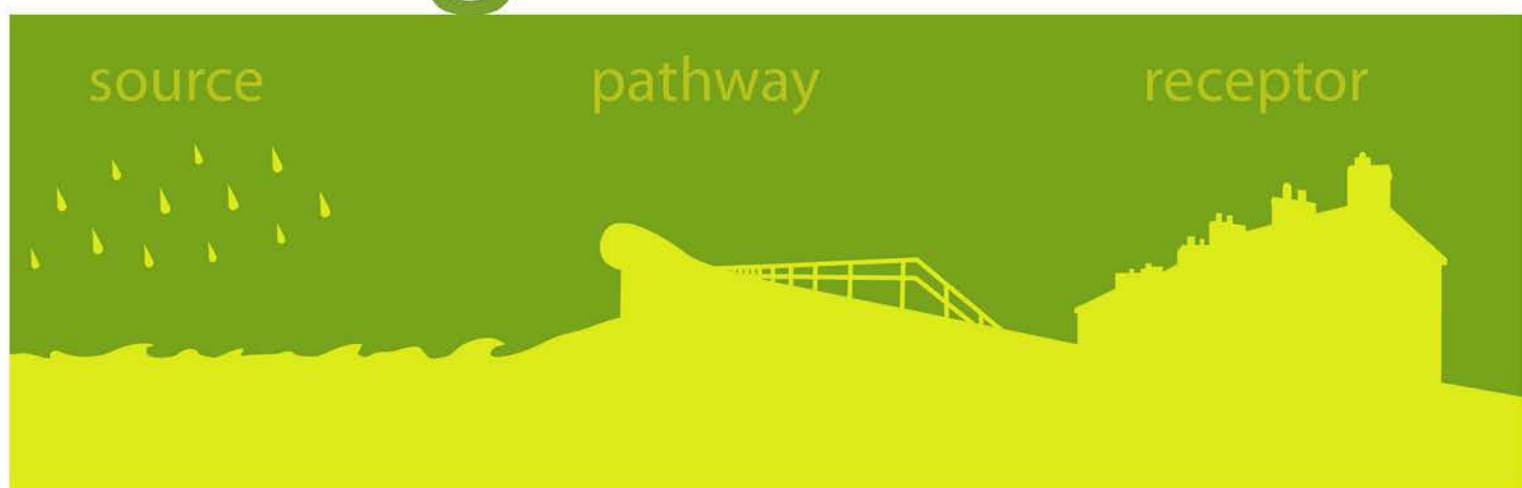


delivering benefits through evidence



Channel Management Handbook

Report – SC110002

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.

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The Channel Management Handbook

Extended executive summary

Purpose

The Channel Management Handbook is a strategic, high-level guide that provides channel managers with the understanding they need to make informed channel management decisions. The handbook also sets out a robust framework that should be followed to ensure that good channel management decisions are made and that flood risk management and land drainage objectives are achieved.

The handbook has been primarily written for flood risk management authorities. However, other groups with an interest in channel management for other purposes will also find the handbook useful.

This extended executive summary has been written specifically to provide a useful overview for those readers not directly involved in the channel management process. The summary introduces the fundamental scientific concepts and the context within which the principles for channel management have been developed, the typical issues facing the channel manager and the decision-making process that should be followed to address these issues.

Handbook content

Good channel management is defined as a course of action that achieves the needs of humans to manage channels for flood risk and / or land drainage purposes, that has due regard of the needs of ecology and wildlife. In some situations, this can be met by allowing natural channel-forming processes to establish.

Good channel management works as much as possible with natural processes and supports a broad range of ecosystem functions and services, including fisheries, navigation and amenity, habitats, biodiversity, landscape and water quality, in addition to flood risk and land drainage. When carrying out channel management, all these functions should be considered even if flood risk and land drainage are the primary drivers for management. For this handbook, channel management encompasses routine maintenance that takes place within a wider programme of channel management and reactive maintenance. This also includes rehabilitation, restoration and modification works to a channel.

It is important that good channel management is based on informed decisions that are underpinned by the fundamental scientific principles of hydraulics and geomorphology and take account of the multiple functions and services that a channel delivers. The handbook is designed to provide channel managers with the information they need to undertake channel management in the most appropriate way, and not to tell them how specifically to manage their channel.

