Evidence

Appraisal of river restoration effectiveness: Seven Hatches case study

Report – SC070024/a

We are the Environment Agency. We protect and improve the environment and make it a better place for people and wildlife.

We operate at the place where environmental change has its greatest impact on people's lives. We reduce the risks to people and properties from flooding; make sure there is enough water for people and wildlife; protect and improve air, land and water quality and apply the environmental standards within which industry can operate.

Acting to reduce climate change and helping people and wildlife adapt to its consequences are at the heart of all that we do.

We cannot do this alone. We work closely with a wide range of partners including government, business, local authorities, other agencies, civil society groups and the communities we serve.

This report is the result of research commissioned and funded by the Environment Agency.

Published by:
Environment Agency, Horizon House, Deanery Road, Bristol, BS1 5AH

www.environment-agency.gov.uk

ISBN: 978-1-84911-345-8

Further copies of this report are available from our publications catalogue:
www.gov.uk/government/publications

or our National Customer Contact Centre:
T: 03708 506506

Email: enquiries@environment-agency.gov.uk

Dissemination Status:
Publicly available

Keywords:
Water Framework Directive; hydromorphology; evidence base; best practice; river restoration; monitoring

Research Contractor:
Royal Haskoning UK, Burns House, Harlands Road, Haywards Heath, West Sussex RH16 1PG, UK
Tel: 0144 445855

Environment Agency's Project Manager:
Natalie Kieboom (nee Phillips), Judy England ,
Evidence Directorate

Collaborator(s):
River Restoration Centre, Environment Agency staff

Project Number:
SC070024/a

Evidence at the Environment Agency

Evidence underpins the work of the Environment Agency. It provides an up-to-date understanding of the world about us, helps us to develop tools and techniques to monitor and manage our environment as efficiently and effectively as possible. It also helps us to understand how the environment is changing and to identify what the future pressures may be.

The work of the Environment Agency's Evidence Directorate is a key ingredient in the partnership between research, guidance and operations that enables the Environment Agency to protect and restore our environment.

This report was produced by the Scientific and Evidence Services team within Evidence. The team focuses on four main areas of activity:

- **Setting the agenda**, by providing the evidence for decisions;
- **Maintaining scientific credibility**, by ensuring that our programmes and projects are fit for purpose and executed according to international standards;
- **Carrying out research**, either by contracting it out to research organisations and consultancies or by doing it ourselves;
- **Delivering information, advice, tools and techniques**, by making appropriate products available.

Miranda Kavanagh

Director of Evidence

Executive summary

This report presents the findings of the primary case study carried out as part of an appraisal of river restoration schemes designed to help achieve Water Framework Directive (WFD) objectives. The case study was one element of a study carried out as part of the broader Environment Agency project, 'Managing Hydromorphological Pressures in Rivers'.

The case study featured a site known as Seven Hatches on the River Wylye in Wiltshire which was restored as part of the STREAM (Strategic Restoration and Management) project. The restoration scheme, which was implemented in 2007, involved:

- channel narrowing
- introducing gravel riffles
- erecting a fence to prevent livestock access to the river
- selective tree felling
- a planting scheme

Monitoring showed that all hydromorphology objectives were met in the direct vicinity of these measures. However, it was not possible to determine the magnitude of change accurately due to the relatively short timescale for monitoring when no geomorphologically relevant flow events took place , therefore the full effects the restoration measures may take several years to manifest in hydromorphological terms.

Assessment against the biological objectives indicated that overall macrophyte coverage and the extent of species that prefer faster flowing water had increased at the restoration site. However, it was not possible to attribute the improvement to the restoration measures because an even greater response was observed at the control site, though this was not seen in the wider catchment. Further changes may become evident as the scheme adjusts following geomorphologically effective flows.

The impact of the restoration works on macroinvertebrates was difficult to ascertain due to the high species diversity at both the restoration and control sites before the restoration and a lack of replicate survey data. The restoration measures appeared to have been initially successful in increasing the population of fish that prefer faster flowing water but the number of these species caught in 2009 fell. A review of wider catchment context and further monitoring to assess long-term trends are therefore recommended.

Despite not being able to draw firm conclusions on the response to restoration of some aspects of the river biology, the scheme is deemed effective in localised areas in providing hydromorphological conditions that are more conducive for the range of biological quality elements expected in the river. The full impact of the changes to macrophytes, macroinvertebrates and fish is expected to materialise over a longer timeframe.

The approach taken for the restoration at Seven Hatches is transferable to other chalk streams however, the effects of river restoration are likely to be localised, particularly in the short to medium term and may not be detected at the water body scale. Such measures should therefore be targeted by careful planning at the catchment or river basin district scale for optimum environmental improvement. A better understanding of hydromorphology-ecology relationships will help us refine our expectations and set

more realistic objectives for schemes and help us prioritise restoration measures to achieve water body changes.

The report highlights a number of lessons learnt relating to scheme design and implementation, setting of objectives, monitoring approach and sharing experiences.

- Understanding how restoration measures impact on restoring hydromorphological processes will improve our ability to design successful schemes. Key to this will be ensuring that processes and pressures are considered at a catchment scale and measures implemented on strategic catchment based approach.
- It is important to set project and monitoring objectives that link hydromorphological change and ecological response and assess using a scientific approach.
- Objectives should be set with consideration of the catchment context, historic conditions and any other pressures. Where multiple pressures are influencing the ecological status the assessing the success of a restoration scheme may rely on measuring hydromorphological changes.
- Objectives should take into account timescales of recovery and monitoring data should be collected over a sufficiently long time period to give the system time to re-equilibrate. Each river system will be different and a degree of flexibility must be built into the monitoring strategy to make best use of resources.
- Communicate results to improve the evidence base and establish what restoration techniques work in which situations and which monitoring techniques work best. It is equally important to understand where schemes have worked and where they have been unsuccessful.

The monitoring methods used in the case study are detailed in an accompanying report, *Appraisal of River Restoration Effectiveness: Seven Hatches Monitoring Report.* Two further reports present the findings from a secondary case study involving the restoration of the Shopham Loop on the River Rother in West Sussex and the monitoring methods used in that case study.

Contents

1 Introduction

This project is part of a broader Environment Agency project, 'Managing Hydromorphological Pressures in Rivers', which seeks to provide practitioners with examples of how to manage hydromorphological and sediment pressures in catchments to aid the delivery of the Water Framework Directive (WFD). This study is one of many projects working towards improving our understanding of hydromorphology-ecology interactions and providing evidence to improve the confidence of the decisions we make.

This part of the project focuses on how we can assess of the effectiveness of river restoration schemes for the Water Framework Directive and transfer the lessons learnt. It uses the Seven Hatches river restoration scheme on the River Wylye as the primary case study and the Shopham Loop scheme on the River Rother in West Sussex as a secondary case study (Environment Agency 2014a).

This report on the Seven Hatches restoration scheme presents findings from the scheme that may have broader application for those involved in river restoration. The report documents the effects of the scheme on the physical and biological quality elements of the Water Framework Directive. It considers the scale and transferability of the restoration techniques and whether the approaches can be effectively scaled up or down, or applied across river types. The report discusses the scheme design and the lessons learned as a result of the scheme's implementation.

