Heavily Modified Waters in Europe

Case Study on the River Kennet

(Case Study submitted by the Environment Agency of England & Wales and the UK Government Department for Food, Environment and Rural Affairs)

Edited by Michael Dunbar (CEH Wallingford)

Authors:
Douglas Booker, Michael Dunbar, Sonja Folwell, Charlie Stratford (CEH Wallingford)
Peter Latimer, Helen Rogerson (JBA Consulting Engineers and Scientists)
Jonathon Bass, Hugh Dawson, Rodolphe Gozlan, Stewart Welton (CEH Dorset)
John Ash, Teresa Fenn, Meg Postle (Risk & Policy Analysts)

Centre for Ecology and Hydrology
Wallingford
Oxon
OX10 8BB
Tel: +44 1491 838800
Fax: +44 1491 692424

JBA Consulting – Engineers & Scientists
South Barn
Broughton Hall
Skipton
North Yorkshire
BD23 3AE
Tel: +44 1756 799919

Centre for Ecology and Hydrology
Winfrith Technology Centre
Dorchester
Dorset
DT2 8ZD
Tel: +44 1305 213500

Risk & Policy Analysts
Farthing Green House
Beccles Road
Loddon
Norfolk
NR14 6LT
Tel: +44 1508 528465

Table of Contents

List of Tables, Boxes, Maps etc.

PART I

1 Preface

On 22nd December 2000, the Water Framework Directive (WFD) came into force. The WFD is a major legislative initiative, which is intended to resolve the piecemeal approach to European water legislation, which has developed since 1975. The overriding goal of the Directive is that Member States should aim to achieve at least "Good Ecological Status" (GES) in all bodies of surface water and groundwater, and also to prevent deterioration in the status of those water bodies.

There will be limited exceptions to achieving good status. In particular, certain bodies of water will be required to achieve an alternate objective of at least "Good Ecological Potential" (GEP). This objective takes account of the constraints imposed by the use-value of modifications to the physical structure of the water body and is equivalent to achieving good ecological status in unmodified water bodies. Such designation will either be as “Artificial” or “Heavily Modified” as appropriate, and will depend on whether it satisfies the designation tests outlined in section 4.3 of the WFD.

Under the agreed common strategy for implementation of the Directive, several working groups have been established to “develop informal guiding and supporting documents on key aspects of the WFD”. There will be at least 10 working groups, Project 2.2. is the working group to develop guidance on the designation of Heavily Modified Water Bodies (HMWBs).

The EU Project 2.2 will co-ordinate *Case Studies* in a number of member states for the identification and designation of Heavily Modified Waters and the identification of good ecological potential under the proposed requirements of the Water Framework Directive (Article 4(3)). The EU project will produce a synthesis of experience from member state case studies and will identify best practice, consensus or differences in approach taken by member states in the case studies. The case studies chosen from all member states include riverine and estuarine/coastal areas and represent a range of modifications (navigation, flood defence, coastal defence, hydropower, agriculture/forestry, water supply, urbanisation etc) and size of catchment area (small-large).

The output from the EU project (with special reference to the UK case-studies) will be used to help develop technical guidance for the identification and designation of heavily modified water bodies in the UK.

This project represents the England & Wales contribution to the EU HMWB project. The project is sponsored by the Environment Agency of England and Wales (Water Framework Directive Group based in Wallingford, Oxfordshire) and the UK Department of the Environment, Food and Rural Affairs (DEFRA). DEFRA is responsible for transposing the Directive in England, while the Environment Agency is the likely competent authority for implementing the Directive in England and Wales.

Existing available information is being compiled and interpreted in order to produce case-study documents for each chosen case study catchment according to a pre-defined format. When this stage is complete, an England & Wales synthesis report will be produced.

2 Summary Table (2 pages)

	Item	Unit	Information
1.	Country	text	UK (England & Wales)
2.	Name of the case study (name of water body)	text	River Kennet (major tributary of the River Thames)
3.	Steering Committee member(s) responsible for the case study	text	David Forrow
4.	Institution funding the case study	text	Environment Agency for England & Wales Department for Environment, Food and Rural Affairs (DEFRA)
5.	Case-studies project manager	text	Marc Naura, Environment Agency of England & Wales
6.	Institution carrying out the case study	text	Centre for Ecology & Hydrology, Wallingford; CEH (with CEH, Dorset; Risk & Policy Analysts RPA; Jeremy Benn Associates JBA. Contractor Project Manager: Mike Dunbar (CEH, Wallingford)
7.	Start of the work on the case study	Date	June 2001
8.	Description of pressures & impacts expected by	Date	September 2001
9.	Estimated date for final results	Date	February 2002
10.	Type of Water (river, lake, AWB, freshwater)	text	River / Artificial water body
11.	Catchment area	km^2	1,164 km^2
12.	Length/Size	km/ km^2	Kennet = approx. 70 km (main channel only - does not include tributaries)
13.	Mean discharge/volume	m^3/s or m^3	Kennet at Marlborough. Mean=0.810 m^3/s (period 1972 to 1997). Kennet at Knighton. Mean = 2.44 m^3/s (period 1963 to 1997). Kennet at Newbury. Mean = 3.022 m^3/s (period 1989 to 1997 with some missing data). Kennet at Theale. Mean = 9.46 m^3/s (period 1961 to 1997).
14.	Population in catchment	number	211,000
15.	Population density	Inh./km^2	181.3 inh./km^2
16.	Modifications: Physical Pressures / Agricultural influences	text	**Pressures:** Navigation (canal runs alongside river downstream of Hungerford, some stretches are concurrent, water transfers between river and canal) Flood defence Limited urbanisation (main towns of Reading, Marlborough, Newbury and Hungerford), rainfall/flow fluctuations (climate change?). Water supply (fish farming, growing population) Agriculture (approx 80% of catchment, of which 60% is arable (predominantly cereal) or set-aside) Groundwater abstraction **Modifications:** Presence of many in-channel structures for navigation / fishery management leading to over-deep and low velocity Considerable resources already being spent on restoring salmon passage past structures. Historical channelisation (re-grading, resectioning) of river, leading to sections of over-wide or over-narrow channel Groundwater abstraction leading to reduced flows. Fish farming, leading to altered water quality and reduced flows in bypassed sections Free-range pig farms are thought to be a growing source of diffuse pollution within the catchment.
17.	Impacts?	text	Elevated nutrient levels from point and non-point sources Highly fluctuating levels of *Ranunculus* growth in non-channelised sections, leading to reduced habitat diversity with a consequent impact

			on invertebrate populations. Silting-up of spawning gravels, likely arising from combination of in-channel management, increased sediment load and low flows at critical times of year Low flows in the K&A Canal results in high phytoplankton densities (spring diatom blooms ~300 ug/l chl-a) which overflow into the River Dun via sluices and which are discharged directly into the Kennet. A completely different habitat exists along channelised sections of the canal compared to the more natural reaches Management practices of private fish farms (e.g. weed cutting, fish re-stoking).
18.	Problems?	text	Channelisation - habitat destruction and reduction in biodiversity, eutrophication, over-abstraction and low-flows (depending on rainfall), fish mortality thought to be due to production of a microbial toxin within the K&A canal.
	Environmental Pressures?	text	Climate change; future residential construction; commercial and business development - increased urban surface water runoff; water abstraction and water supply; waste disposal; recreation-navigation, illegal practices/accidental pollution.
	What actions/alterations are planned?	text	Gradual changes. Recent habitat restoration work includes: • reedbed restoration (Thatcham Reedbeds); • narrowing of the River Lambourn; • creation of a backwater fry refuge site on the Kennet at Brampton; • narrowing and removal of impoundment on the River Dun at Froxfield; • fencing 2 km of poached riverbank along the river Og north of Marlborough; • gravel cleaning and use of deep incubation boxes for trout ova on the R. Dun; • re-establishing the former pathway of the River Shalbourne so that it underpasses the Kennet and Avon Canal and connects directly to the River Dun. This latter arrangement improves water level management at Freemans Marsh SSSI - designated because of its terrestrial, rather than its aquatic features. The Kennet catchment is itself a sub-catchment of the River Themes, designated as a Sensitive Area under the UWWTD. As such, P-stripping has been introduced at Marlborough and Reading STWs, and it is planned to install it at Newbury. Improvements to a total of 12 STWs in the catchment have been proposed under Water Company Asset Management Plans 3 (AMP3). This work will be undertaken between 2000 and 2005. By-pass weirs will shortly be installed at all lochs on the Kennet and Avon Canal between its feeder Reservoir, Wilton Water, and its confluence with the River Kennet. Further work may be undertaken to separate the exchange of water between the River Dun and the Kennet & Avon Canal. A recreation manager has recently been appointed in Thames Region, part of whose job is to investigate options for funding and managing navigation. This is likely to result in a more holistic approach to navigation, involving a cost-benefit analyses and the development of alternative scenarios. Recent flooding in the UK has highlighted the importance of upper catchment wetlands in controlling the delivery of water downstream, so protection of wetlands such as those associated with the Kennet is likely to be given a higher priority
19.	Additional Information	text	The Kennet has been selected for Thames Region's first Catchment Abstraction Management Strategy (CAMS) and has also been selected for one of the first Agency-promoted Nutrient Management Action Plans (the only one in Thames Region). Recommendations for further work are likely to made as a result of these initiatives. A study also planned for next year to investigate the effect of navigation on turbidity levels in the canal/river. There are many sites of cultural and historical importance along the

			Kennet. Some, such as mills have a physical impact on the river
20.	What information / data is available?	text	River flow, river water chemistry, groundwater chemistry, macroinvertebrate surveys, river corridor surveys (1993-95), mean trophic rank (macrophyte) surveys and trophic diatom index surveys at selected sites. Fisheries surveys for much of the Kennet and its tributaries. River Habitat surveys at selected sites and some ecological monitoring of wetlands for input to water level management plans. Extensive geomorphological and flood defence data in GIS format.
21.	What type of sub-group would you find helpful?	text	Navigation/ mixed The Kennet and its tributaries contain some of the finest chalk river habitats, features and ecology in the UK. However, the presence of the Kennet and Avon Canal, albeit a canal of high water quality, is likely to have a deleterious effect on the Kennet. It would be useful for chalk rivers (or possibly rivers fed predominantly by groundwater) to be considered separately from those fed predominantly by overland flow. It may help to classify rivers impacted by canals separately from rivers impacted by other 'point sources'.
22.	Additional Comments	text	The catchment contains nationally important wildlife sites and habitat types. There are two river SSSIs within the catchment - the River Lambourn and the River Kennet itself between Marlborough and Woolhampton, designated because of their outstanding chalk river plant and animal communities. The Lambourn has also been notified as a cSAC, in addition to the Kennet and Lambourn Floodplain (internationally important populations of Desmoulin's Whorl snail) and Pewsey Downs. Other nationally important sites include areas of reedbed, fen, chalk grassland and ancient woodland. In contrast, channelised reaches of the river are ecologically impoverished.

3 Introduction

3.1 Choice of Case Study

The River Kennet represents a river that has many pressures from human activity. These include navigation, flood defence, groundwater abstraction, fisheries (commercial and recreational), and some urbanisation. It also receives effluent from sewage treatment works, and its catchment, especially the floodplain area are high quality agricultural land.

