including species which are probably recently extinct (eg burbot) where reintroduction may be possible<br><br>**Nationally important recreational fisheries**<br>(e.g. Trent, Thames) | **10** |
| __Regionally important fisheries resources__<br><br>Within individual NRA Regions, the prioritisation of fish populations would be made on the basis of diversity and biomass of fish populations. Priority populations would include:<br><br>**The most diverse fish populations regionally**<br>(other than those selected on national criteria), often composed of mixtures of cyprinids, percids, salmonids and others (pike, eel, loaches) in various combinations.<br><br>**High salmonid biomass**<br>(the EC 15/m² limit could be used)<br><br>**High cyprinid biomass**<br>(the EC 20g/m² limit could be used)<br>The latter are likely to include the important recognised recreational fisheries so it is not necessary to include a further criterion specifically for this aim | **5** |
| __Locally important fisheries resources__<br><br>The attributes associated with biodiversity see Table 5.1 are also appropriate for fisheries. | **Up to 2** |

| Table 5.1 Assessment of the conservation status of river reaches | Score |
|---|---|
| <u>Nationally important conservation resources</u><br><br>Nationally important conservation resources are nationally uncommon river types and associated habitats (uncommon either because they have declined in area/extent or because they are intrinsically rare). Three types are identified:<br><br>**River dependent floodplain habitats (including fen, wet grassland, bog, floodplain ponds).**<br>These are uncommon and threatened in England and Wales and on an international scale. Internationally include river types which are intrinsically rare (eg large rivers; unusual river types) or (eg most floodplain wetland habitats).<br><br>**4th and 5th order rivers**<br>There are only 25 4th and 5th order river systems in Britain. They provide a refuge for species and habitats that are inherently uncommon.<br><br>**River types with a restricted national distribution**<br>as classified by the NCC e.g. Type VIII rivers in the lowlands | **10** |
| <u>Regionally important conservation resources</u><br>At a regional scale the NCC river types (Types I-X) (NCC, 1989) should be used as the basis for assessment.<br><br>**Least damaged examples of each NCC river type in the region.**<br>The least damaged example of each river type will probably make the largest contribution to biodiversity.<br><br>**River community types which are uncommon in that region.** | **5** |
| <u>Locally important conservation resources</u><br>Locally important conservation resources are defined in terms of attributes of the river environment which are known to be positively associated with biodiversity.<br><br>**Water quality**<br>Rivers with good water quality usually support plant or animal communities of higher conservation value than polluted rivers.<br><br>**Richness of the invertebrate community** (as measured using standard **BMWP/ASPT or RIVPACS data)**<br>Family level invertebrate richness is usually correlated with species richness.<br><br>**Adequate water quantity**<br>Rivers with adequate flows are more likely to supoort valuable plant and animal communities that rivers impacted by low flows.<br><br>**Diversity of physical features** (**as indicated by the level of service for flood defence**)<br>Reaches with a low level of service for flood defence (ie relatively litle engineered) are likely to be of relatively high nature conservation value. | **Up to 2** |

The conservation, fisheries and recreation resources are each considered separately in Tables 5.1 to 5.3. In order to prioritise sites for rehabilitation works it is necessary to rank reaches within each catchment. To do this the national, regional and local resources are each given a score, with the highest scores given to nationally important resources (eg nationally uncommon habitat types). This ensures that assessments of status reflect national and regional goals, as well as those relating specifically to the catchment. The following scoring system is suggested:

- reach supports any nationally important resource: score 10 for each
- reach supports any regionally important resoource: score 5 for each
- reach supports any locally important resource: score 2 for very good and 1 for good

For each use a total score for the reach is calculated by adding all the scores of the resources occurring in that reach. Scores for each reach can be used as they are, or grouped into classes. Results will probably be mapped in CMPs to show the current (and future) status.

The process results in the production of three maps, (one each for conservation, fisheries and recreation) showing existing reaches of high and low value (or in the case of amenity, high potential interest). The maps would also show how areas of river and floodplain habitat interrelate.