The information on which this report is based was gathered through discussions with Environment Agency staff involved in the restoration scheme at Seven Hatches.

1.1 Structure of this report

Section 2 presents the background to the restoration project including the baseline conditions and the project's aims and objectives.

Section 3 describes the preliminary studies, the main engineering tasks required to implement the scheme and the monitoring carried out post-restoration. It also considers the lessons learnt and recommendations for future schemes.

Section 4 presents the WFD relevant objectives set as part of the project and makes an initial assessment of the hydromorphological and biological impacts of the scheme at the time of writing.

Section 5 provides brief conclusions and summarises the lessons learnt from the Seven Hatches scheme.

An accompanying monitoring report provides further details of the monitoring performed (Environment Agency 2014b). It describes the analysis techniques and interpretation of results used to assess the effectiveness of the restoration scheme against WFD objectives.

2 Seven Hatches restoration

2.1 Introduction

The STREAM (Strategic Restoration and Management) project was a £1 million four-year conservation project centred on the River Avon and the Avon Valley in Wiltshire and Hampshire with financial support from the European Commission's LIFE-Nature programme. The River Avon and its main tributaries are designated as a Special Area of Conservation (SAC) and the Avon Valley is designated as a Special Protection Area (SPA) for birds.

A conservation strategy for the River Avon SAC (Wheeldon 2003) identified the main issues affecting the ecological health of the River Avon SAC, and agreed on a range of actions required to address them. It also highlighted the complex relationship between the river and the Avon valley.

The STREAM project (2005-2009) tackled the effects of past engineering and loss of good quality habitat by restoring the river channel at six sites. The project's achievements included:

- improving over 7 km of river habitat
- restoring suitable conditions for the River Avon SAC habitats and species
- demonstrating innovative techniques and proven habitat enhancement methods
- sharing best practice through advice notes, demonstration days, conferences, seminars and public open days

2.2 Pre-restoration

One of the six sites selected for restoration in the STREAM project was Seven Hatches, located on the River Wylye in Wiltshire just upstream of Wilton (Figure 2.1). The River Wylye is a tributary of the River Nadder, which meets the River Avon before flowing through Salisbury to the sea at Christchurch. The River Wylye rises through the Upper Greensand springs upstream of Kingston Deverill and reaches the River Nadder upstream of Wilton. The Wylye catchment is 430 km^2 and the river itself is 54 km long with two main tributaries – the Chitterne Brook and the River Till.

The Wylye has candidate SAC (cSAC) status and the length of the river is a Site of Special Scientific Interest (SSSI). The proposal for cSAC designation is based on the presence of several internationally rare or threatened species such as:

- brook lamprey (*Lampetra fluviatilis*)
- bullhead (*Cottus gobio*)
- Atlantic salmon (*Salmo salar*)
- Desmoulins' whorl snail (*Vertigo moulinsiana*)

In addition, communities of water crowfoot (*Ranunculus penicillatus* var. *pseudofluitans)* are present through most of the river.

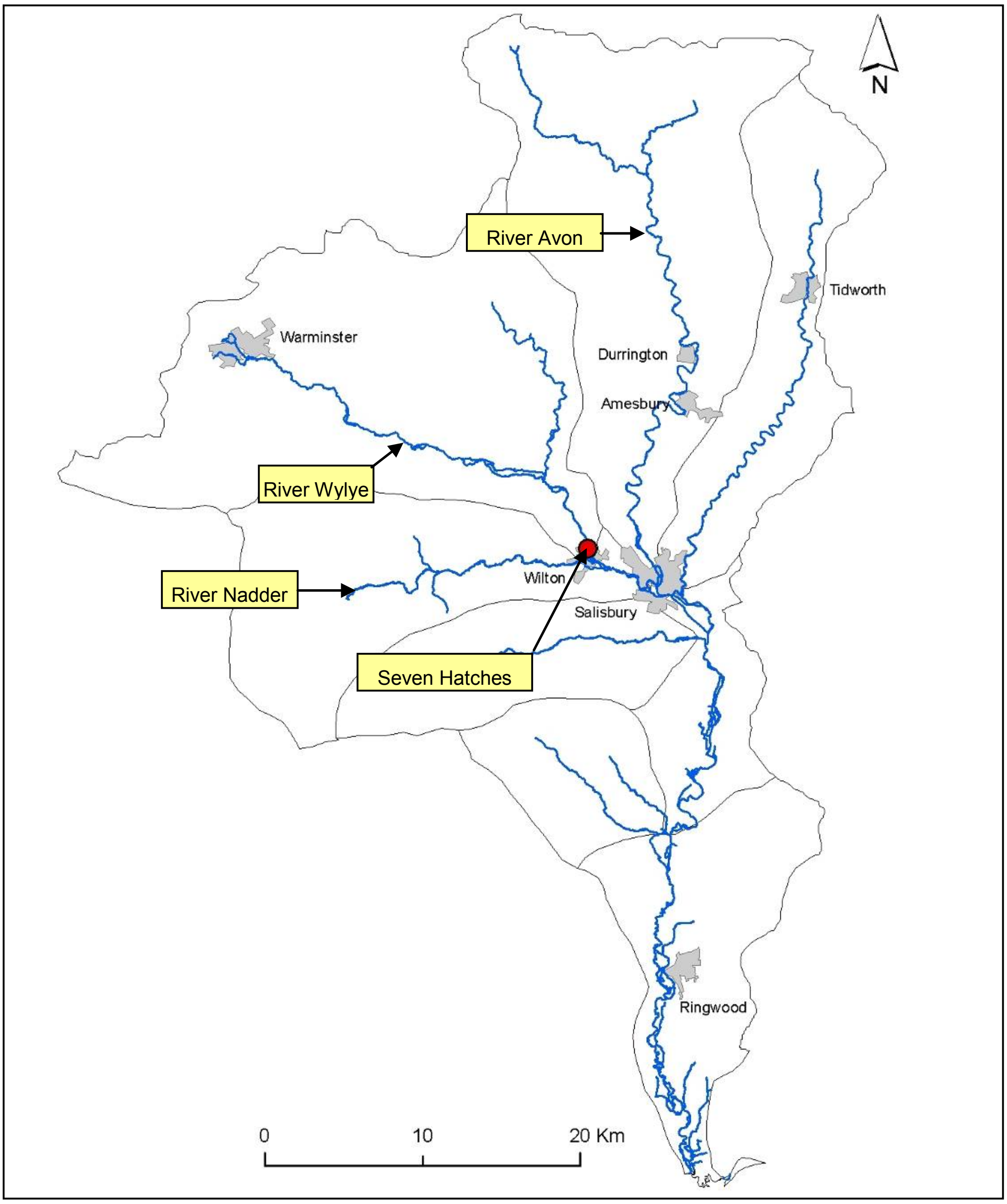

Figure 2.1 Location of Seven Hatches

The Avon system, including the River Wylye, has an extremely diverse fish fauna including wild populations of migratory sea trout (*Salmo trutta*) and brown trout. A wide range of coarse fish is present including:

- minnow (*Phoxinus phoxinus*)
- three-spined stickleback (*Gasterosteus aculeatus*
- dace (*Leuciscus leuciscus*)
- stone loach (*Noemacheilus barbatulus*)
- pike (*Esox Lucius*)
- grayling (*Thymallus thymallus*)
- eel (*Anguilla Anguilla*)
- perch (*Perca fluviatilis*)

- roach (*Rutilus rutilus*)
- gudgeon (*Gobio gobio*)

The location of the reach selected for restoration is shown in Figure 2.2. The location of the control reach and the reasons for its selection are given in the accompanying monitoring report (Environment Agency 2014b).