Despite these pressures ecological the ecological status of the river is generally considered to be good. The Kennet is primarily a groundwater-fed river, so it has a stable flow regime with high levels of base flow. It is also a good example of a waterbody with a relatively extensive data sources. There is a great deal of information available including regular biomonitoring, a flood defence GIS, a geomorphological inventory, fish population data and various scientific studies relating to the ecological effects of groundwater abstraction in the catchment. Surprisingly, the number of River Habitat Surveys (RHS) is relatively low.

3.2 General Remarks

The River Kennet is the largest tributary of the Thames in south-central England (Figure 1). It rises to the north west of the town of Marlborough and flows eastwards to its confluence with the Thames at Reading, some 70km east of its source. It passes through the towns of Marlborough, Hungerford, Newbury and Thatcham. The Kennet Valley catchment area is 1164km², consisting of 315km of Main River[1]. The Kennet and Avon canal runs parallel with the River Kennet downstream of Hungerford, at times sharing the same channel. Defined by the Berkshire and Marlborough Downs to the north and the Hampshire Downs to the south, the area is predominantly rural in character.

[1] "Main River" indicates river channel that the Environment Agency has permissive powers for undertaking flood defence works. The Environment Agency has fewer powers on "Ordinary Watercourses".

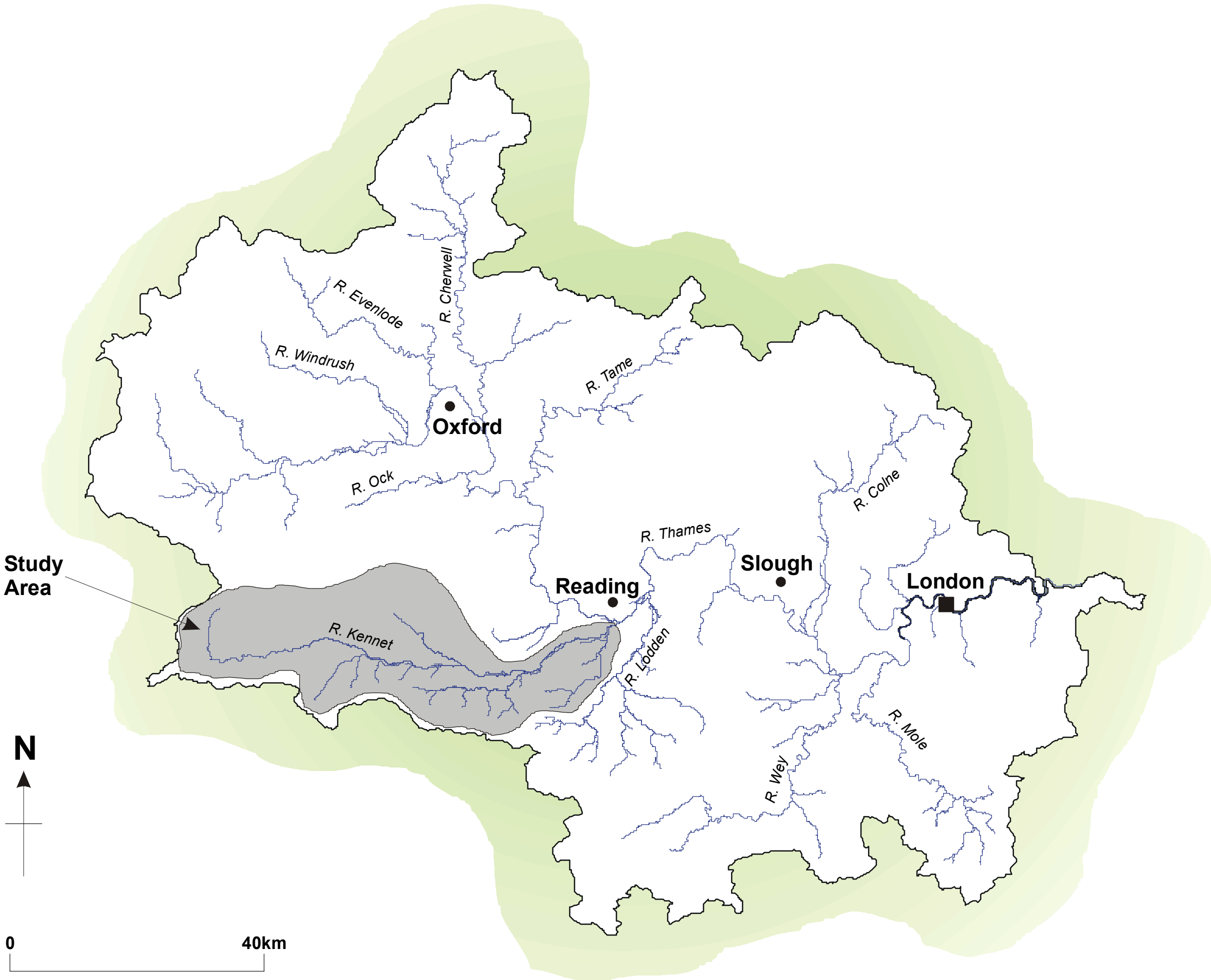


Figure 1. The Kennet and Thames catchments

4 Description of Case Study Area

4.1 Geology, Topography and Hydrology

The Kennet Valley's solid geology is comprised of chalk which is overlain in the east by the clay sands of the western end of the London Basin syncline. The Lower chalk outcrops along the northern boundary of the catchment with progressively younger rocks to the south east. These include the Middle and Upper chalk and above those the tertiary Clays and sands of the Reading beds, London clay and Bagshot beds. The gravel deposits in the Lower River Kennet and on the Tertiary strata outcrops are an important mineral resource whose use is of significance to the water environment.

Aside from the upper Kennet (the main river upstream of Hungerford), the river has seven tributaries, the Lambourn, Enbourne, Foudry Brook, River Dunn, Aldbourne, Shalbourne and the River Og (Figure 2). The Kennet catchment has a maximum altitude of 297mAOD[2], the river itself flows from an altitude of 190mAOD at its source to 50mAOD at its confluence with the Thames.

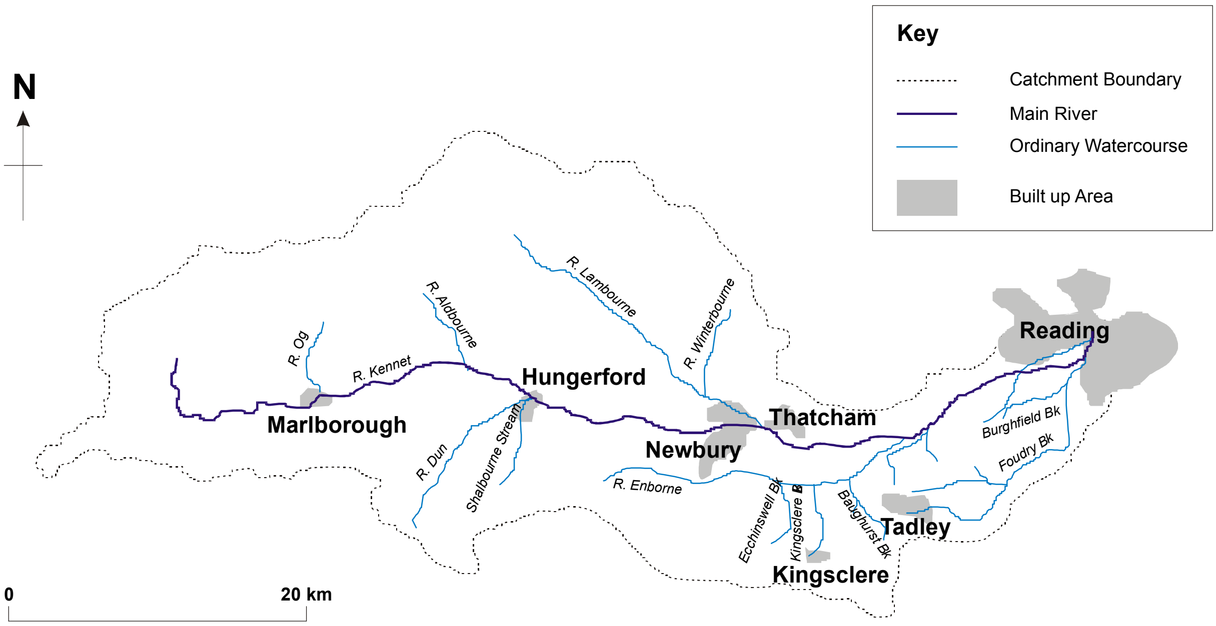


Figure 2. The Kennet Catchment

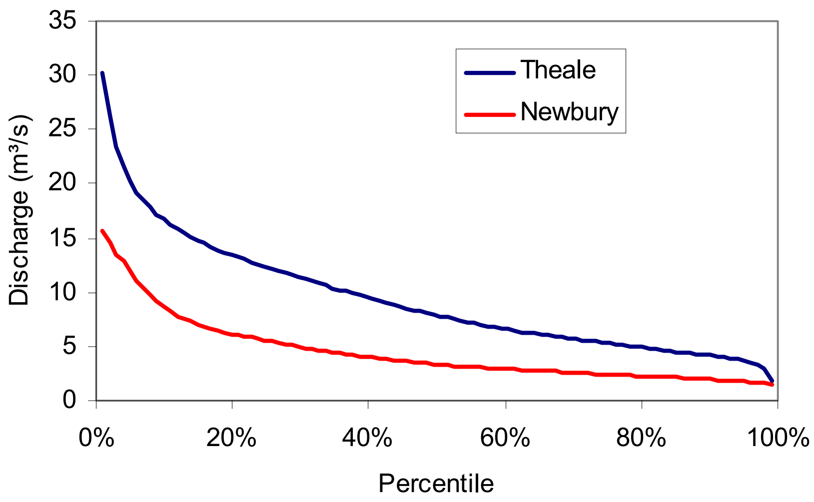
The Kennet catchment receives a Standard Average Annual Rainfall (SAAR) of 764mm, although spatial variation in topography and climate cause rainfall totals to range from 900mm on the Hampshire Downs to 650mm at Reading[3]. The hydrological regime of the catchment is typical of a Southern English Chalk stream. A permeable geology creates a flow regime that reacts relatively slowly to rainfall events with variations in flow occurring at a seasonal temporal scale. Peak flow occurs between January and March with a steady decline in discharge throughout the year until October.

[2] Above Ordnance Datum
[3] Howarth, S.M., Whitehead, P.G. and Mumford, C.P. 1996. Hydrological variability in the Upper Kennet catchment: patterns in rainfall, runoff and streamflow. Report by Aquatic Environments Research Centre, University of Reading, to Thames Water Utilities Ltd.

This steady flow regime causes there to be less difference between extreme high flow and extreme low flow events in comparison to other catchments of a similar size. When extreme events do occur they can be prolonged in nature. For example, at Theale the mean flow of the River Kennet was $9.6m^3s^{-1}$ for the period 1961-1995 with the 10 and 95 percentiles being 16.8 and $3.8m^3s^{-1}$ respectively. The high flows in winter 2000/2001 and the summer drought of 1976 are examples of exceptionally extreme events. Flow statistics are illustrated in Table 1 and Figure 3. The tributaries of the Og, Aldbourne, Dun, Lambourne and Enbourne are also gauged.