The handbook is divided into three sections:

- **Section 1: Introduction.** This section provides an overall introduction to channel management, and introduces the three main factors that affect channel performance and thus may require management: **sediment, vegetation and debris**.
- **Section 2: Scientific fundamentals and context.** This section provides channel managers with the fundamental scientific knowledge and context they need to understand how their channel functions and make informed decisions about how it should be managed. This includes a summary of the basic hydraulic and geomorphological controls on channel behaviour, the regulatory context in which decisions need to be made, and a description of the main sediment, vegetation and debris issues that typically affect channels. This section uses the contextual information to establish seven **guiding principles** for the effective management of channels.
- **Section 3: Decision-Making Process.** This section builds on the guiding principles for channel management to set out the step-by-step **Adaptive Channel Management Framework** that channel managers should follow to ensure that they make the most appropriate decisions for their channel.

Section 1: Introduction

Background

In the context of this Handbook, a ‘channel’ forms part of a watercourse system along with other associated structures such as sluices, weirs, pumps, locks and culverts. The channel includes the watercourse bed and banks, and incorporates both natural and artificial channels. It does not include estuaries or those channels affected by tidal regimes.

Understanding channel performance

A channel’s ability to convey flow is a measure of its performance for flood risk or land drainage purposes. This may be influenced by a variety of factors. Three factors that affect channel performance need to be considered. They are: **sediment, vegetation and debris**.

Understanding multiple scales

While a channel performance issue might manifest itself at a particular location within the channel, it is important to seek to understand the source of the problem and the mechanisms creating it (that is, not just the visible symptom). The most sustainable and cost-effective approach to addressing the issue may lie elsewhere (that is, the ‘cause’ and not the symptom). It may be necessary, where practicable, to manage the surrounding banks, upstream and downstream watercourses and, potentially, the wider catchment.

Extent of channel management at multiple scales

Channel management takes place at multiple scales. At the site of interest it is first important to understand the channel itself. This includes how water level regime and sediment are moving, how the bed and banks are being shaped, and what other local influences there are (**local scale**). The reaches upstream and downstream are also important. For example, sluggish flow and sediment deposition in the channel’s reach may reflect flow restrictions downstream, or increased sediment inputs further upstream. As well as considering factors from elsewhere that impact upon the channel, it is essential to also consider the effects that the channel is having on those other areas and our requirements of them (**reach scale**). Broadening your focus even further, you should consider the channel in the context of its catchment. This includes land uses, geology and soils, and other issues considered in

catchment plans. In addition, you need to consider changes over time on a local and broad scale, identifying changes within the catchment that have occurred and considering potential future changes (**catchment scale**).

[Why does channel management matter?](#)

A channel can perform multiple functions and services, each of which is influenced by management actions (or inaction). Deciding how to achieve and balance these requirements is an important part of channel management. This requires effective understanding of each relevant function and the services it provides, engagement and co-creation of solutions and management plans with the relevant stakeholders and functional experts. It is also important that these functions are considered across the entire catchment.

Section 2: Fundamentals and context

[Catchment context – Environmental](#)

The hydraulic and geomorphological conditions of a channel are strongly linked with the quality of the natural environment. These conditions determine the range of physical habitats that are found in a channel, and by extension, determine the species that can be supported within and adjacent to the channel. The impacts of channel management activities should be minimised through careful site characterisation and planning. The following factors should be considered when considering management actions: **location, type, timing and mitigation**.

[Catchment context – Catchment controls](#)

The overall behaviour of a channel depends on the complex interaction of a range of physical, climatological and human controls. These interact with local factors at a reach scale to determine how a channel behaves and responds to different pressures and management interventions. Flood Risk Management Authorities use various forms of management plans to direct the management of their watercourse catchments and systems. These plans are usually underpinned by catchment and system studies and assessments. These are often supported by varying levels of details of risk-based assessments of the benefits and costs of strategic management approaches and standards of service. These can include: **Catchment Flood Management Plans, Flood Risk Management Plans, River Basin Management Plans**, etc.

[Fundamental scientific concepts – Geomorphology](#)

Geomorphology is the shape and physical characteristics of a channel. The geomorphology of a channel (a secondary control of channel dynamics) is the product of catchment scale controls and local scale controls. Different types of channel can have varied management requirements as a result of the diverse geomorphological processes that operate in them.

The cumulative impact of multiple factors can play a significant role upon channel dynamics. When attempting to obtain an all-encompassing picture of your channel and catchment so as to identify cumulative impacts, the following influences should be considered: **actions of surrounding land owners, surrounding land uses, surrounding catchment factors**.