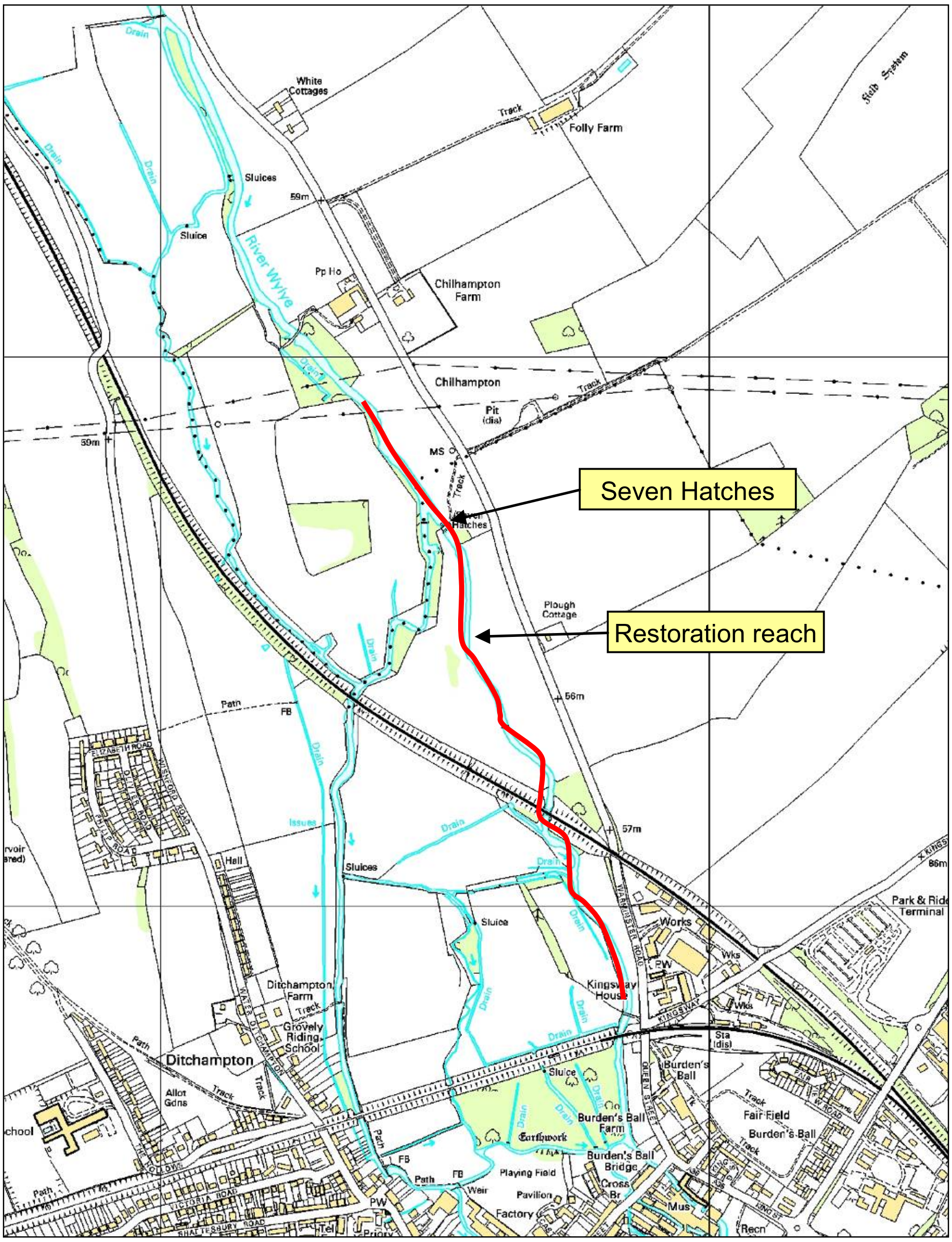

Figure 2.2 Location of restoration reach

2.2.1 Historical modifications

The River Wylye at Seven Hatches was selected as one of the restoration sites because of the degraded nature of the channel. Past land drainage work had resulted in a reduction of bed level, loss of hard bed substrate, over-widening of the channel, and the creation of raised flood banks, with an associated loss of hydrological connectivity with the floodplain over much of the project reach (RRC 2009). In addition, the large modern radial gates that replaced the historical structure that gave the site its local name are impounding upstream water levels with associated deposition of fine sediments (Figure 2.3).

Figure 2.3 Impoundment upstream of Seven Hatches

The slower flows (Figure 2.4) and resulting siltation from the impoundment and historical land drainage had damaged favourable status for the *Ranunculus* macrophyte community and resulted in the absence of salmon spawning (RRC 2009).

The paucity of large woody debris had reduced the morphological variation present in the river, with an associated reduction in habitat quality and availability for, amongst others, bullhead, Atlantic salmon, brook lamprey and *Ranunculus*.

Riparian vegetation had also been restricted by cattle grazing on the adjacent floodplain and a line of poplar trees on the left hand bank was resulting in overshading along the reach.

Figure 2.4 Slow uniform flow conditions due to historical modifications

2.2.2 Baseline conditions

The restoration scheme was completed in 2007. Prior to restoration, the large radial gates (Seven Hatches) were impounding upstream water levels and resulting in slow, laminar and uniform flow conditions in the river. In combination with historical modifications to the channel width and depth, this was leading to the deposition of fine sediments on the channel bed. The channel displayed little morphological diversity with associated impacts on biological conditions.

Downstream of Seven Hatches, a scour pool and riffle are present and downstream of the railway crossing there is a more varied section of alternating pools and riffles. In the reach between Seven Hatches and the railway bridge, the dominant sediment process was deposition of silt on the channel bed. Toe undermining was also occurring in localised areas along the right hand bank which, combined with cattle poaching, was sourcing fine sediment to the channel.

The pool–riffle reach downstream of the railway crossing is geomorphologically active. It exhibits cliff erosion and deposition of gravels as discrete point bar deposits. This reach terminates at a widened section where two field drains join the main channel sourcing fine sediment to the channel.

Ranunculus growth throughout much of the project reach was poor. Conditions for spawning and juvenile salmonids were generally poor.

2.2.3 Water Framework Directive catchment context

The environmental objectives for the River Wylye are outlined in the South West River Basin Management Plan (Environment Agency 2009). Seven Hatches is located within water body GB108043022510 (Lower Wylye).

The water body is currently designated as heavily modified, due to flood protection and urbanisation, and of moderate ecological potential. The current potential of the Lower Wylye for fish is ‘moderate’ and for macroinvertebrates ‘high’.