Table 1. Gauges on the main Kennet

Gauge	Catchment Area (km²)	Record	Mean Flow (m³/s)	Mean Annual Flood (m³/s)	Base Flow Index (m³/s)	Q10 (m³/s)	Q95 (m³/s)
Marlborough	142	1972-	0.85	3.2	.95	2.0	0.08
Knighton	295	1962-	2.50		.95	5.2	0.60
Newbury	548	1989-	4.64		0.92	9.5	1.82
Theale	1033	1961-	9.64	37.3	.87	16.8	3.84



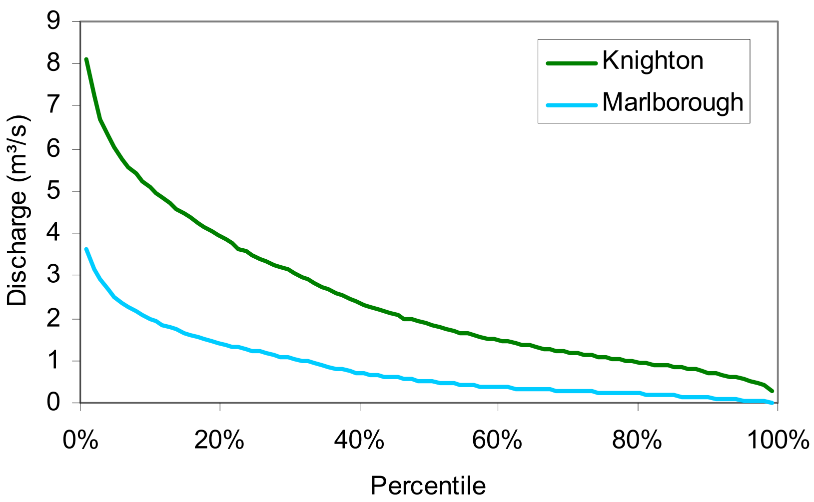


Figure 3. Flow duration curves for gauges on the main Kennet

4.2 Socio-Economic Geography and Human Activities in the Catchment

Around 211,000[4] people live within the Kennet Valley catchment with the population concentrated mainly in the larger towns of Reading, Newbury/Thatcham and Marlborough. The Kennet Valley has seen significant change over the last 45 years with many large housing developments in Newbury, Thatcham and Reading, There has also been construction of the M4 motorway and Newbury by-pass and extensive mineral extraction between Newbury and Reading. This area has also seen the growth of numerous business and retail schemes, for example the Reading and Theale business parks and the Oracle shopping centre. There will continue to be pressure for development in the east of the area, particularly to accommodate additional housing.

The Kennet valley contains nationally important wildlife sites and habitat types. There are 55 Sites of Special Scientific Interest (SSSIs) designated by English Nature within the Kennet catchment. These have been notified in recognition of their outstanding chalk river plant and animal communities. In addition there also 300 Wildlife Heritage Sites as designated by Berkshire County Council, several Areas of High Ecological value designated by Wiltshire County Council and a number of Countryside Heritage Site selected by Hampshire County Council. Of particular note is that English Nature has designated the River Kennet itself as a Site of Special Scientific Interest (SSSI).

Other nationally important sites include areas of reedbed, fen, chalk grasssland and ancient woodland. There is also a candidate Special Area of Conservation which is proposed for its internationally important populations of Desmoulin's Whorl snail. The Kennet and Avon Canal provides an additional biological resource and is particularly notable for its important water vole populations. Otters are also present and their population is recovering. The large amount of still water habitat provided by old gravel pits in the lower Kennet Valley are also important ecologically for their ornithological interest.

Historically, the Kennet has been exploited for many purposes. The upper part of the river is a renowned trout fishery, and there is still considerable stocking of trout. There are also several fish farms, these take water from the river, via parallel channels into holding pens on the floodplain, before returning the water to the river. The water itself has been used for agriculture, historically this has entailed using structures such as sluices in the channel to raise water levels to flood adjacent areas in early spring, in order to warm the ground and encourage early growth of grass. Finally there are many historic structures along the channel, most notably mills. Some are still working, others are not, but they often have a significant influence on local hydromorphological conditions.

4.3 Identification of Water Bodies

An *a-priori* (prior) approach to defining water bodies specific to this project has been rejected. This is because the Water Body should be defined by management considerations, and it is only possible to understand all the management considerations once the HMWB assessment has been completed. Two approaches have been considered – use of existing

[4] Figure for 1993.

stretches and a new bottom-up approach. Their advantages and disadvantages are outlined below.

The six draft criteria for identification of reaches with homogenous morphology (as defined by the Environment Agency RHS team) are as follows:

1. Significant change in underlying geology based on erodable characteristics of rocks grouped as:
    a) Peat, Alluvium, Clay,
    b)'No drift – soft rocks (shale, sandstone, chalk, limestone)',
    c) No drift – hard rocks.
2a. Significant change in discharge OR
2b. Change in stream order.
3. Significant changes in landuse. - ITE landuse classification[5] grouped as urban/ woodland/ agricultural/ semi-rural,semi-natural).
4. Major structures in the channel (major weirs and dams).
5. Significant breaks in slope. Resolution 500m vs available spot heights and test for levels of change > 2%, 5%, 10% or 20%).
6. Presence of 'Indicative flood plain'

As a result of problems in implementing the bottom-up approach, we looked at an alternative approach using stretches defined for existing Water Quality Assessment purposes, these designations are referred to as GQA (General Quality Assessment) stretches. These stretches are referred to in the pre-screening assessment in chapter seven of this report. In other case studies, these existing designations were very easy to work with. However on the Kennet, because of the nature of the modified hydromorphology, these stretches were not suitable. Instead, an even more pragmatic approach was adopted, based on map data, indicating the course of the river and urbanisation, was adopted. These water bodies are indicated in Table 2 and Figure 1.

Table 2. Water Bodies in the Kennet catchment

Name of group	**Main pressures on group**	**Main physical alterations of group**	**Water bodies**
Heavily Urbanised canal sections	Urbanisation, Canal	Bank reinforced Channel dredged Channel straightened Floodplain diversity lost Water impounded	8. Reading A33 to Thames

[5] Institute of Terrestrial Ecology (now CEH Monks Wood).
The Land Cover Map of Great Britain (1990) is a digital dataset, providing classification of land cover types into 25 classes, at a 25m (or greater) resolution. Data from the map provide:
- the first complete map of the land cover of Great Britain since the 1960s
- the first time the land cover of Great Britain has been comprehensively mapped from satellite information
- the first digital map of national land cover
- accuracy to the field scale, checked against ground survey

Fuller, R.M., Groom, G.B. & Jones, A.R. 1994a. The Land Cover Map of Great Britain: an automated classification of Landsat Thematic Mapper data. *Photogrammetric Engineering & Remote Sensing* **60** 553-562.

Name of group	Main pressures on group	Main physical alterations of group	Water bodies
Semi-urban canal sections	Urbanisation, Agriculture (land drainage and flood defence), Canal	Bank reinforced Channel dredged Channel straightened Floodplain diversity lost Water impounded	3. Kennet within Newbury
Rural	Agriculture (land drainage and flood defence)	Channel dredged Channel straightened Channel culverted Floodplain diversity lost Water impounded	1. Upper Kennet to Denford (Hungerford) 2. Hungerford to Newbury 4. d/s Newbury to Woolhampton 6. d/s Woolhampton to d/s Aldermaston
Rural canal sections	Agriculture (land drainage and flood defence), Canal	Channel dredged Channel straightened Channel culverted Floodplain diversity lost Water impounded	5. Concurrent canal at Woolhampton 7. Concurrent canal from d/s Aldermaston to Reading A33 bridge

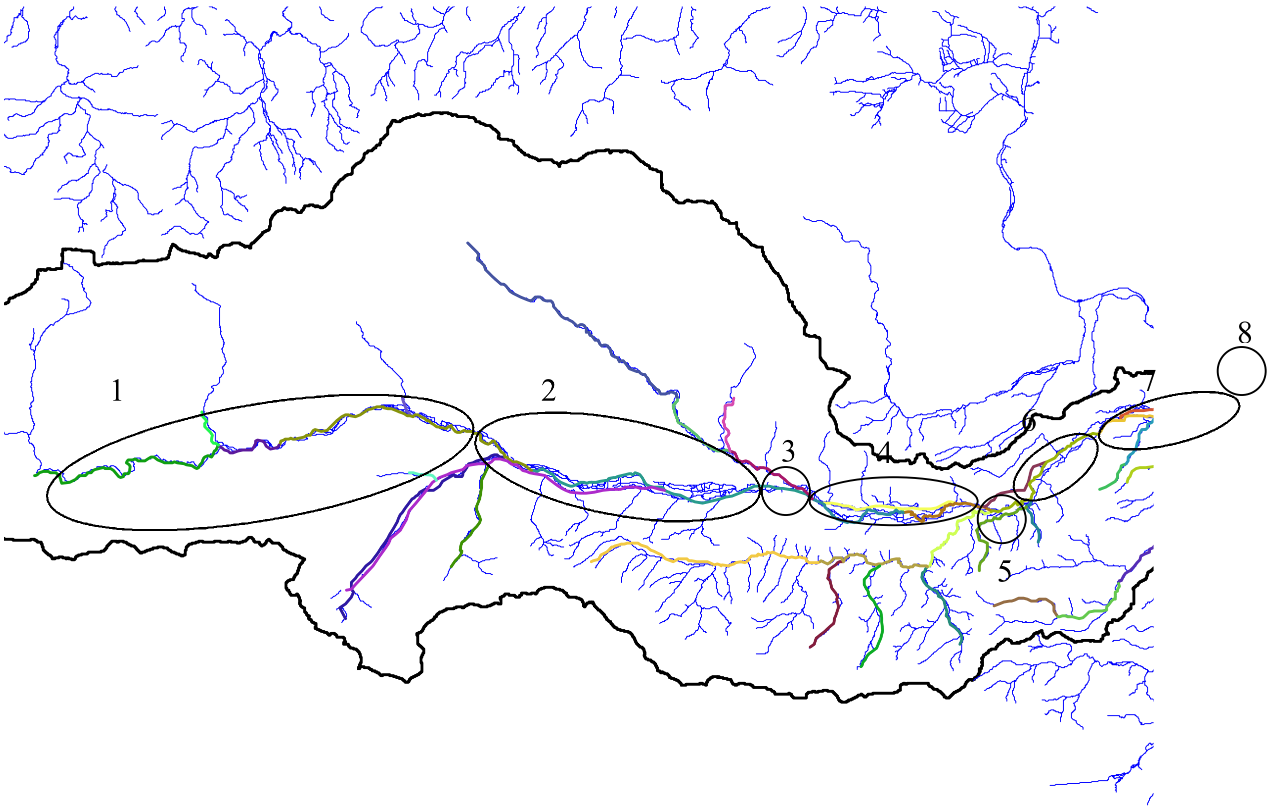


Figure 4. River Kennet coloured GQA stretches and water bodies

(GQA stretches are randomly coloured)

4.4 Discussion and Conclusions

The Kennet has an extremely wide variety of modifications, which in turn will affect the definition of management units. In particular, the juxtaposition of free-flowing and impounded sections must be considered, as must the sections where the canal and river run as one body. The GQA stretches as used on the other case studies are not really suitable for dividing up the Kennet.