## 5.3 Assessing the current status of rivers: the quality of conservation, fisheries and recreation resources

### 5.3.1 Introduction

The first stage in identifying sites for rehabilitation is to assess the current status of rivers in terms of their existing conservation, fisheries and recreation resources. The aim of assessment is to identify the sites where rehabilitation work would be most likely to fulfil the objectives described above (Section 5.2 ). As will be clear from the statement of objectives these are not likely to be the most degraded sites. In fact, rehabilitation work should generally build out from areas where valuable resources (habitats, fish populations, facilities) already exist.

This section proposes one approach to assessment. It should be noted that, although the principle is sound (ie site selection on the basis of biodiversity and human use/appreciation), the assessment method is provisional and would require a full-scale trial before implementation in CMPs.

### 5.3.2 Assessing the status of river resources

The assessment method proposed uses standard information which is usually included in CMPs (or is readily available within NRA departments) and other information where this is available. Generally it would not require new informationto be gathered about the catchment or the individual reaches.

Standard information used in CMPs includes:

- water quality surveys
- invertebrate surveys
- levels of service for flood defence purposes
- fisheries surveys
- information on recreational sites

Other less widely available information:

- river corridor surveys
- plant classifications
- otter surveys
- public perception surveys

The value and status of the river resource is assessed for each individual river **reach** in terms of nationally, regionally or locally important resources. For conservation, fisheries and recreation these resources are, respectively, habitats and general environmental quality, fish populations and recreational facilities.

### 5.2.2 Objectives of rehabilitation for fisheries

The main aim of river rehabilitation for fisheries is to increase fish species numbers or biomass and to improve population age structure. Three general principles which govern rehabilitation for fisheries can be identified:

- Fish are generally at the top of the food chain in riverine ecosystems and, because of this, generally reflect the quality of the environment on which they depend (physical, chemical and biological features). Consequently high quality, biologically diverse, rivers ususally support high quality fisheries.

- Rehabilitation measures which benefit plant and invertebrate communities (whether designed to protect vulnerable species or increase species numbers/biomass) are likely to benefit fish.

- Rehabilitation for fisheries should focus on extending the range of high quality areas. Investment in physical rehabilitation at sites experiencing water quality or quantity problems may lead to money being wasted in creating low quality fisheries.

### 5.2.3 The objectives of rehabilitation for recreation

The main aim of rehabilitation for recreation is to improve the quality of river related recreation for the largest number of people. Rehabilitation may be intended to improve either the actual or potential value of sites.

Four general principles may help to guide rehabilitation work for recreation:

- Rehabilitation may be appropriate at sites/rivers that vary widely in quality. Rehabilitation works will, therefore, be appropriate in disturbed urban landscapes where sites are used mainly by local residents (eg in urban and suburban parks) as well as in more natural river environments with higher quality landscapes.

- Rehabilitation should usually aim to upgrade and extend the sites which have the greatest current or potential value for recreation and amenity.

- Rehabilitation should ideally include a balance of both urban and rural sites.

- Most existing evidence suggests that the river rehabilitation techniques which are most generally desired/popular are those which promote natural beauty and a diversity of natural habitats, rich in wildlife (see Chapter 4). However complete naturalness/wildness is likely to be more desirable in rural rather than urban settings

## 5.2 The objectives of river rehabilitation

This section describes the main objectives of rehabilitation work undertaken for conservation, fisheries c recreation.

### 5.2.1 Objectives of rehabilitation for conservation

It is widely accepted that the basic aim of conservation is to maintain biodiversity. This involves protectin both species diversity and genetic diversity (eg trout sub-populations). At a national level therefore, th ultimate aim of river rehabilitation for nature conservation is to protect and increase **biodiversity** in riverin ecosystems. This includes not only the wildlife of river channels but also species associated with floodplai and riparian zone habitats.