The fish classification is based on the Environment Agency’s Fisheries Classification Scheme 2 (FSC2) fish diagnostic data. This tool assesses the probability of catching an equal or lower number of fish than that observed under reference conditions. At the catchment scale, the diagnostic results show that observed minnow catches are less than expected across the half of the sites in the Wylye catchment (that is, four of the eight sites). The numbers of stoneloach, chub and salmon are less than expected at two of the eight sites. A limitation of the data is that the monitoring surveys used for the fish classification in this water body typically focus on salmonids so smaller fish (that is, minnow, stoneloach, spine loach, three-spined stickleback and bullhead) can easily be missed. This is not expected to be a significant problem in the Wylye due to the type of river (Peirson G, personal communication).

Two of the eight sites, South Newton and Chilhampton Farm, are located near Seven Hatches. The South Newton site is at good status, although observed minnow numbers are low. The status at Chilhampton is poor due to low observed numbers of minnow. However, as outlined previously this is not expected to be a significant problem.

It should also be noted that the high macroinvertebrate potential classification may be misleading, as this principally describes water quality status. Hydromorphological stress (flow/sediment) will not be detected by current WFD macroinvertebrate classification procedures.

A number of mitigation measures are in place within the water body including:

- appropriate channel maintenance strategies and techniques

- retention of marginal aquatic and riparian habitats

Full details of the condition of the water body and mitigation measures are provided in Table 2.1.

Table 2.1 Details of water body GB108043022510

Water body ID	GB108043022510
Water body name	Lower Wylye
Ecological potential	Moderate
Status objectives	Good ecological potential by 2027
Hydromorphological designation	Heavily modified (due to flood protection, urbanisation)
Biological elements	Fish: currently moderate Invertebrates: currently high
Hydromorphological supporting conditions	Quantity and dynamics of flow: currently supports good potential
Mitigation measures	**In place** • Appropriate channel maintenance strategies and techniques – woody debris • Appropriate channel maintenance strategies and techniques – minimise disturbance to channel bed and margins • Sediment management strategies (develop and revise) • Retain marginal aquatic and riparian habitats (channel alteration) • Appropriate techniques (invasive species) • Appropriate timing (vegetation control) • Appropriate vegetation control technique • Selective vegetation control regime • Increase in-channel morphological diversity **Not in place** • Educate landowners on sensitive management practices (urbanisation) • Operational and structural changes to locks, sluices, weirs, beach control and so on • Improve floodplain connectivity • Alteration of channel bed (within culvert) • Re-opening of existing culverts

Source: Environment Agency (2009)

2.3 Aims and objectives

2.3.1 Original aims and objectives

Within the STREAM project, the specific objectives at Seven Hatches were to:

- modify the operation of Seven Hatches sluices, reducing height by an average of 0.15 m, thus increasing ecological connectivity between reaches and improving upstream habitat quality
- restore the historic bed level and increase the heterogeneity of bed morphology in previously dredged reaches by the reclamation and reintroduction of excavated gravel/stone bed material
- narrow over-wide channels where necessary to re-establish a sinuous channel of appropriate cross-sectional area with respect to present day hydrographs
- increase the amount of large woody debris in the channel to increase the availability of this habitat type and the morphological diversity of the channel
- break out and remove the tractor bridge footings and replace with a single span bridge, thus eliminating the impounding effect of the structure
- enhance the availability and quality of habitat for SAC species and habitats, in particular:
    - bullhead – increased diversity of hard bed, particularly pools during winter and insertion of large flints in new riffle/fast glides during summer and increased shading/large woody debris (particularly for juveniles)
    - salmon – a more usable migration route, viable spawning sites, and appropriate habitat for fry and parr
    - brook lamprey – increased availability of well sorted, fine sediment in shaded, marginal areas with large woody debris for ammocoetes and gravel/sand dominated shallows <40 cm deep for spawning adults
    - Desmoulin's whorl snail – marginal zone enhancement of all channels
    - *Ranunculus* community – by increasing heterogeneity in velocity and bed morphology

2.3.2 Water Framework Directive relevant objectives

The Seven Hatches restoration scheme was not implemented specifically to meet the requirements of the Water Framework Directive. This project therefore developed objectives relevant to the Water Framework Directive which could be used to measure the success of the restoration scheme. These objectives were set according to the SMART system (Specific, Measurable, Achievable, Realistic and Time-bound) as presented for the STREAM restoration project at Seven Hatches in a report by the River Restoration Centre (RRC 2009).

The hydromorphological objectives were developed by considering the pre-restoration issues within the reach in relation to the quality elements identified in the Water Framework Directive:

- hydrological regime
- river continuity
- morphological conditions

After assessing the issues, a link was made between each issue and the likely impact of specific restoration measures on the issue. Draft objectives were set based on the expected hydromorphological changes resulting from the restoration scheme. The issues identified, the relevant restoration measures and the description of the expected hydromorphological change are outlined in Table 2.2.

Table 2.2 Expected hydromorphological changes resulting from restoration scheme

Hydromorphological quality element	Description of the problem	Relevant restoration measures	Description of expected hydromorphological change
Hydrological regime			
Quantity and dynamics of flow	Historical channel modifications (widening and deepening) resulting in slow flows and lack of flow diversity	Installation of aquatic ledge Bed raising	Localised change in water depth Increased localised flow diversity No change in impounding effect
River continuity			
Continuity providing for migration of aquatic organisms and sediment transport	Possible issues with fish migration and sediment transport due to South Newton gauging weir and Seven Hatches	Restoration does not include structural modifications to in-channel barriers	Not applicable
Morphological conditions			
Channel patterns	Previous dredging has resulted in a uniform, straight channel with low morphological diversity	Installation of aquatic ledge (locally narrowing channel) and changes to riparian vegetation	Flow sinuosity will be promoted by the aquatic ledge and depositional features associated with increased flow variability caused by the ledge and riparian zone
Width, depth variation	Seven Hatches was previously dredged and was therefore of uniform width and depth	Installation of aquatic ledge locally narrowing channel and raising of channel bed	Increased variation in localised depth and width due to bed raising and channel narrowing and increased diversity of riparian zone

Hydromorphological quality element	Description of the problem	Relevant restoration measures	Description of expected hydromorphological change
Flow velocities	Historical channel modifications (widening and deepening) resulting in slow flows and lack of flow diversity	Installation of aquatic ledge	Increased morphological diversity in local restored areas Increased localised flow velocities due to creation of riffles
Substrate conditions	Seven Hatches was previously dredged resulting in slow flows and siltation on the channel bed. Livestock trampling the banks has increased sediment supply to the channel	Gravel import. Installation of aquatic ledge	Decreased localised siltation due to higher flow velocities More localised areas of gravel substrate
Structure and condition of riparian zone	Livestock trampling the riverbank damaging structure and condition of riparian habitat and refuge (in addition to increasing erosion causing increased sediment supply – see substrate condition)	Fencing and creation of drinking areas to stop cattle trampling the river banks	Increased height of vegetation Increased coverage of vegetation

The hydromorphological and biological WFD objectives developed for the Seven Hatches site are presented in Table 2.3, together with the type of data that can be used to assess them. Further details on the development and rationale for these objectives, together with the results of data analysis are provided in the accompanying monitoring report (Environment Agency 2014b).