PART II

5 Physical Alterations

5.1 Pressures and Uses

The main physical pressures on the Kennet are:

- Land drainage and other management for agriculture
- General management of the channel
- Navigation
- Groundwater abstraction, especially in the upper Kennet
- Flood defence
- Heritage, such as old mill structures
- Urbanisation
- Road building

Other non-physical pressures include nutrient runoff from agricultural land, discharge of treated sewage effluent, discharge of water from fish farms, runoff from roads.

5.2 Physical Alterations and Changes in the Hydromorphological Characteristics of the Water Bodies and Assessment of Resulting Impacts

5.2.1. Overall summary for different pressures

Land drainage and other management for agriculture
Virtually all of the Kennet has been modified to some extent. Quite a lot of this modification has consisted of dredging the bed and re-sectioning the channel to allow land drainage.

General river management
In general, English chalk streams are highly artificial environments, in their natural state they would consist of multiple small channels flowing through boggy woodland. The Kennet is just such an example of an altered river. In addition, the channel is subject to ongoing management such as through the presence of weirs to raise water levels, and sluices / hatches which control how water is diverted when the channel splits. A considerable proportion of the river channel is influenced by some sort of water level control of this sort. There has been a perception of a decline in the ecological quality of the Upper Kennet over the last twenty years, and considerable resources have been spent on trying to identify and solve problems. It is still not certain of the relative impacts of physical river management, abstraction, water quality, land management and climate on the river.

Navigation
The Kennet is famous for the Kennet and Avon Canal, which runs parallel to the River Dun from Crofton/Burbage and parallel to the Kennet from Hungerford onwards to Reading. In some cases, the river and canal form one channel, such as at Marsh Benham, in Newbury and Woolhampton. However, these are relatively short stretches, and for the greater part of the river, the canal runs in an artificial channel, or greatly widened secondary channel. There are

many structures which control water transfers to and from the canal which have a localised impact on the river. In addition, water transfers from canal to the river could possibly cause water quality problems to spread.

Groundwater abstraction, especially in the upper Kennet
Historically the Kennet has been exploited for good quality groundwater. Much of this is exported from the catchment to supply growing towns such as Swindon to the north. This abstraction does likely have an impact on the river during naturally low flow years, but its magnitude is difficult to gauge. There are ongoing programmes of works, financed by Thames Water, to look into the ecological response of the river, and how any impacts could best be mitigated.

Flood defence
In general, modifications for flood defence are difficult to separate from those for land drainage. There are some embankments, particularly protecting Newbury, Reading, and individual hamlets close to the river.

Heritage, such as old mill structures
There have also been historical reasons for modification that are no longer economic or social forces that create on-going pressures. These modifications have left a legacy which create pressure on the water bodies. An example is the presence of water mills on the Kennet. There are some social pressures to maintain culturally and historically significant modifications on the river.

Urbanisation
The presence of the main towns along the river has led to more engineered channels in these areas. In particular, in Newbury, there are buildings right up to the river bank and extensive bank reinforcement. For historical reasons (probably connected with this lack of space), the river and canal form one channel, so water levels are maintained artificially high. The same is true of the river close to where it meets the Thames at Reading.

Roads
Two major trunk roads cross the Kennet catchment, the A34 from north to south and the M4 from east to west. Where the roads cross the river, considerable effort has gone into mitigation of possible physical and water quality impacts.

5.3.2. Physical data available

River habitat survey sites are very sparse on the River Kennet. The river contains only five 0.5km long River Habitat Survey (RHS) sites. The Habitat Modification Scores (HMS) vary in value from 4 to 44, with a median of 15. According to the HMI classification system, two of the RHS sites are classified as ‘Predominantly Unmodified’, two sites as ‘Obviously Modified’ and one as ‘Significantly Modified’.

The flood defence asset data for the River Kennet are not in standard FDMS (Environment Agency Flood Defence Management System) form, but rather a proprietary format chosen by Thames Region of the Environment Agency. The data consist of two databases, one of which contains information regarding defences, and the other contains information about structures.

The databases are more descriptive than the FDMS database, making any objective procedure more difficult.

Although river habitat survey are very sparse for the Kennet, the Environment Agency has had some alternative geomorphological audit channel surveys undertaken by Southampton University. The data are referenced with respect to four separate watercourses, based on geology. This does not exactly match with the waterbodies given above (Table 3 and Figure 5). However it does give a broad picture of the extent of different management activities in the catchment. Results are presented below as proportions of river length, for the following activities:

- General river maintenance
- Widening or narrowing
- Agricultural drainage and flood defence
- Re-alignment and re-sectioning
- Bank protection and embankments
- Weirs
- Whether the channel is recovering

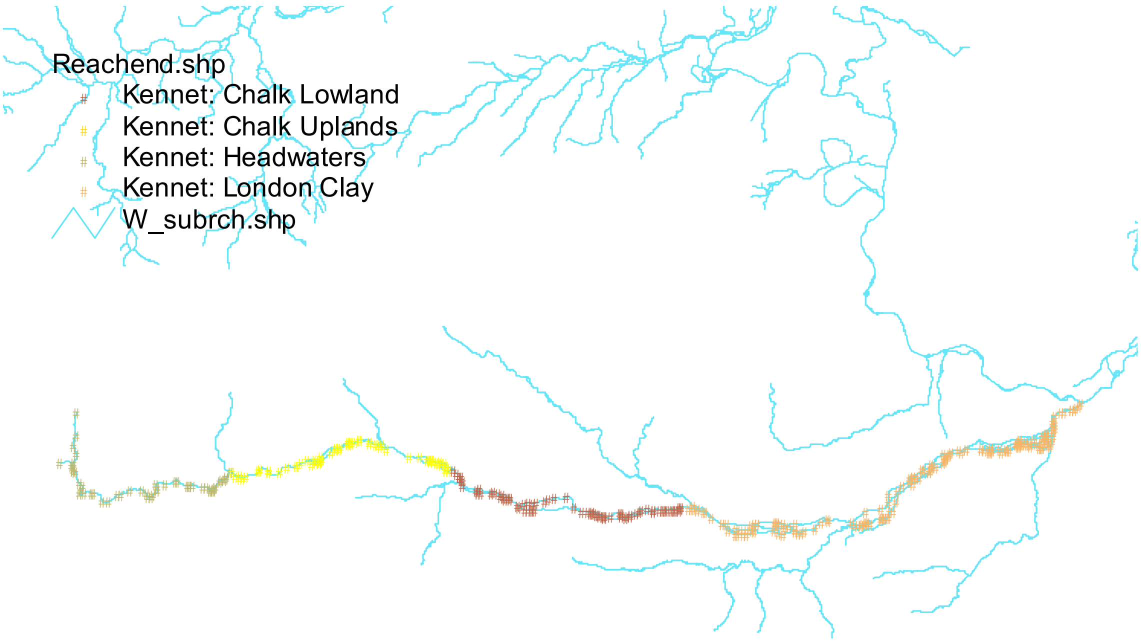


Figure 5. Watercourses used in Kennet Geomorphological audit

Table 3. Link between HMWB waterbodies and Kennet Watercourses

Watercourse	Water Bodies
A: Headwaters	1
B: Chalk uplands	1-2
C: Chalk lowlands	2-3
D: London clay	4-8

Table 4. River Kennet: extent of maintenance

Watercourse	Maintenance

A - Kennet: Headwaters	45%
B - Kennet: Chalk Uplands	49%
C - Kennet: Chalk Lowlands	64%
D - Kennet: London Clay	74%

Table 5. River Kennet: exent of widening and narrowing

Watercourse	Widening	Narrowing
A - Kennet: Headwaters	0%	35%
B - Kennet: Chalk Uplands	3%	7%
C - Kennet: Chalk Lowlands	0%	5%
D - Kennet: London Clay	5%	0%

Table 6. River Kennet: extent of agricultural drainage and flood defence works

Watercourse	Agricultural drainage	Flood defence
A - Kennet: Headwaters	83%	12%
B - Kennet: Chalk Uplands	42%	8%
C - Kennet: Chalk Lowlands	26%	4%
D - Kennet: London Clay	51%	8%

Table 7. River Kennet: extent of re-alignment and re-sectioning

Watercourse	Re-alignment	Re-section
A - Kennet: Headwaters	6%	93%
B - Kennet: Chalk Uplands	39%	75%
C - Kennet: Chalk Lowlands	39%	89%
D - Kennet: London Clay	24%	66%

Table 8. River Kennet: extent of bank protection and embankments

Watercourse	Bank protection	Embankment
A - Kennet: Headwaters	18%	0%
B - Kennet: Chalk Uplands	28%	18%
C - Kennet: Chalk Lowlands	33%	27%
D - Kennet: London Clay	15%	30%

Table 9. River Kennet: presence of weirs

Watercourse	Weir: hydraulic influence	Weir: present
A - Kennet: Headwaters	11%	0%
B - Kennet: Chalk Uplands	48%	3%
C - Kennet: Chalk Lowlands	19%	11%
D - Kennet: London Clay	12%	4%

Table 10. River Kennet: morpological recovery of channel

Watercourse	No Recovery	Not applicable	Recovered	Recovering
A - Kennet: Headwaters	21%	0%	0%	79%

B - Kennet: Chalk Uplands	25%	1%	2%	71%
C - Kennet: Chalk Lowlands	53%	11%	0%	35%
D - Kennet: London Clay	41%	13%	1%	40%

5.4 Discussion and Conclusions

The channel of the River Kennet has been modified over many hundreds of years, and modification may have started over 1000 years ago. The current modifications to the river will be as much a reflection of historical activities (which may no longer be undertaken) as current pressures. Often modifications may be clear, but they will be serving multiple purposes, such as land drainage and flood defence. It is thus difficult to make links between particular pressures and consequent alterations to hydromorphology.

6 Ecological Status

6.1 Biological Quality Elements

6.1.1 Fish

The River Kennet as a Fishery,
The general condition of the fish captured was good, with many of the species attaining "specimen" size. It is this ability to grow fish to higher than average sizes that has given the Kennet its reputation as one of the premiere fisheries in the country.

<u>u/s Hungerford to Kintbury</u>
The species richness extracted from "EA Fish population Survey 1994" reaches in this part of the catchment a maximun of 13 species (brown trout, chub, common bream, crussian carp *Carassius carassius,* dace, grayling *Thymallus thymallus*, gudgeon, perch, pike, rainbow trout *Salmo gairdneri*, roach, salmon *Salmo salar,* tench).

River sites
- Dominant species: brown trout (25%), roach (21%),
- Abundant species: c. bream (12%), grayling (12%), salmon (10%), perch (8%), pike (8%)
- Common species: dace (4%), gudgeon (1%),
- Rare (each <1%): chub, rainbow trout, tench

Biological (biomass) quality: Class A

Canal sites
- Dominant species: roach (68%),
- Abundant species: c. bream (14%), perch (12%),
- Common species: pike (4%), gudgeon (1%), tench (1%)
- Rare (each <1%): carp, crussian carp, dace, grayling

Biological (biomass) quality: Class A

<u>Newbury to d/s Woolhampton</u>
The species richness extracted from "EA Fish population Survey1994" reaches in this part of the catchment a maximum of 15 species (barbel *Barbus barbus*, bleak, brown trout, carp, chub, common bream, dace, eel, grayling, gudgeon, perch, pike, roach, salmon, tench).