There are four general principles which are likely to govern rehabilitation for conservation:

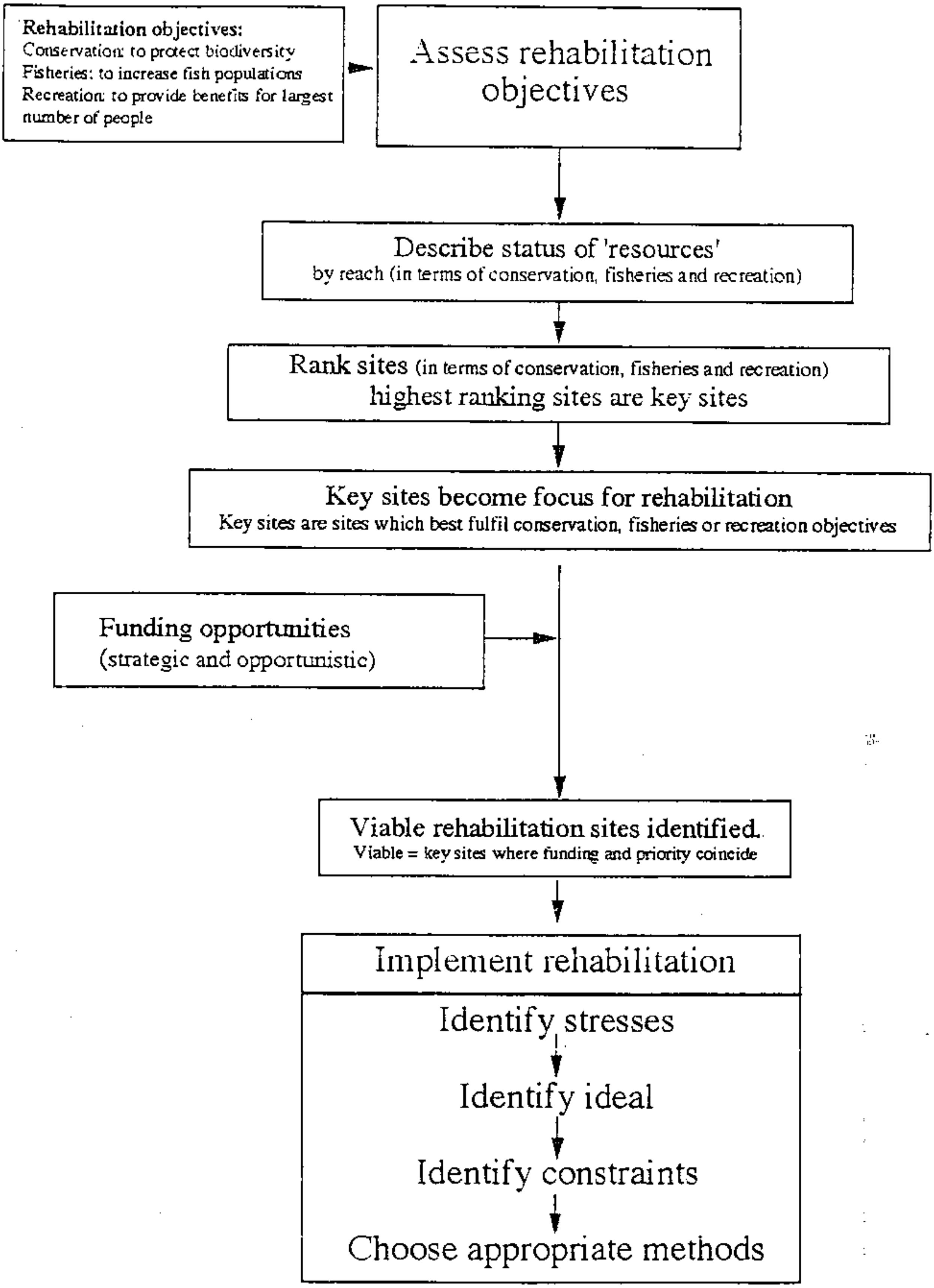
- The main aim of rehabilitation for conservation will generally be 'preservation of biodiversit through preservation and restoration of critical aquatic habitats' (NRC, 1992).

- Prioritisation on the basis of biodiversity should focus on protection and rehabilitation of: (i) a rang of river types (including a range of floodplain habitats eg fen, alder woodland) (ii) a good geographica spread of sites. The CMP format is ideal in this respect since it automatically prioritises a variety o sites in each catchment.

- Rehabilitation at a regional level should ensure particular protection and rehabilitation of nationall threatened and uncommon habitat types (eg portions of large rivers, fens and floodplain grasslands) (NRC 1992). Thus it should recognise and prioritise rehabilitation of sites of national interest where they occur as well as sites of regional and local interest.