Table 2.3 WFD relevant objectives

Objectives	Data to be used to assess objectives
Hydromorphological	
• Increased variation in depth and width within three years of implementation	• Variability in width and depth identified from cross-sections • Long profile
• Increased localised and average velocities immediately after restoration	• Velocity measurements recorded in 2006 and 2008 • Visual assessment of flow types from repeat photography
• Increased area and frequency of exposed gravel substrate within three years of implementation	• Substrate observations taken in 2006 and 2008 • Repeat photography
• Increased height and coverage of riparian vegetation within a year of implementation	• River corridor survey • Repeat photography
• Increased morphological diversity (based on width, depth and sinuosity and in-channel features) within three years of implementation	• Physical biotope mapping • Variability in width and depth identified from cross sections
Biological	
Macrophytes	
• Increase percentage cover of macrophytes within one year of implementation (excluding negative indicator species and invasive species) • Increase in number of macrophyte species preferring faster flows within one year of implementation • Decrease in number of macrophyte species preferring slower flows within one year of implementation	• Compare species lists, species coverage and presence of indicator species
Macroinvertebrates	
• Increase in macroinvertebrate species diversity within three years of implementation • Increased evenness of macroinvertebrate community within three years of implementation • Increase in species preferring faster flows (LIFE) and increase in the proportion of sediment-sensitive invertebrates (PSI) within three years of	• Community Conservation Index (CCI) • Lotic Invertebrate index for Flow Evaluation (LIFE) • Ecological Quality Ratio (EQR) calculated using the River Invertebrates Classification Tool (RICT) • Proportion of Sediment-sensitive Invertebrates (PSI)

Objectives	Data to be used to assess objectives
implementation • Increase in conservation value (CCI) within three years of implementation • High quality WFD status of benthic macroinvertebrates maintained (EQR)	• Number of taxa (NTAXA) • Average score per taxon (ASPT)
Fisheries	
• Increased abundance of fish species preferring clean fast-flowing water within three years of implementation	• Comparison of number of fish caught • Comparison of size frequency data and densities for the three key species (salmon, lamprey and bullhead) • Comparison of populations of other fish species preferring clean fast flowing water • Comparison of size frequency data and densities
• An increase in density and diversity of rheophylic juvenile species in the first year after completion when the gravel substrate is still relatively unstable.	• Comparison of number of juvenile rheophylic species before and after restoration
• Spawning on the new gravel areas once stabilised, subject to winter flows which have a direct effect on spawning range	• Observed spawning post-restoration

3 Details of restoration scheme

3.1 Introduction

Some aspects of the original proposals for the restoration scheme were not implemented as summarised below.

- There was insufficient gravel onsite to construct the riffles and it was therefore necessary to purchase material from a local supplier.
- The tractor bridge at the downstream end of the site was not removed as a topographic survey showed that there was no hydraulic benefit.
- Regrading banks and introducing gravel downstream of the railway bridge was not carried out due to practicalities concerning access and the cost implications.
- Only selected tree felling was performed rather than removal of all the poplar trees on the left hand bank to balance landscape and ecological needs.
- Trees were planted within the buffer strip to comply with planning permission obligations.
- Changes to the operation of Seven Hatches have not occurred due to concerns raised over potential flooding issues in Wilton; raising the hatches would mean less water is diverted down the 'Butcher Stream'[1] and flood risk would increase in the main channel. Butcher Stream is also considered to provide habitat for salmon and changes to the flow regime could impact on this habitat.

The following sections outline the preliminary studies and engineering required to implement those elements of the scheme that were progressed.

3.2 Scheme elements

3.2.1 Preliminary studies

During the design of the restoration scheme, hydraulic modelling was performed by consultants to assist with the design of the proposed riffles. The aim of the modelling was to:

- predict the impact of the riffles on flow velocities within the reach
- ensure that downstream flood risk would not be increased

3.2.2 Channel narrowing

The berm (Figure 3.1) was created by placing large tree trunks perpendicular to the bank with a line of posts along the front edge. Large wood deflectors were also placed so as to protrude further out into the channel. Brushwood was then placed within the

[1] Immediately above the sluices at Seven Hatches, the River Wylye splits into two channels just above the sluices – the main Wylye (known locally as the 'Union') and the Butcher Stream.

structure and soil was used to backfill the structure. The brushwood and soil were then topped off with pre-planted coir mats and the whole structure was cross-wired together. The coir mats had been planted with reed canary grass, water mint, yellow flag, water parsnip and marsh marigold. The deflectors narrowed the channel by 3–3.5m.

Figure 3.1 Channel narrowing berm in 2008 (one year after installation)

3.2.3 Reintroducing gravel bed material

Gravels were imported to create riffles in the reach between Seven Hatches and the railway bridge. The base of the riffles was constructed using larger material (approximately 200 mm in diameter), which was topped with gravel (20–60 mm in diameter). Three riffles, each approximately 50 m long, were created in this section. The aim of the riffles was to create varied flow dynamics and habitat suitable for salmon and trout spawning. In addition, four large log deflectors were installed on each riffle to provide increased localised flow diversity.

3.2.4 Deep water log deflectors

Downstream of the railway line, two tree deflectors were installed on the left hand bank. The trees are held in place with vertical wooden stakes and are creating localised flow diversity.

3.2.5 Erection of fence to prevent stock access

A fence was erected on both banks, upstream and downstream of Seven Hatches. The fence is set-back 11 m from the bank top and is designed to restrict livestock access to the bank top to prevent grazing and poaching of the banks.

Cattle drinking areas were created to retain access for the cattle to the river channel in short localised sections.

Erection of a fence has encouraged the establishment of riparian vegetation by restricting livestock access to the bank top. However, the area within the fence requires careful management to ensure an appropriate habitat is maintained.

3.3 Implementation

The restoration scheme was implemented in 2007 by contractor Clancy Docwra under the Environment Agency minor works framework. Onsite health and safety and site supervision was provided by Halcrow.

One of the aims of construction was to minimise waste and, as such, the earth material that was excavated to form the cattle drinking areas was reused to backfill the aquatic ledge. The wood material for deflectors and the aquatic ledge was sourced onsite, although some hazel bundles were purchased and imported. In addition, an accredited source of material was used for the site compound so that, on completion, the material could be used to fill farm tracks rather than being transported offsite.

3.4 Photographic record of restoration scheme

The photographs below were taken pre (2006) and post (2009) restoration and highlight the impact the restoration measures have had on the reach.

The photographs in Figure 3.2 were taken upstream of Seven Hatches and show the berm constructed to narrow the channel. The berm has become colonised by emergent vegetation and is likely to be increasing flow velocities in this section of the reach.

(a) **(b)**

Figure 3.2 Upstream of Seven Hatches (a) before (2006) and (b) after (2009) construction of beam to narrow the channel

The photographs in Figure 3.3 show a section of the reach where a gravel riffle has been constructed. The flow was slow and uniform pre-restoration (Figure 3.3a), but post-restoration, flow depth has decreased and localised velocities have increased, creating more diverse morphological conditions (Figure 3.3b).

(a) (b)

Figure 3.3 Downstream of Seven Hatches (a) before (2006) and (b) after (2009) construction of a gravel riffle

Figure 3.4 shows the increase in emergent vegetation at the channel margins between 2006 and 2009. There was also an increase during this period in the height of riparian vegetation in response to restricting livestock access.