River sites
- Dominant species: roach (32%)
- Abundant species: gudgeon (15%), perch (15%), dace (13%), barbel (7%)
- Common species: common bream (5%), pike (5%), chub (3%), brown trout (1%), eels (1%), salmon (1%), tench (1%)
- Rare: carp, grayling, bleak

Biological (biomass) quality: Class A

<u>Canal sites</u>
- Dominant species: roach (59%)

- Abundant species: bleak (11%), common bream (10%), dace (6%)
- Common species: gudgeon (5%), perch (5%), chub (3%), pike (1%), tench (1%)
- Rare: barbel, bleak, carp, grayling rudd,

Biological (biomass) quality: Class A[1]

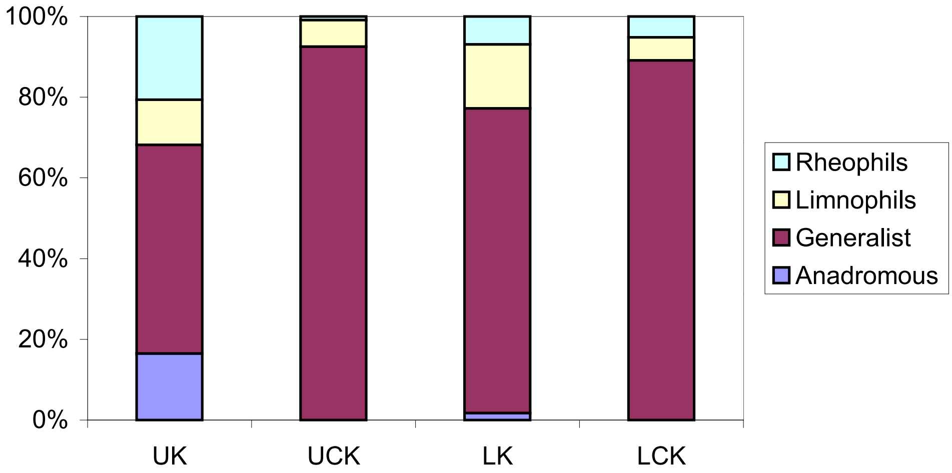


Figure 6. Ecological group composition for the fish fauna

(UK = upper Kennet, UCK = upper Kennet's canals, LK = lower Kennet, LCK = Lower Kennet's canals).

Connectivity
The numerous weirs and structures on the river represent barriers to connectivity. This has most impact on anadromous species such as Atlantic salmon. The Thames Salmon Trust has been developing salmon ladders and reintroducing salmon to the River Thames since 1967. Fish ladders have been fitted to weirs on the Kennet as far upstream as Hamstead Marshall (just above Newbury), these were opened in 2001.

Data types

Upper River Kennet (u/s Hungerford to Kintbury)
- Sampling frequency: One long survey report from 1986 to 1989 followed by one in 1993/94
- Methods: 11 sites are sampled by electrofishing
- Data types: Densities and Biomass estimates for each species

Lower River Kennet (Newbury to d/s Woolhampton)
- Sampling frequency: One long survey report from 1986 to 1989 followed by one in 1993/94
- Methods: 13 sites are sampled by electrofishing
- Data types: Densities and Biomass estimates for each species

6.1.2 Macro-invertebrates

[1] Environment Agency classification (A 20 ± 2g/m^2, B 10 ± 2g/m^2 to 20± 2g/m^2, C 5± 1g/m^2 to 10± 2g/m^2, D 0 to 5± 1g/m^2)

Biological water quality in UK rivers and streams is classified using the composition of the macro-invertebrate community, in terms of a predicted composite score based on a small suite of physico-chemical site descriptors. The system, know as RIVPACS (River InVertebrate Prediction And Classification System), allocates a score between 1-10 to 82 macro-invertebrate families. For each family the score reflects its sensitivity to organic pollution (10=very sensitive). The combined scores for each taxon and the average score per taxon reflect both community richness and the balance between pollution tolerant and pollution sensitive taxa present. Within RIVPACS a series of 'Expected' scores are generated, based on the standard site physico-chemical descriptors/variables. Trends in these Expected values were examined from the routine monitoring sites on the Kennet. Rises or falls in Expected values were matched to recorded differences in habitat modifications between sites and hence provide scope for cross-referencing the rises or falls in expected values to differences in habitat modifications between sites.

The 1995 General Quality Assessment (GQA) results were available in consistent format (spring and autumn) for all sub-catchments, therefore broad assessments are based on this dataset. These samples are taken for water quality monitoring purposes, and are taken at sites that are easy to sample, commonly with either riffles, or shallow flowing water. Deep ponded sections are not routinely sampled.

Supplementary macro-invertebrate data supplied by the Environment Agency Regions was incomplete and contained variable information, both in terms of coverage and accuracy.. Some datasets included non-scoring BMWP taxa and, in one case, fish data. Some limited interpretation of the supplementary data was undertaken.

Our analysis consisted of the following elements:
- Patterns in site groupings
- Unexpected absences of taxa
- Provisional scoring system to assess biological impacts of habitat modification

Patterns in RIVPACS site groupings
All GQA sites on the Kennet were members of RIVPACS TWINSPAN Groups 25-35, broadly covering lowland river sites and excluding small streams. Sites on the Kennet exhibit both a downstream increase in site Group number and a rise in the probability of the site matching the predicted TWINSPAN Group. A step-change occurs towards the lower end of the Kennet, with a jump from Group 27 to Group 35, the latter Group being generally characteristic of larger river sites.

Unexpected absences of broad taxonomic groups, based on RIVPACS predictions
The 1995 GQA results were available in consistent format (spring and autumn) for all sub-catchments, therefore the following assessments are based on this dataset. Supplementary macro-invertebrate data supplied by the Environment Agency Regions contained variable information. Some datasets included non-scoring BMWP taxa and, in one case, fish family data.

An initial check was made on the occurrence of *Simuliidae* at each site, in the expectation that this group would be excluded from sites with low water velocities associated with impounded river reaches (see Table 11 below).

The mean percentage occurrence rates of broad taxonomic groups within the four major divisions of RIVPACS III site groups were compared with their occurrence rates at sites within the HMWB candidate sub-catchments. The absence of groups with high (>95%) predicted rates of occurrence are highlighted below.

River Kennet
Asellidae were absent from three of the nine sites on one sampling occasion and a fourth site in both spring and autumn. Gastropoda and Ephemeroptera were absent at one site, in one season. Absence of simuliidae are recorded below.

Attribution of cause/effect regarding missing macro-invertebrate taxa is problematic. Predominately high scoring RIVPACS taxa are susceptible to poor water quality but may also be disfavoured by habitat degradation associated with HMWBs. Groups of lower scoring taxa that were absent from some sites may relate more closely to poor habitat quality than water quality. These groups include Coleoptera and Gastropoda that have a high proportion of taxa associated with aquatic and emergent plants. Degradation or absence of these habitats may exclude these groups. The absence of Simuliidae at some sites may be related to un-naturally slow flowing water on the Kennet, however, no consistent picture emerges based on presence/absence of taxon groups along the Kennet

Table 11. River Kennet occurrence of simuliidae

Site	Spring 1995	Autumn 1995
STITCHCOMBE MILL	1	1
WATER GARDENS INLET, CHILTON FOLIAT	1	0
AT HAMBRIDGE ROAD, NEWBURY	1	1
ABOVE ALDERSHOT WATER	1	1
AT BRIMPTON MILL	1	1
AT UFTON BRIDGE	0	0
AT WATER INTAKE, FOBNEY	1	0
AT BERKELEY AVENUE, READING	1	1
ABOVE THAMES	0	0

(1 = present, 0 = absent)

6.2 Physico-Chemical Elements

Impacts of this sort could arise from the linkages between the river and the canal. In addition, ponded reaches upstream of structures could have their quality affected, but in practice this is not a great problem.

6.3 Definition of Current Ecological Status

Overall, based on an expert assessment of the fish macro-invertebrate data, supported by RIVPACS lists of expect macro-invertebrate taxa, the Kennet appears to be at good status.

6.4 Discussion and Conclusions

The biological data indicate that as a whole, the Kennet is at good status. However, this picture may be slightly biased in that the biological samples are generally taken at sites with good habitat.

7 Identification and Designation of Water Bodies as Heavily Modified

7.0 Provisional identification

The pre-screening procedure, as documented in the accompanying guidelines report, has been applied to the upper-middle reaches of the Kennet. The pre-screening pro-forma, completed for the four GQA stretches between Ramsbury and Aldermaston are shown in four columns in Table 12. River habitat survey sites are very sparse on the River Kennet, and the asset data for the River Kennet are not in the form of FDMS data. The data consist of two databases, one of which contains information regarding defences, and the other contains information about structures. The databases are more descriptive than the FDMS database, making any objective procedure more difficult.

The nature of the river makes any assessment difficult. For much of Stretch 1, there are additional channels and many weirs and sluices. In Stretch 2, there are again reaches with additional channels together with the Kennet and Avon Canal. This is generally separate from the river, but in three locations, the river itself forms the navigation. There are complex interconnections between the river and the canal. In Stretch 3, the canal runs parallel to the river. There are additional channels for the whole stretch. In Stretch 4, there is a reach where the river forms the navigation. Elsewhere, the canal is separate from the river. Again there are many additional channels for much of the stretch.

The small number of RHS sites means that little confidence can be attached to the data for assessing the river as a whole. Use of the asset data does not offer much help either. Most of the asset data refers to point assets such as weirs, sluices, fords, culverts and bridges, rather than data about the channel bed or sides.

The conclusions reached on the Kennet are very subjective and would be greatly improved through the involvement of local Agency staff. Looking at the available information without the benefit of local knowledge, it is suggested that Stretches 1 and 2 should be classified as Potential HMWBs because of the presence of additional channels and the number of weirs and sluices. Stretches 3 and 4 appear to be more Borderline. **The overall stretch of river should therefore be classed as a Potential HMWB and should proceed to the economic tests.**

Table 12. HMWB Pre-screening pro-forma – Kennet

HMWB Pre-screening pro-forma

River: Kennet | **Completed by:** Helen Rogerson

Draft WB: Upper Kennet to Hungerford to Newbury and Woolhampton | **Date:** 31/01/02

GQA stretch:	**Stretch 1 Upstream of Ramsbury – Denford Mill**	**Stretch 2 Denford Mill - Thatcham**	**Stretch 3 Thatcham – Aldershot Water**	**Stretch 4 Aldershot Water – Upstream of Aldermaston Bridge**
Upstream NGR:	426400 171000	435130 168370	449920 166620	454430 166000
Downstream NGR:	435130 168370	449920 166620	454430 166000	459200 166200
Approx length (km):	11.0	17.6	5.7	6.1
RHS sites				
Number of RHS sites	2	1	0	2
Average spacing of RHS sites (km)	5.5	17.6	-	3.1
Percentage of stretch defined by RHS data	9%	3%	0%	16%
Number of non-candidate sites (HMS <8)	1	0		1
Number of Borderline sites (HMS = 9-20)	0	1		1
Number of potential HM sites (HMS >21)	1	0		0
Percentage of defined stretch:				
Non-candidate	50%	0		50%
Borderline	0	100%		50%
Potential HMWB	50%	0		0
Channel modifications:				
Wholesale channel moved (% length)				
Additional artificial flood channels (% length)	70%	88%	100%	74%
Culverts (number)	1	1		1
Culverts (number per km)	0.09	0.06		0.16
Weirs/sluices (number)	22	23	6	3
Weirs/sluices (number per km)	2	1.3	1.1	0.5
Water level influenced by d/s weir/dam (% length)	Significant	Significant		
Bed re-sectioned/dredged/deepened (% length)				
Bed reinforced (% length)				
Bank modifications (% length) (NB total length = stretch length*2)				
Bank re-aligned/straightened				
Bank re-sectioned (i.e. widened)				
Bank reinforced (whole)		5%		5%
Bank toe reinforced				
Bank top embankments		11%		5%
Bank top set-back embankments				
Maintenance (% length)				
Regular maintenance (at least every 2 years)		Significant	Significant	Significant
Occasional maintenance	Significant			
No maintenance				
Data informed by FDMS (% length)	100%	100%	100%	100%
Overall assessment (NC = Non-candidate, B = Borderline, P = Potential HMWB)	P	P	B	B

7.1 Necessary Hydromorphological Changes to Achieve Good Ecological Status

The following sections consider the Kennet from Hungerford to Newbury.