- In general the approach will be to capitalise upon, and build-out from, the most important sites which make the greatest contribution to biodiversity. Areas of current (and predicted) low water quality should not be prioritised. To quote Kern (1992), who is one of the most experienced rehabilitation practitioners in Europe: 'the structural rehabilitation of "most polluted" rivers and streams is a waste of tax-payers' money'.

Figure 5.1 Selecting sites for rehabilitation



# 5. CRITERIA AND PROCEDURES FOR SELECTING SITES FOR REHABILITATION IN TERMS OF CONSERVATION FISHERIES AND RECREATION

## 5.1 Introduction

This chapter outlines criteria and procedures for selecting sites for rehabilitation. The selection of sites is made at the catchment level (allowing rehabilitation to be implimented within Catchment Management Plans) but it also considers wider (ie regional and national) objectives.

Suggestions are made about ways in which existing opportunities for rehabilitation can be directed towards achieving strategic regional and national goals within NRA functions. The opportunites available for rehabilitation work are discussed further in Chapter 6.

### 5.1.1 Undertaking rehabilitation within the CMP framework

Undertaking river rehabilitation as part of the the integrated catchment management process has two main advantages:

(i) much of the data needed to help in the selection of rehabilitation sites is already (or will be) collected for Catchment Management Plans (CMPs).

(ii) catchment planning provides a good framework for planning river rehabilitation since its main objectives are 'to conserve, enhance, and where appropriate, restore the total river environment through effective land and resource planning across the total catchment area' (Gardner and Cole, 1982).

The criteria and procedures for rehabilitation suggested here also follows the CMP format (see Draft Catchment Management Plan Guidelines (NRA, 1993)). This should enable river rehabilitation planning to fit readily into CMPs. In the following sections rehabilitation is, therefore, considered in the following terms:

- The environmental objectives for different river uses (ie conservation, fisheries and recreation ).
- The current status of these uses.
- The options for action.

The stages in the planning and implementation of river rehabilitation works are summarised in Figure 5.1.

| Table 4.6 | Physical rehabilitation features and their effect on pollutants |
|---|---|
| Oxygen | $O_2$ levels increased by water turbulence at riffles.<br>Stable channel morphology and buffer strips reduces sediment erosion/deposition and $O_2$ demand from associated organics.<br>Oganics deposited and stored on the floodplain as a result of flooding.<br>Oxidation of organics in floodplain soils and at channel margins. |
| Nitrate and Phosphate | Intercepted in buffer zones.<br>Stable channel morphology reduces sediment erosion/deposition.<br>Deposited on the floodplain during flooding.<br>Long-term storage in floodplain biomass eg woodland.<br>Permanent removal from the floodplain by cutting or grazing.<br>Denitrification of nitrate in organic soils (see text).<br>Phosphate is bound into wetland soils by marshland plants. |
| Biocides | Spray drift interception by buffer zones.<br>Storage of persistent biocides in buffer zones or floodplain. may be stored or buried.<br>Degradation of biodegradable biocides in buffer zone or riparian soils.<br>Deposited on the floodplain during flood events |
| Heavy metals | Interception and storage in buffer zones.<br>Complexed in organic soils.<br>Deposited on the floodplain and may be stored or buried.<br>May be accumulated by plants and removed by cutting or grazing. |

### Breakdown of biodegradable pollutants eg denitrification, oxidation

One of the benefits of natural floodplain features is that they often facilitate and enhance the degradation of pollutants by natural means. This is particularly valuable for nitrate which may be degraded to gaseous nitrogen and oxygen (by the process of denitrification) and released to the atmosphere.

Denitrification is particularly effective in wet organic rich soils with abundant vegetation, which are typical of many of the desirable features reinstated during rehabilitation such as:

- marsh and fen areas
- wet alder woodland (Pinay & Decamps, 1988)
- permanent or infilled ponds on the floodplain

In addition, natural channel features such as meanders, riffles and pools, debris dams and others help slow water-flow and increase water contact with edge habitats rich in marginal vegetation and organic matter.

Natural degradation of other pollutants eg organics is summarised in Table 4.6