(a) (b)

Figure 3.4 Extent of emergent vegetation at the channel margins downstream of Seven Hatches (a) before (2006) and (b) after restoration (2009)

3.5 Monitoring

As part of the STREAM project, pre (2006) and post (2008) restoration monitoring was carried out at the restoration and control sites to:

- document the restoration works
- identify their possible influence on the physical habitat and ecology at the site

The surveys performed as part of the STREAM project were repeated in 2009-2010 to allow for a more robust analysis and assessment as part of this project. Some additional surveys were also carried out to enable the success of the scheme to be assessed against the WFD relevant objectives more effectively.

The accompanying monitoring report (Environment Agency 2014b) provides further details on the monitoring and analysis underpinning the results and conclusions presented in this case study report. Readers are recommended to read the monitoring report for a more detailed technical explanation of the methods and techniques employed.

4 Hydromorphological and biological response

This section summarises the impact of the restoration scheme against the hydromorphological and biological objectives. For further information see the monitoring report (Environment Agency 2014b), which documents the methods and results of data analysis.

4.1 Hydromorphological

The restoration measures implemented at the restoration site have caused increased variation in width and depth. The restoration measures have caused increased localised velocities along the length of each gravel riffle in the restoration reach (approximately 180 m of the 500 m reach). Some of this increase is likely to be attributable to natural variations as a result of increased water levels, as shown in the results at the control site.

The restoration measures have increased the extent of exposed gravel substrate. This is as a direct result of importing gravel to create riffles. Although there is some evidence of increased gravel material where riffles have not been created, changes to the substrate at the control site mean that these are more likely to be attributable to natural processes within the system rather than as a result of the restoration.

The restoration measures have increased the height and coverage of riparian vegetation in absolute terms. This is directly attributable to the erection of the buffer strip fence. Some increase in height and coverage of vegetation would be expected due to natural growth patterns and this is confirmed by the increase evident at the control site.

The monitoring of the scheme demonstrated some indicators of hydromorphological change. At the time of the monitoring the overall effectiveness of the measures was limited to those parts of the reach that have been directly restored, probably as a result of the relatively short timescales over which monitoring has taken place. More significant changes are likely to occur in the future (for example, after geomorphologically effective flood flows) as the river gradually adjusts to the altered conditions. However, in low energy rivers such as the Wylye, the frequency of geomorphologically relevant events is likely to be low and therefore the full effects the restoration measures may take several years to manifest in hydromorphological terms.

4.2 Biological

4.2.1 Macrophytes

Macrophyte cover at the restoration site has increased since the restoration measures were implemented, although this increase is considerably smaller than that observed at the adjacent control reach. Compared with the wider catchment data, the increases observed at the restoration site appear more significant. Macrophyte coverage at the restoration site is likely to have been impacted during the restoration works when gravel substrate was placed on the existing channel bed. Re-establishment of macrophytes is likely to occur over a longer timeframe and this could explain the lower overall percentage increase.

The proportion of macrophyte species that prefers swift flows has increased at the restoration site. This corresponds to the velocity measurements which found that velocities increased at the restoration site post-restoration. However, the increase in proportion of macrophyte species is considerably smaller than that observed at the control site, where velocities increased, but to a lesser extent (see section 4.1). Comparison of the results with wider catchment data shows that the rapid increase observed at the control site has not been replicated elsewhere, suggesting that it is attributable to localised changes in conditions as a result of management practices or flow characteristics. Potential explanations for the increase at the control site are a reduction in grazing from swans, a change in management or the accidental release of fertilisers into the water that has promoted growth in localised areas.

The proportion of macrophyte species that prefers slow flows has decreased in the restoration site as a response to an increase in flow velocities. Conversely, the proportion of these species at the control site has increased slightly. This suggests that the restoration measures might have been effective in reducing the coverage of slow-flow tolerant species.

The changes in macrophyte composition at the restoration site appear to be relatively insignificant compared with the results displayed at the control reach. However, the changes in macrophyte communities at the control reach could be partially attributable to unconfirmed external factors such as a large flood event or pollution incident which occurred prior to 2006 resulting in a loss of macrophytes and the subsequent recovery of macrophyte communities in this reach. This may mean that the data for the control site are misleading and that the effectiveness of the measures at the restoration site is underestimated. Further changes to the macrophyte composition can be expected as hydromorphology within the restored section changes over time.

4.2.2 Macroinvertebrates

The diversity of the macroinvertebrate assemblage at the restoration site initially decreased as a result of the restoration works due to the bed disturbance that this involved. Although diversity has since recovered, this does not appear to have changed significantly more than that observed at the control site. However, species diversity was already high at both sites before the restoration works and so the measures may not be expected to have a significant impact on macroinvertebrate communities once they have recovered from the initial disturbance. It is therefore not possible to determine the effectiveness of the restoration measure accurately in terms of improvements to macroinvertebrate population diversity.

Macroinvertebrate species evenness has increased in the restoration site, but corresponding increases have also been observed at the control site. It is therefore not possible to determine the effectiveness of the restoration measures on the evenness of macroinvertebrate communities.

RICT enables an assessment of the condition of ‘benthic invertebrates’ listed in Annex V of the Water Framework Directive. The method assesses the condition of invertebrates using the parameters:

- number of taxa (NTAXA)
- average score per taxon (ASPT)

A comparison of the observed/expected scores of NTAXA and ASPT from RICT as used for WFD classification indicates that there have been only minor changes in the condition of benthic invertebrates. However this is to be expected because the observed scores pre-restoration exceeded the EQR boundary for ‘high’ status.

Family level LIFE scores were consistent throughout the study period and CCI scores remained high. It is therefore not possible to state categorically that the measures have been effective in improving macroinvertebrate communities at the restoration site. However, the high taxonomic richness observed at both sites suggests that a significant increase due to restoration measures is unlikely.

A review of the PSI scores derived from the macroinvertebrate data shows that there was an overall increase in the number of fine sediment-sensitive taxa recorded as a proportion of all taxa found at both the restoration and control sites. While this indicates a general reduction in silt and associated improvement in abundance of sensitive macroinvertebrate species, the data do not support the hypothesis that the restored site has improved in regard to impacts from siltation on macroinvertebrate species compared with the control site. The restoration measures did not increase the taxonomic composition at the restoration site within the timescales of this study.

A review of the WFD status of macroinvertebrates for the study water body and surrounding water bodies is presented within table 4.1 (data was obtained from the Environment Agency's Catchment Planning System accessed March 2014). The results show a consistently high status for the study water body and high or good status in surrounding water bodies.

Table 4.1 Macroinvertebrate status

	study WB	upstream		downstream
	GB108043022510	GB108043022550	GB108043022570	GB108043015880
2009	high	high	high	high
2010	high	high	high	high
2011	high	high	high	high
2012	high	high	high	no data
2013	high	good	good	no data

4.2.3 Fish

The restoration measures appear to have been initially successful in increasing the population of fish that prefer faster flowing water. This is shown by the increase in salmon and trout populations in the first year after restoration. The magnitude of change was not replicated at the control reach, suggesting that the restoration measures were directly responsible. However, the number of these species caught in 2009 decreased. Results from the Butcher Stream, close to the restoration reach, show that salmon populations were lower in 2007, 2008 and 2009 than in 2006. A similar trend exists for populations of trout and grayling.