Overall, the most major impact to the Kennet is through the combination of historical river management and the presence of in-channel structures in the form of weirs and sluices. In terms of overall hydromorphological impact, the linkages with the canal do have an impact, but are less important. An overall strategy for improvement of the Kennet would include targeted removal of weirs with habitat restoration, such as introducing more in-channel diversity. Other options such as raising bed levels would also be desirable. In the upper part of the catchment, there is considerable evidence that providing the channel is not over-wide, there is sufficient stream power for the river to recover. In the lower parts of the river, more active rehabilitation would be required.

The Kennet, more so than the other case studies considered here, in that linkage of pressures to modifications to status is problematic. There are few, or no "natural" large chalk streams to consider as reference conditions for the Kennet. Based on the reference conditions that are available, the river is undoubtedly already at Good Status, despite the modifications.

7.2 Assessment of Other Environmental Options

Assuming that true Chalk stream reference conditions were available, it may be that the Kennet would not be considered at good status along its whole length. In this case, the first stage would be consideration as to whether the necessary changes for achievement of GES would have a significant adverse effect on the wider environment. It is difficult to interpret this phrase, however it may apply to the Kennet. It is clear that river maintenance and management lead to un-natural rivers, however the Kennet is so un-natural that considerable ongoing management is required for it to maintain its status. Given the designations of the Kennet as a site of special scientific interest for its diverse flora and fauna, any measures that would begin to bring the Kennet closer to natural would need to be carefully considered under the criteria of 3.a)i).

Again, assuming this test was passed (ie river not designated), the next stage of assessment would be the consideration of other options for delivery of the same functions as the existing modifications. On the Kennet we are handicapped by the long history of modifications. The most clear-cut linkages between function and modification relate to channel alterations for flood defence and land-drainage. Possible other environmental options for flood defence would include enhancement of the parallel channels and sluice systems to carry flood waters, removal of embankments to allow more floodplain storage, combined with sacrifice of agricultural land. These options could have significant benefits to floodplain habitats. Such options would need to be examined in great detail to see whether they did indeed provide the same level of flood protection to properties, this would not be a simple task.

For land drainage, there are really no practical options if the agricultural value of the floodplain land is to be retained.

For the concurrent canal / river sections, the only option could be to build new bypass canal sections and restore the river sections, including removing the existing structures. However there are good land-use and geotechnical reasons why these lengths are concurrent. Given that they are small in relation to the overall water body length, this option is excluded, in favour of some habitat improvement works. For this stretch it is not necessary to divide the concurrent sections into separate a water body. However this has been undertaken for the downstream stretch within Newbury itself.

7.3 Designation of Heavily Modified Water Bodies

Assuming the Kennet were not reaching GES, a series of proformas have been filled in to describe the costs and benefits associated with the current situation and various alternative river management options. Options are targeted to various sections of the river, remembering that even with the existing conditions, there is high variability in hydromorhology along this water body.

The overall assessment is that the direct costs of rehabilitation of the Kennet would be high. Because the benefits would also be extensive, further quantification of them both is necessary. The Kennet is an excellent example of a Chalk stream which is a rare habitat on a national and European scale, thus the population to which any improvement benefits would apply is potentially large. Furthermore, because parts of the river already have good habitat and status, the potential for the colonisation of rehabilitated areas is high.

The water body is described as “costs outweigh benefits slightly (sensitivity analysis shows benefits could outweigh costs); significant qualitative benefits (particularly environmental)”.

8 Definition of Maximum Ecological Potential

The following section has been filled in on the assumption that the Kennet from Hungerford to Newbury has been designated a HMWB.

8.1 Determining MEP and GEP

There are no current scoring systems or models for linking ecological status with modifications so there needs to be a high reliance on expert opinion in this area. This also means that the difference between MEP and GEP is somewhat arbitrary, and so a pragmatic approach has been adopted which interprets GEP as adopting best practice in river management, given the continued use of the modifications for the functions that were intended.

In the case of the Kennet, this would mean ongoing management of the upper Kennet as a trout fishery, ongoing utilisation of the agricultural land on the floodplain, continuation of use of the canal as before, and use of embankments for flood defence.

There are a number of comparable rivers, such as the Itchen, Test and Hampshire Avon. Of these the Test also has a large number of in-channel structures while the Avon is possibly more free flowing. These rivers could provide some comparable reference conditions, but in practice, using existing methods for biotic scoring, there is little difference between them.

8.2 Measures for Achieving GEP

In defining GES, the procedure for HMWB designation has already scoped the kind of measures that could be adopted for achieving GEP. The difference is that the options for GEP would be adopted to a more limited extent and probably incrementally, starting with the measures which are most cost-effective.

Possibly the single most productive measure would be to manage the existing weirs and sluices to allow as much free-flowing water as is possible. This would encourage colonisation by fish, macro-invertebrates and plants which prefer shallower faster flowing water with sand and gravel substrates. The next measure would be targeted structural river rehabilitation, consisting of introducing greater diversity in bank structure and long profile. These measures on their own should be enough for this stretch of the Kennet to achieve GEP.

PART III

10 Conclusions

The Kennet is a highly managed river that is probably far from its “natural” state. However it, along with other similar rivers, has been modified for such a long time that determination of any reference state is problematic.

Overall, having reviewed available data, the Kennet from Hungerford to Newbury is, despite its modifications, probably already at Good Ecological Status. However we have undertaken the full HMWB screening anyway in order to illustrate certain points that the Kennet raises.

- Some maintenance can have negative effects, but Kennet so highly managed, that general reduction in river management is perceived to have negative effects.
- Length of river. Some of the best parts of the upper Kennet are already at GES without a doubt. The question is whether these are enough for the water body overall to be at GES. Because of its long history of modification the Kennet does not divide up easily unless the river was split into very many small parts with some parts designated and some not. However this would be impractical and potentially not lead to integrated management.
- Data availability. In general, data availability for the River Kennet is very good. However, this may be giving a biased picture because historically the data have mostly been collected for water quality assessment purposes. This means that the “best” habitats are generally sampled. There is relatively little systematic sampling of the biology of different types of modification. This is an issue common to other rivers in the UK, and increased monitoring of impacted and marginal areas is desirable.
- Availability of reference conditions. As with many other cases, a true picture of GES is difficult because of the lack of suitable unimpacted reference conditions.

NOTE: This is an example proforma. The conclusion from the ecological assessment was that the Kennet from Hungerford to Newbury is already at GES. Some options have been scoped for improving the river assuming the hypothetical situation that it was not at GES.

Proforma 1: Assessment for Test 4.3(a) - would restoration have a significant adverse effect on uses?

River Kennet – Hungerford to Newbury

Modification and Intended Uses	**Potential Restoration Measures**	**Impacts of Restoration on Intended uses**	**Significance of Impacts (on intended uses) and Direction**			**Impacts of Restoration on Wider Environment**	**Significance of Wider Impacts**			**Significant Adverse Effect?**
			Small	**Mod**	**Large**		**Small**	**Mod**	**Large**	
Channel dredged to connect with field under-drainage to lower water levels in floodplain	Raise river bed level, recreate longitudinal diversity in channel form	Loss of agricultural land, reduced yields of arable crops and/or effects on cropping patterns; potential increase in flood damages on adjacent land areas		-ve		Partial achievement of GES; greater opportunities for marginal plants and increased diversity of invertebrates (although floods could wash out plants affecting invertebrates); land will go to grazing or wetland with potential conservation, possible flood attenuation and landscape benefits	+ve			Unsure
	Selected areas: channel narrowing and creation of lateral channel diversity	Some loss of agricultural land and possible increase in flood related damages	-ve			Partial achievement of GES; greater opportunities for marginal plants and increased diversity of invertebrates (although floods could wash out plants affecting invertebrates) ; potential creation of wetland areas with potential conservation, flood attenuation, and landscape benefits	+ve			Unsure

Proforma 1: Assessment for Test 4.3(a) - would restoration have a significant adverse effect on uses?

River Kennet – Hungerford to Newbury

Modification and Intended Uses	Potential Restoration Measures	Impacts of Restoration on Intended uses	Significance of Impacts (on intended uses) and Direction			Impacts of Restoration on Wider Environment	Significance of Wider Impacts			Significant Adverse Effect?
			Small	**Mod**	**Large**		**Small**	**Mod**	**Large**	
Re-sectioning and embanking of river for flood protection purposes	Removal of embanked sections, cessation of some maintenance, works to narrow channel and diversify bank structure	Possible flood damages on adjacent agricultural land and residential areas		-ve		Partial achievement of GES; greater opportunities for marginal plants and increased diversity of invertebrates; potential loss of some agricultural land; landscape benefits		+ve		Unsure
	Re-engineering of channel - meanders, etc.	Likely increase in flood damages on adjacent agricultural land and residential areas; loss of agricultural land areas		-ve		Achievement of GES in relevant stretches. Increase in marginal plant communities and increased diversity of invertebrates; fishery improvements; wetland creation with potential conservation, flood attenuation and landscape and recreation benefits		+ve		Unsure
Structures e.g. weirs – general river management	Remove structures	Lower income for put-and-take fisheries. Would need to compensate fisheries owners. Loss of heritage in some cases		-ve		Benefits to river – more free-flowing, more “natural” macrophyte, fish and macro-invertebrate communities. Improved hydro-morphology, e.g. less silt deposition.		+ve		Unsure
Structures – Canal, including concurrent river/canal sections	Even greater separation of river and canal, bypass concurrent sections of river	None, intended use maintained				Take of land for bypass canal sections, possible geotechnical issues	+ve			

Proforma 2: Assessment for Test 4.3(b) - are there technically feasible alternatives?