Fundamental scientific concepts – Hydrology and hydraulics

In the fluvial environment, hydraulics principles are typically considered in the context of open channels and structures, or features that either constrain or control the flow of water. In all cases, however, the change in the water level (WL), and hence the ability of a channel to meet the flood risk and land drainage objectives for a given land use, will be governed by the hydraulic characteristics of the channel.

Regulatory context

Before making a decision to carry out channel management, and throughout the decision-making process, it is vital that all legislation relevant to your channel, together with the upstream and downstream reaches, is given thorough consideration. Relevant legislation will influence your functional objectives and thereby shape your choice of management approach.

Typical channel management issues

The main management issues in many channels are typically related to the performance factors of channel management: **sediment**, **vegetation** and/or **debris**. Although each of these factors can cause management issues in isolation, more typically management is required as a result of the interaction between two or more of the factors, for example sediment may not become a channel management issue unless vegetation or debris reduce flow energy and encourages deposition.

Guiding principles for channel management

To develop a channel management plan for a channel or to decide on the need for, or form of, intervention that may be necessary to address a channel management issue, it is important to take proper account of the fundamental scientific concepts that govern channel behaviour, the potential opportunities of delivering multiple functional benefits and the potential harm or adverse impacts of action or inaction. Channel management can be costly, so when deciding on appropriate management, it is essential that the benefits of carrying out management activities outweigh the cost and effort involved. With these considerations and more in mind, the **guiding principles of channel management** (see overleaf) have been developed to guide and inform the planning and delivery of channel management.

Agree and define success criteria

- Recognise that a channel may have multiple functional objectives to provide consensus benefits, with potentially conflicting requirements.
- Engage with experts associated with the other associated functions to ensure that flood risk or land drainage objectives are not outweighed by other considerations.
- Engage with relevant partners, riparian owners and the community as appropriate.
- Set clear, realistic and auditable targets and agree these with relevant stakeholders.

Challenge the need for intervention

- Only intervene if channel is demonstrably not performing against desired objective(s).
- Any decision to intervene must be evidence-based. Simply relying on past activities to guide future actions is not a sufficient basis on which to make a decision. However, past activities may provide indicators as to required intervention(s).
- Regularly review decisions and plans to reflect potential changes in evidence collected from monitoring or observations, changes in policy and funding.

Act in proportion to the risk

- The level of management intervention or maintenance performed should be proportionate to the level of risk that is being managed.
- The level of detail required to characterise the channel context and make an informed management decision should also depend on the level of risk.

Recognise that channels form part of a dynamic system

- Understand how the channel in question is changing through time in response to natural geomorphological and hydrological processes.
- Consider how the current state of the channel and a channel management issue of interest reflect catchment, reach and local scale processes.
- Understand the impact that anthropogenic activities may have had (or be having) on these natural processes.
- Engage with experts in geomorphology.

Deal with the cause, NOT the symptom

- Appreciate that management issues may not be manifested at the source of the problem and the most effective solutions may be action in the upstream or downstream channel or elsewhere in the wider catchment.
- Weigh the long-term costs of managing the symptoms against those of addressing the root cause.

Aim to work with natural processes and deliver multiple objectives

- It is important to work with natural processes rather than against them.
- Recognise that working with natural processes can achieve real management benefits as well as environmental improvements.
- Aim to balance the requirements of multiple objectives to achieve a consensus benefit.
- Use best practice to minimise disruption to the environment.