Further monitoring is required to fully understand the impact on salmon and trout populations. However, the restoration does seem to have been effective in increasing grayling populations, particularly when comparing results with longer term data from the Butcher Stream, which shows that populations of salmon, trout and grayling peaked in 2006 and decreased in 2007, 2008 and 2009.

The restoration measures do not seem to have increased the abundance of bullhead and lamprey; numbers of these species actually decreased between 2006 and 2009. In the first year after restoration the numbers of salmon increase markedly but then decreased in 2009.

The data are not sufficient to perform a full analysis of the age distribution of lamprey and salmon parr. However, results suggest that the restoration may have been successful in changing the age structure of bullheads with an increase in juvenile bullheads.

Further monitoring within the restoration section is needed to establish the long-term impacts of the restoration measures on the fish populations. Further changes may be expected as hydromorphology within the restored section changes over time.

A review of the WFD status of fish for the study water body and surrounding water bodies is presented within table 4.2 (data obtained from the Environment Agency's Catchment Planning System access March 2014). The results suggest a general improvement in status to good throughout the Wylie. Through this period the overall status of the study water body has been Moderate Ecological Potential.

Table 4.2 Fish status

	study WB	upstream		downstream
	GB108043022510	GB108043022550	GB108043022570	GB108043015880
2009	moderate	moderate	no data	no data
2010	good	moderate	no data	no data
2011	good	moderate	no data	no data
2012	moderate	good	no data	good
2013	good	good	no data	good

5 Conclusions and lessons learnt

5.1 Conclusions

The River Wylye has been historically modified for land drainage purposes. This had resulted in slow, uniform flow conditions and a lack of morphological diversity in the study reach. This and the resulting widespread siltation resulted in poor *Ranunculus* growth throughout much of the project reach. Conditions for spawning and juvenile salmonids were also generally poor.

The restoration scheme involved:

- channel narrowing
- introducing gravel riffles
- erecting a fence to prevent livestock access to the river
- selective tree felling
- a planting scheme

One of the original aims of the restoration scheme was to alter the operation of Seven Hatches to lower upstream water levels and reduce impoundment. Due to concerns about reduced flows and the potential effect on salmon communities in the Butcher Stream and flooding downstream in Wilton, this was not implemented.

In terms of hydromorphology, all the objectives have been met in the direct vicinity of the measures. However, a number of factors prevent the magnitude of change from being determined accurately. The extent of hydromorphological response is likely to be constrained by the relatively short timescales over which monitoring has been performed and which did not capture any geomorphologically relevant events, therefore the full effects the restoration measures may take several years to manifest in hydromorphological terms.

The assessment against the biological objectives indicates that overall macrophyte coverage and the extent of species that prefer faster flowing water have increased at the restoration site. An even greater response was observed at the control site, although this was not seen in the wider catchment. Based on these data it is not possible to attribute the improvement to the restoration measures. Further changes may become evident as the scheme adjusts following geomorphologically effective flows.

The impact of the restoration works on macroinvertebrates is difficult to ascertain because of the high species diversity at both the restoration and control sites prior to restoration and a lack of replicate survey data. In relation to fish, the restoration measures appear to have been initially successful in increasing the population of fish that prefer faster flowing water. However, the number of these species caught in 2009 decreased. A review of wider catchment context and further monitoring to assess long-term trends are therefore recommended.

Despite not being able to draw firm conclusions on the response to restoration of some aspects of the river biology, the scheme has been effective in localised areas in providing hydromorphological conditions that are more conducive for the range of biological quality elements expected in the river. Although these changes are expected to result in improvements to macrophytes, macroinvertebrates and fish, the full impact will materialise over a longer timeframe than has been monitored thus far.

The view of the Environment Agency project manager for the Seven Hatches scheme is that channel narrowing and the placing of log deflectors could have protruded further into the channel so as to maximise the impact on flow diversity. Future schemes should therefore consider the scale of the structures to ensure they have the desired impact for more information about large wood (LW) see Mott (2010).

The approach taken for the restoration at Seven Hatches is transferable to other chalk streams as the introduction of riffles, deflectors and narrowing has proved successful to some extent. In low energy systems such as the Wylye, however, the effects of river restoration are likely to be localised, particularly in the short to medium term and may not be detected at the water body scale. Such measures should therefore be targeted by careful planning at the catchment or river basin district scale for optimum environmental improvement.

In recent years there has been a shift in approach to river restoration with a focus upon restoring riverine processes on a more catchment scale rather that localised restoration measures. The Government have adopted a catchment-based approach to the management of fresh water and transitional water bodies, in recognition of the many factors which affect water quality (DEFRA, 2013). This approach aims to integrate land and water management in a sustainable way to balance environmental, economic and social demands at a catchment scale. The conservation strategy for the River Avon SAC (Wheeldon 2003) and the STREAM project was amongst the first strategic approach to river. It is anticipated that addressing the impacts of physical modification together with measures to address other pressures will move the water bodies within the catchment to Good Ecological Status or Potential, depending on their designation.

The monitoring protocol was not entirely effective for assessing against the WFD objectives. The main reason for this was that detailed monitoring was only performed on part of the overall restoration reach. No cross-sections, macrophyte data or electric fishing were recorded in the reach where a berm was constructed to narrow the channel. This therefore prevents the full impact of the restoration works being assessed. In addition, the relatively short timescale over which monitoring took place limits the conclusions that can be made.

Where detailed monitoring was performed, the methods used to measure the cross-sections and to collect macrophyte and fish data have proved to be successful in providing suitably detailed results. These methods could be applied to other schemes.

A better understanding of hydromorphology-biology relationships will help us refine our expectations and set more realistic objectives for schemes and help us prioritise restoration measures to achieve water body changes. The EU LIFE project REstoring rivers FOR effective catchment Management (REFORM available at http://www.reformrivers.eu/) was established to help address these issues. The overall aim of REFORM is to provide a framework for improving the success of hydromorphological restoration measures to reach, in a cost-effective manner, target ecological status or potential of rivers.

5.2 Lessons learnt

5.2.1 Design and implementation

For this type of scheme the design process was perhaps too detailed and complex. The hydraulic modelling of the riffles did not predict the expected increase in velocities and, if the results had been relied upon, the scheme may not have been progressed. The riffles are performing well, contradicting the modelling results.

Additional channel narrowing/flow deflectors on the right hand bank upstream of the hatches would have created more diverse flow conditions. The narrowing measures implemented have been effective in creating marginal habitat, but have had minimal visual impact on flow conditions or velocities (no detailed monitoring has taken place in this reach).

Similarly, the log deflectors downstream of the railway line could have protruded further into the channel to have a greater and more immediate impact on the river. It is likely to be more than five years, depending on high flows, before the channel begins to change shape and form. Securing large willows could have been more effective in achieving the aims.

The impact of the restoration works upstream of Seven Hatches was limited by the continued impoundment caused by the structure. The project therefore highlights the importance of being able to influence flow management where restoration works are planned.

Although the introduction of riffles downstream of the hatches has been successful in improving morphological diversity, the reaches in between remain over deep and over wide with slow uniform flow conditions. Constructing riffles is expensive and to maximise the benefit in future schemes, increased funding is required to undertake more widespread bed raising.