River Kennet – Hungerford to Newbury

Modification	**Possible Alternatives for Providing Intended Uses**	**Technically Feasible? (✔)**		**Factors Affecting Implementation**
		Yes	**No**	
Channel dredging to connect with field underdrainage	Put in parallel drainage channels with pumped wellpoints	✓		Loss of land; power requirements for pumping
Re-sectioning and embanking for flood protection	Re-engineering of river channel with meanders, etc.	✓		Requires purchase of agricultural land and can only be implemented on certain stretches
	Off-channel embankments	✓		Not always feasible because of proximity of housing to river
	Residential protection works (e.g. flood gates, barriers at doors)	✓		Relies on householders being home and responding to flood warnings; high risk of failure on demand
Structures e.g. weirs – general river management	Convert smaller side-channels to put-and-take fisheries.	✓		River more un-natural
Structures – Canal, including concurrent river/canal sections	Bypass sections of river with new canal sections		**Possibly not**	No loss of intended use. However there are probably geotechnical reasons why the canal and river are concurrent where they are. Also lack of land - potential affecting property

Proforma 3: Assessment for Test 4.3(b) - are there alternatives that would not be disproportionately costly?

River Kennet – Hungerford to Newbury

Modification	**Cost of Operating/ Maintenance for Existing Modification (✔)**			**Alternatives**	**Costs of Alternatives: Capital and Operating/Maintenance (✔)**				**Potential Environmental Benefits**	**Disproportionately Costly? (✔)**		
	<£100k <€160k	**<£1m <€1.6m**	**>£1m >€1.6m**		**<£100k <€160k**	**<£1m <€1.6m**	**<=£10m <=€16m**	**>>£10m >>€16m**		**Yes**	**No**	**Unsure**
Channel lowered for flood defence and land drainage to lower water levels in floodplain	✓			put in parallel drainage channels with pumped wellpoints (dig channel/pipe around field and pump out)		✓			Returns to more natural flooding regime; potential improvement in water quality; more natural river profile; benefits of additional ditch habitat			✓ (need more data)
Re-sectioning and embanking of river for flood protection purposes	✓			Re-engineering of river channel with meanders, etc.		✓			Create a natural river channel with improved flow regime and more natural river profile; conservation, recreation, fisheries and landscape benefits			✓
				Off-channel embankments		✓			Must be combined with other works to generate any environmental gains			✓
				Residential protection works			✓		Must be combined with other works to generate any environmental gains	✓	Most expensive and would not (on its own) generate significant environmental benefits	

Proforma 3: Assessment for Test 4.3(b) - are there alternatives that would not be disproportionately costly? *River Kennet – Hungerford to Newbury*													
Modification	**Cost of Operating/ Maintenance for Existing Modification (✔)**			**Alternatives**	**Costs of Alternatives: Capital and Operating/Maintenance (✔)**				**Potential Environmental Benefits**	**Disproportionately Costly? (✔)**		
	<£100k <€160k	**<£1m <€1.6m**	**>£1m >€1.6m**		**<£100k <€160k**	**<£1m <€1.6m**	**<=£10m <=€16m**	**>>£10m >>€16m**		**Yes**	**No**	**Unsure**
Structures e.g. weirs – general river management	✓			Create other fishing opportunities		✓			More free-flowing (un-impounded) river			✓ (significant loss of value of Kennet as recreational fishery)
Structures – Canal, including concurrent river/canal sections		✓		Bypass sections			✓			✓		

Proforma 4: Measures Carried Forward for More Detailed Assessment

River Kennet – Hungerford to Newbury

Modification	**Restoration Measure or Alternative Means of Providing Intended Use**	**Effect on Ecological Status? (Achieve Full or Partial GES?)**	**Reason More Detailed Assessment Required**
Channel dredged to connect with field under-drainage to lower water levels in floodplain	Raise river bed level, recreate longitudinal diversity in channel form	Partial (needs to be combined with removal of structures)	More data needed to determine whether ecological status gains together with other benefits are significant enough to justify capital works, losses in agricultural land and possible increases in flood risk
	Put in parallel drainage channels with pumped extraction of water	As above – in addition to raising bed, would allow existing agriculture to continue in some areas	More data needed to determine whether the costs of this alternative means option are balanced by the economic benefits to agriculture
Re-sectioning and embanking of river for flood protection purposes	Channel narrowing and creation of lateral channel diversity	Full (but only across part of the whole reach)	Although impacts on intended uses are likely to be smaller, so are wider gains in comparison to costs of works
	Re-engineering for diversity in channel - meanders, etc	Full (but only across part of the whole reach)	Greater loss of land, more costly works than other options and considerable uncertainty over the potential increase in flood risk to residential properties. However environmental and wider benefits may be considerable
	Off-channel embankments	Partial (needs to be combined with other options)	May be good option in certain locations but feasibility is uncertain; costs will depend on location-specific factors
Structures e.g. weirs – general river management	Remove weirs on main channel	Partial (needs to be combined with re-introduction of longitudinal channel diversity)	More data needed to determine the extent of the effects of the weirs and whether ecological status gains together with other benefits are significant enough to justify capital works and loss of recreational fishing
	Provide alternative channels for recreational fishing	As above	Mitigation measure for above to provide alternative means

Proforma 5: Measures Dropped from the Further Analysis (Fail Test 4.3(a) or 4.3(b))

River Kennet – Hungerford to Newbury

Modification	**Restoration Measure or Alternative**	**Test Failed**	**Reason**
Channel dredging	Pumped wellpoints	Test 4.3(b)	Estimated to cost the same as other options but generate fewer benefits
Straightening and embanking of river for flood protection	Residential protection works	Test 4.3(b)	Most expensive alternative and is not expected to generate significant environmental benefits
Structures – Canal, including concurrent river/canal sections	Construct new canal sections	Test 4.3(b)	Doubtful technical feasibility

Proforma 6: Detailed Description of Restoration and Alternative Measures

River Kennet – Hungerford to Newbury

Measure	Capital Works Required	Operating Works Required	Number, Length or Area Affected
Current modifications: channel drainage and field underdrainage (dredged channel); some flood embankments; weirs on main channel, structures where river/canal concurrent	None	Some channel dredging every 10 years, maintenance of flood embankments, maintenance of structures	
Raise river bed level, recreate longitudinal diversity in channel form	Raise bed by importing material	Ongoing maintenance over first 5 years until stabilised; annual clearance works may be required	10km (stretch of river basis) – no work associated with current modifications required
Channel narrowing and creation of lateral channel diversity	Reduce width by placing material on banks; replanting to stabilise	Ongoing maintenance over first 5 years until stabilised; annual clearance works may be required	5km (stretch of river basis) – no work associated with current modifications required
Removal of embanked sections	Remove flood banks and re-engineer river over section downstream of reach	Maintenance ongoing for first five years and then annual clearance	2km (stretch of river basis) – no work associated with current modifications required
Re-engineering for diversity in channel planform - meanders, etc	Remove flood banks and construct natural channel to appropriate gradient, including meanders. Footpath access and planting of banks to be undertaken	Ongoing maintenance for first five years with annual clearance as required	3 km (stretch of river basis) – no work associated with current modifications required
Off-channel embankments	Construction of flood embankments on a retired line	Annual mowing and inspection	1km (2 when considering both banks) – no work associated with current modifications required
Remove river management structures (weirs)	Removal of structures, local dredging and bank stabilisation	None	7km of river (estimated)
Provide alternative areas for recreational angling	Capital works to modify existing side channels and raise water levels	Ongoing maintenance for first five years with annual clearance as required	

Proforma 7: Estimated Capital Costs of Restoration Measures and Alternative Means ***River Kennet – Hungerford to Newbury***		
Measure	**Cost component**	**Capital costs estimate**
Current modifications: channel drainage and field underdrainage (dredged channel); some flood embankments; weirs on main channel, structures where river/canal concurrent	Design and planning costs	-
	Land costs	-
	Site works	-
	Other	-
	Total capital(to nearest £10,000)	**-**
Raise river bed level, recreate longitudinal diversity in channel form	Design and planning costs	£50,000 (€82,000)
	Land costs	-
	Site works	£800,000 (€1,300,000)
	Other	-
	Total capital(to nearest £10,000)	**£850,000 (€1,400,000)**
Channel narrowing and creation of lateral channel diversity	Design and planning costs	£25,000 (€40,000)
	Land costs	-
	Site works	£150,000 (€245,000)
	Other	-
	Total capital(to nearest £10,000)	**£175,000 (€285,000)**
Removal of embanked sections protecting agricultural land	Design and planning costs	£4,000 (€6,500)
	Land costs	-
	Site works	£45,000 (€74,000)
	Other	-
	Total capital(to nearest £10,000)	**£49,000 (€80,000)**
Re-engineering for diversity in channel - meanders, etc	Design and planning costs	£15,000 (€24,500)
	Land costs	£40,000 (€65,000)
	Site works	£150,000 (€245,000)
	Other (planting along banks)	£10,000 (€16,000)
	Total capital(to nearest £10,000)	**£215,000 (€350,000)**
Off-channel embankments to protect properties	Design and planning costs	£10,000 (€16,000)
	Land costs	£20,000 (€32,000)
	Site works	£80,000 (€130,000)
	Other	-
	Total capital(to nearest £10,000)	**£110,000 (€170,000)**
Remove existing major weirs	Design and planning costs	£20,000 (€32,000)
	Land costs and compensation	£100,000 (€160,000)
	Site works	£150,000 (€245,000)
	Other	-
	Total capital(to nearest £10,000)	**£270,000 (€440,000)**
Note: [1] €1 is taken as £0.61 (all cost estimates are given to a maximum of two significant figures)		

Proforma 8: Estimated Operating Costs of Restoration Measures and Alternative Means

River Kennet – Hungerford to Newbury

Assumes time period of 30 years over which present value costs are incurred

Measure	**Cost Component**	**Cost Estimate**
Current modifications: channel drainage and field underdrainage (dredged channel); some flood embankments; weirs on main channel, structures where river/canal concurrent	Annual maintenance of drainage system	£10,000 per annum (€16,000)
	Dredging costs (every 7 years)	£10,000 (€16,000)
	Total present value costs (to nearest £10,000)	**£160,000 (€260,000)**
Raise river bed level, recreate longitudinal diversity in channel form	Each year for first 5 years	£8,000 per annum (€13,000)
	Annual	£2,000 per annum (€3,200)
	Total present value costs (to nearest £10,000)	**£60,000 (€98,000)**
Channel narrowing and creation of lateral channel diversity	Each year for first 5 years	£4,000 per annum (€6,600)
	Annual	£2,000 per annum (€3,300)
	Total present value costs (to nearest £10,000)	**£36,000 (€60,000)**
Removal of embanked sections	Each year for first 5 years	£4,000 per annum (€4,900)
	Annual	£2,000 per annum (€2,000)
	Total present value costs (to nearest £10,000)	**£36,000 (€60,000)**
Re-engineering for diversity in channel planform - meanders, etc	Each year for first 5 years	£6,000 per annum (€9,800)
	Annual	£2,000 per annum (€3,300)
	Total present value costs (to nearest £10,000)	**£50,000 (€82,000)**
Off-channel embankments	Annual mowing and inspection	£7,500 per annum (€12,000)
	Total present value costs (to nearest £10,000)	**£80,000 (€130,000)**
Remove existing major weirs	Annual	£0
	Total present value costs (to nearest £10,000)	**£0**

Note: [1] €1 is taken as £0.61 (all cost estimates are given to a maximum of two significant figures)

Proforma 9: Total Estimated Costs - Present Value Costs and Equivalent Annual Cost ***River Kennet – Hungerford to Newbury***				**Discount Rate: 6%** **Time Period: 30 years**
Measure	**Present Value Costs**		**Economic life of asset**[2]	**Net Costs (in PV)**
Current modifications: channel drainage and field underdrainage; flood embankments; culverts	Capital	£0	> 50 years	£0
	Operating	£160,000 (€260,000)		£16,000 (€260,000)
	Total[1]	**£160,000 (€26,000)**		**£16,000 (€260,000)**
Raise river bed level, recreate longitudinal diversity in channel form	Capital	£850,000 (€1,400,000)	> 50 years	£850,000 (€1,400,000)
	Operating	£60,000 (€98,000)		£60,000 (€98,000)
	Total[1]	**£910,000 (€1,498,000)**		**£910,000 (€1,498,000)**
Channel narrowing and creation of lateral channel diversity	Capital	£175,000 (€286,000)	> 50 years	£175,000 (€286,000)
	Operating	£36,000 (€60,000)		£36,000 (€60,000)
	Total[1]	**£210,000 (€346,000)**		**£210,000 (€346,000)**
Removal of embanked sections	Capital	£49,000 (€80,000)	> 50 years	£49,000 (€80,000)
	Operating	£36,000 (€60,000)		£36,000 (€60,000)
	Total[1]	**£85,000 (€140,000)**		**£85,000 (€140,000)**
Re-engineering for diversity in channel planform - meanders, etc	Capital	£215,000 (€350,000)	> 50 years	£215,000 (€350,000)
	Operating	£50,000 (€82,000)		£50,000 (€82,000)
	Total[1]	**£255,000 (€432,000)**		**£255,000 (€432,000)**
Off-channel embankments to protect properties	Capital	£110,000 (€170,000)	> 50 years	£110,000 (€170,000)
	Operating	£80,000 (€130,000)		£80,000 (€130,000)
	Total[1]	**£190,000 (€310,000)**		**£190,000 (€310,000)**
Remove existing major weirs	Capital	£270,000 (€440,000)	> 50 years	£270,000 (€440,000)
	Operating	£0		£0
	Total[1]	**£270,000 (€44,000)**		**£270,000 (€44,000)**

Notes: [1] all **Total** values are given to the nearest £/€10,000 (or to a maximum of two significant figures)
[2] if the asset is considered to have significant residual value this can be subtracted from the present value costs. Any residual values should be described in full with details given as to why the asset is considered to have residual value

Proforma 10: Cost Effectiveness of Restoration Measures and Alternative Means

River Kennet – Hungerford to Newbury

Measure	Achievement of Good Ecological Status - Length Affected (km)	Net Cost (Present Value)	Cost per km Delivered FULL - WHOLE REACH	Lower cost-effectiveness than other measures?	Cost per km Delivered FULL (PART REACH)	Lower cost-effectiveness than other measures?
Raise river bed level, recreate longitudinal diversity in channel form	10 km – part (part reach)	£910,000 (€1,498,000)			£91,000 (€150,000)	No, but would need to be packaged with another measure
Channel narrowing and creation of lateral channel diversity	5 km - part (part reach)	£210,000 (€346,000)			£42,000 (€69,000)	Unsure, would need to be packaged with another measure
Removal of embanked sections	2 km – part (part reach)	£85,000 (€140,000)			£43,000 (€70,000)	No, but would need to be packaged with another measure
Re-engineering for diversity in channel planform - meanders, etc	3 km – part (part reach)	£255,000 (€432,000)			£85,000 (€144,000)	Probably
Off-channel embankments to protect properties	1 km - part (part reach)	£190,000 (€310,000)			Not available – relative level of benefits is unknown	Yes – more expensive than measures which are likely to achieve full GES over a longer reach
Remove river management structures (weirs)	7km full (part reach)	£270,000 (€44,000)			£38,000 (€62,000)	No, but may need to be packaged with another measure

Notes: All Present Value costs are given to the nearest £10,000 (or to a maximum of two significant figures)
Measures which would achieve only partial GES (or would deliver full GES for only part of the whole reach) are compared to provide an indication as to which measures could be packaged together to achieve full GES across the whole reach

Proforma 11: Assessment Summary Table for Determining Disproportionate Costs *Measure: Raise bed levels, selective channel narrowing and remove major weirs*			*Discount Rate : 6%* *Time Period: 30 years* *Length achieving good ecological status: 10 km* *Net Present Value Costs: £1,400,000/€2,200,000*		
Impact Category	**Current Situation (Baseline)**	**Qualitative Description**	**Quantitative Data**	**Benefit/Cost Transfer Assessment**	
				Benefits	**Costs**
Water-Related Environment					
Water quality	Point source and diffuse pollution (nutrients) are issues. Overall water quality is good	Nutrient and sediment inputs from agriculture should be reduced	Would help to achieve GES	**Impact Rating**: *major positive* – affects 10km of the reach, mainly diversity of river bed, although bank habitat may also be improved **Nature Conservation Evaluation**: Category *B* – SSSI **Impact Assessment**: major positive and B – very large *benefit*	
Physical habitat		Major increase in diversity of in-channel and bank habitats for 10km	GES achieved for 10km stretch		
Conservation Importance:			N/a		
Designated sites	Kennet Valley SSSI	Would help to maintain existing designations, positive impact	N/a		
Non-designated sites	Sites of Community Wildlife Interest		N/a		
Plants		Major benefits for diversity and resilience of system. Colonisation from existing good quality areas.	Increased opportunities for plants along 10km stretch - increases chance of achieving GES		
Macro invertebrates		Increased diversity of habitats should encourage more diverse invertebrate fauna. Colonisation from existing good quality areas.	Increased macroinvertebrate status along 10km stretch		

Proforma 11: Assessment Summary Table for Determining Disproportionate Costs

Discount Rate : 6% *Time Period: 30 years*
Length achieving good ecological status: 10 km
Measure: Raise bed levels, selective channel narrowing and remove major weirs
Net Present Value Costs: £1,400,000/€2,200,000

Impact Category	Current Situation (Baseline)	Qualitative Description	Quantitative Data	Benefit/Cost Transfer Assessment	
				Benefits	Costs
Fish		Likely overall decrease in biomass, but major increase in resilience of system. Major increases in spawning / reproduction. Increase in nursery areas for fish using marginal vegetation. Improved connectivity.	Increased fish status along 10km stretch		
Recreation and Amenity					
Angling	Kennet is major salmonid fishery, but considerable stocking and inadequate natural recruitment	Major issues relating to willingness of fishery owners to change their existing practices to achieve a more natural Kennet.			
In-stream recreation	Presence of canal	Options will not affect running of canal	N/a		
Informal recreation	Quality of informal recreation areas is high, but limited access	Creation of new footpath access along river as part of re-engineering and agricultural set-aside works;			
Residential amenity	small number of properties located in the 1:100 flood plain area	Regeneration works may lead to increase in amenity value; potential gains captured by informal recreation benefits as no properties adjoining affected length)			
Commercial amenity					

Proforma 11: Assessment Summary Table for Determining Disproportionate Costs *Measure: Raise bed levels, selective channel narrowing and remove major weirs*			*Discount Rate : 6%* *Time Period: 30 years* *Length achieving good ecological status: 10 km* *Net Present Value Costs: £1,400,000/€2,200,000*		
Impact Category	**Current Situation (Baseline)**	**Qualitative Description**	**Quantitative Data**	**Benefit/Cost Transfer Assessment**	
				Benefits	**Costs**
Priced Uses of Waterbody					
Public water supply	Existing abstractions	Either not affected or measures could benefit security of water supply	N/a	Minor positive	
Industrial water use		N/a	N/a	No impact on industrial water use	
Agricultural water use and productivity		Loss of 100-500 ha of Grade 1/2 agricultural land included in costs of measure;	N/a		Costs included in costs of measure (see Proforma 7)
Commercial fisheries/shellfisheries		No commercial fisheries/shellfisheries	N/a	No commercial fisheries/shellfisheries	
Wider Environment					
Archaeology	Some existing sites	No data	N/a	Minor negative	
Heritage	Several existing sites e.g. mills	Mitigation may be required, but not infeasible	N/a		
Landscape and geomorphology		Improvement in landscape through creation of more natural river valley; river now plays virtually no role in landscape quality	Landscape along a 3km stretch of river to be improved	*Intermediate positive*	
Townscape		Works outside Newbury	N/a	Slight positive	
Air quality:					
Local		No impacts expected – measure does not affect local air quality	N/a	No impact on local air quality	
Regional		No impacts expected – measure does not affect regional air quality	N/a	No impact on regional air quality	

Proforma 11: Assessment Summary Table for Determining Disproportionate Costs

Measure: Raise bed levels, selective channel narrowing and remove major weirs

Discount Rate : 6% *Time Period: 30 years*
Length achieving good ecological status: 10 km
Net Present Value Costs: £1,400,000/€2,200,000

Impact Category	Current Situation (Baseline)	Qualitative Description	Quantitative Data	Benefit/Cost Transfer Assessment	
				Benefits	Costs
Global		No impacts expected – measure does not affect global air quality	N/a	No impact on global air quality	
Waste		No impacts expected – measure result in additional waste being generated	N/a	No impact on waste	
Energy		No impact expected – measure does not result in a change in the amount of energy being consumed	N/a	No impact on energy (consumption or generation)	
Wider Economic Impacts					
Employment	Agriculture, fisheries	Some gains, some losses	N/a	No impact or slight negative effect on employment	
Regeneration/development		No impacts likely – regeneration/development areas not affected	N/a	No impact on regeneration/development	
Tourism		Likely increase in visitors to the area	Not known	Not possible to value – may be moderate	
Competitiveness		No impacts expected – measure does not affect businesses	N/a	No impact on competitiveness	
Property (i.e. flood damages)	Some existing risk	Possible positive or negative effects – ie floodplain storage.	Requires further modelling	No change in flooding risk	
Infrastructure (transport)		No impacts			Not possible to value
Social Considerations					
Social inclusion/cohesion		N/a	N/a	No impact on social inclusion/cohesion 'neutral' area	

Proforma 11: Assessment Summary Table for Determining Disproportionate Costs *Measure: Raise bed levels, selective channel narrowing and remove major weirs*				*Discount Rate : 6%* *Time Period: 30 years* *Length achieving good ecological status: 10 km* *Net Present Value Costs: £1,400,000/€2,200,000*	
Impact Category	**Current Situation (Baseline)**	**Qualitative Description**	**Quantitative Data**	**Benefit/Cost Transfer Assessment**	
				Benefits	**Costs**
Equity	N/a	Losses to farmers and fishery owners that are not offset by gains to them		Environment, local residents and visitors (recreation)	Farmers and fishery owners
Policy Integration		No relevant policies identified	N/a	No impact on policy integration (*neutral*)	
Summary of Results and Sensitivity	**Net Present Value Costs of Measure**				£1,400,000 (€2,200,000)
	Additional Present Value Costs				None quantified
	Total Quantified Present Value Costs				£1,400,000 (€2,200,000)
	Total Annual Benefits			Significant	
	Present Value Benefits (Benefit Transfer) - discounted at 6% over 30 years			Significant	
	Notes on benefit estimate and sensitivity analysis - Further investigations required on extent of loss of agricultural land, and costs and benefits to fishery owners - Both costs and benefits high				
	Designation Decision and reasons: Costs outweigh benefits slightly (sensitivity analysis shows benefits could outweigh costs); significant qualitative benefits (particularly environmental) Need further quantification of ecosystem (sustainability) functions of benefits			*Not HMWB or borderline*	