Understanding how restoration measures impact on restoring hydromorphological processes will improve our ability to design successful schemes. Key to this will be ensuring that processes and pressures are considered at a catchment scale and measures implemented on strategic catchment based approach.

5.2.2 Objective setting

Allowing time to consider the likely hydromorphological response of the river to the proposed measures, both spatially and temporally, helps to set realistic objectives and to design a more suitable monitoring strategy. Historic hydrological and geomorphological data are useful if available. However, simply looking at rainfall, topography, geology and the size of catchment can give an indication of whether the river has high or low hydraulic energy to cause geomorphological change.

Ecological improvement is likely to be a principal motivation for undertaking restoration work. It is therefore important to establish whether there are other pressures affecting the ecology which may mask or prevent ecological improvements from being realised. River basin management plans are a useful starting point and can help to establish an ecological baseline against which improvements can be measured.

Setting both project and monitoring objectives that can be assessed using a scientific approach that links hydromorphological change and ecological response is essential in demonstrating the effectiveness of restoration schemes. Timescales of recovery need to be taken into account within the setting of objectives with the expectation that changes to the hydromorphological regime may be evidence before the ecology responds. The objective setting should be undertaken with consideration of the catchment context, historic conditions and any other pressures. Where multiple pressures are influencing the ecological status the assessing the success of a restoration scheme may rely on measuring hydromorphological changes.

Making objectives specific reduces the likelihood of achieving an objective while causing a harmful environmental response. For example, an increase in percentage cover of undesirable species would rate as a success for an objective of increased macrophyte cover; however, if the objective was specific to *Ranunculus* it would not. Following the SMART method should help with this and make subsequent measurement easier. For further information and guidance about objective setting see RRC (2011).

5.2.3 Monitoring

The methods used for detailed monitoring of cross-sections, macrophytes and fish were successful and collected data of sufficient quality for analysis. However, measurements over a longer timeframe are required to enable statistically robust analysis to be undertaken.

Monitoring of velocities and substrate was not effective in producing data of sufficient quality and resolution. Velocity measurements should be made in a variety of flow conditions and repeated when water levels are similar. Substrate measurements should be taken using a sediment sieve to collect grain sizes and to enable a more detailed analysis of sediment distribution.

Macroinvertebrate sampling should be undertaken at a number of locations and replicated to enable statistical analysis to be undertaken. A Before-After, Control-Impact (BACI) sampling design should be used to help distinguish between changes attributable to the restoration measures against any background changes.

Monitoring should be undertaken throughout the entire reach rather than in specific sections. This will enable holistic conclusions to be drawn on the effectiveness of the scheme. Co-location of hydromorphologcial and ecological assessments will help with link habitat changes and ecology.

Use of routine monitoring data from across the catchment is essential to provide context for local changes and so help distinguish between responses to measures and macro-scale or longer term trends.

It is recommended that monitoring at Seven Hatches is continued as many of the effects of the restoration will take longer than the study period to become apparent.

Monitoring data should be collected over a sufficiently long time period to give the system time to re-equilibrate. Each river system will be different and a degree of flexibility must be built into the monitoring strategy to make best use of resources.

5.2.4 Sharing experiences

It is essential that the results of the assessment of restoration schemes are communicated and shared to improve the evidence base and to establish what restoration techniques work in which situations and which monitoring techniques work. It is equally important to understand where schemes have been unsuccessful.

Several information resources are dedicated to sharing information about restoration schemes. These include:

- the National River Restoration Inventory (http://www.therrc.co.uk/rrc_nrri.php) held by the River Restoration Centre
- the RESTORE wiki (http://www.restorerivers.eu/) established as part of an EU Life project dedicated to communicating river restoration experiences across Europe

References

ENVIRONMENT AGENCY, 2009. *River Basin Management Plan*. *South West River Basin District.* Bristol: Environment Agency. Available from: www.environment-agency.gov.uk/research/planning/125027.aspx [Accessed 28 November 2013].

ENVIRONMENT AGENCY, 2014a. *Appraisal of River Restoration Effectiveness: Shopham Loop case study.* Evidence Report. Bristol: Environment Agency

ENVIRONMENT AGENCY, 2014b. *Appraisal of River Restoration Effectiveness: Seven Hatches monitoring report.* Evidence Report. Bristol: Environment Agency.

MOTT, N., 2010. *Fish Live in Trees Too! River Rehabilitation and Large Woody Debris.* Stafford: Staffordshire Wildlife Trust.

RRC, 2009. *Post works assessment of the STREAM restoration project sites at Seven Hatches (R. Wylye): Summary of pot works assessment following final site visit on 30th April 2009*. Cranfield, Bedfordshire: River Restoration Centre.

RRC, 2011. *Practical River Restoration Appraisal Guidance for Monitoring Options (PRAGMO): Guidance document on suitable monitoring for river and floodplain restoration projects*. Cranfield, Bedfordshire: River Restoration Centre. Available from: http://www.therrc.co.uk/rrc_pragmo.php [Accessed 22 November 2013].

WHEELDON, J. 2003. *The River Avon cSAC Conservation Strategy*. Peterborough: English Nature.

Bibliography

LIFE IN UK RIVERS, 2003. *Monitoring Watercourses Characterised by* Ranunculion fluitantis *and* Calitricho-Batrachion *Vegetation Communities*. Conserving Natura 2000 Rivers Monitoring Series No. 11. Peterborough: English Nature.

MOTT, N., 2006. *Managing Woody Debris in Rivers, Streams & Floodplains*. Stafford: Staffordshire Wildlife Trust.

ROYAL HASKONING, 2006. *Physical and Biological Monitoring of STREAM Restoration Projects, Year One Report.* Peterborough: Natural England.

ROYAL HASKONING, 2008. *Physical and Biological Monitoring of STREAM Restoration Projects, Year Three Report.* Peterborough: Natural England.

ROYAL HASKONING, 2009*. Physical and Biological Monitoring of STREAM Restoration Projects, Year Four Report.* Peterborough: Natural England.

List of abbreviations

ASPT	average score per taxon
BMWP	Biological Monitoring Working Party
CCI	Community Conservation Index
FSC2	Fisheries Classification Scheme 2
cSAC	candidate Special Area of Conservation
EQR	Ecological Quality Ratio
LIFE	Lotic Invertebrate index for Flow Evaluation
NTAXA	number of taxa
RICT	River Invertebrates Classification Tool
RRC	River Restoration Centre
SAC	Special Area of Conservation
SPA	Special Protection Area
SSI	sediment-sensitive invertebrates
SSSI	Site of Special Scientific Interest
WFD	Water Framework Directive

Would you like to find out more about us or about your environment?

Then call us on
03708 506 506 (Monday to Friday, 8am to 6pm)

email
enquiries@environment-agency.gov.uk

or visit our website
www.gov.uk/environment-agency

incident hotline 0800 807060 (24 hours)
floodline 0345 988 1188 / 0845 988 1188 (24 hours)

Find out about call charges: www.gov.uk/call-charges

Environment first: Are you viewing this on screen? Please consider the environment and only print if absolutely recessary. If you are reading a paper copy, please don't forget to reuse and recycle if possible.