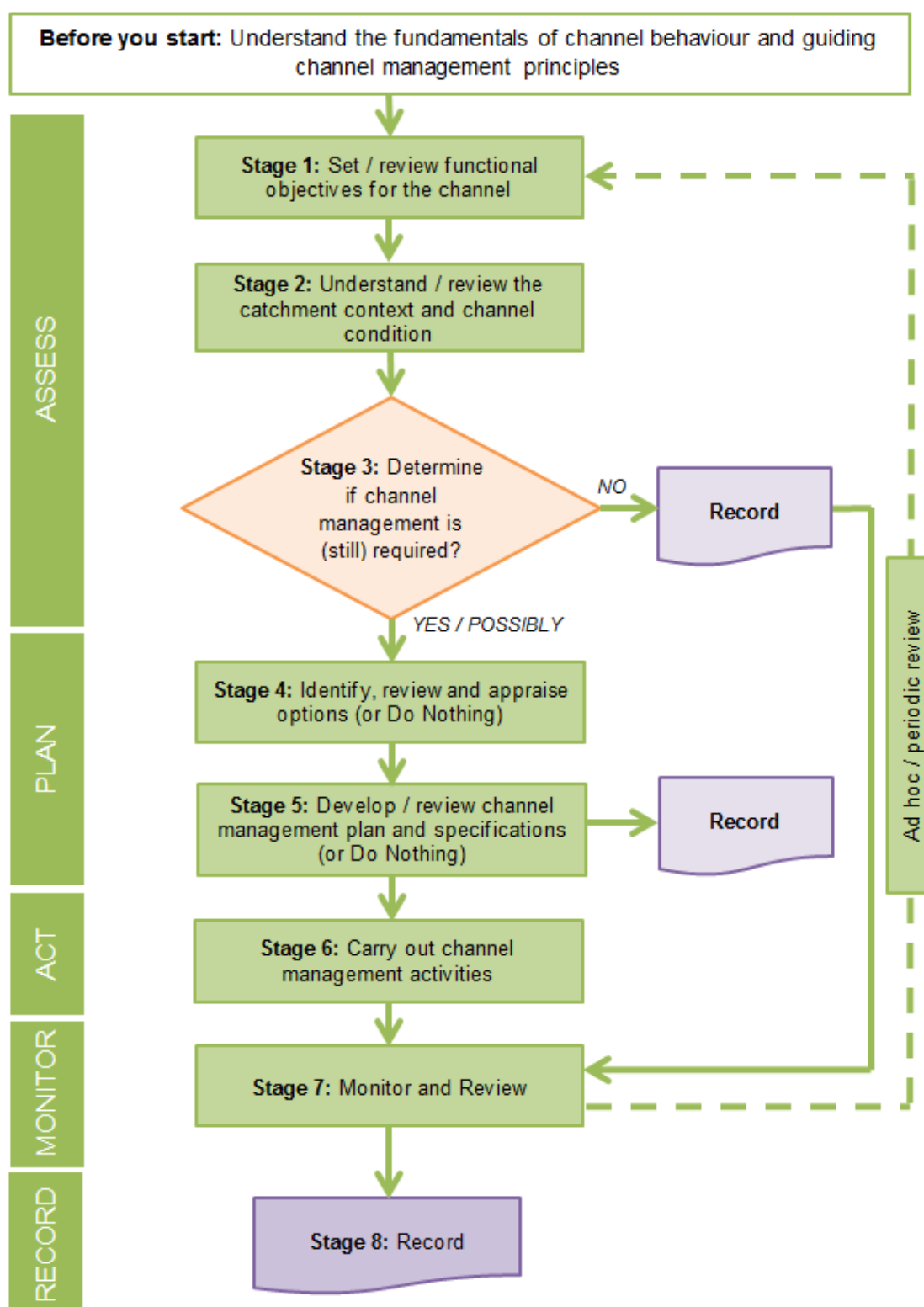
Learn and adapt

- Ensure that the results of channel management are properly monitored and recorded.
- Use evidence and the results of monitoring to review and, if necessary, amend key decisions.
- Ensure that lessons learned are clearly recorded and used to inform future decisions.

Section 3: Decision-Making Process

It is important that the approach selected to manage a channel (including, where appropriate, doing nothing) reflects the objectives that need to be achieved in that channel and is appropriate for the catchment and controls of the channel in question.

This section of the Handbook is designed to guide you through a process that helps you to make the most appropriate management decision for your channel. This **Adaptive Channel Management Framework** (ACMF) is presented below.



Stage 1: set / review functional objectives for the channel

Once you have developed a good understanding of how your channel functions, you are now ready to determine which functional objectives are appropriate to your channel. This stage provides guidance on what functional objectives are, how they should be set, and the importance of considering multiple objectives.

Stage 2: understand / review the catchment context and channel condition

The aim of this stage is to develop a specific understanding of the issues that affect your channel, and the wider catchment context that it sits within. This stage applies the general concepts outlined in **Section 2**, to provide a more detailed understanding of how a particular channel functions.

Stage 3: deciding whether channel management is (still) required

The decision whether or not to intervene by carrying out management in a channel can often be down to expert judgement or historical precedent. However, the channel, its functions, land use, legislative and regulatory framework will change over time. This decision should therefore always be based on:

- An understanding of the functional objectives of a channel (developed from all relevant functional perspectives); and
- A comparison of the performance of the channel on the basis of its current condition with that required by its functional objectives.

Stage 4: identify, review and appraise options

The option development and appraisal is an objective led process. The options are identified and developed to optimise the achievement of the full range of functional objectives. The option screening and development process involves removal or modification of options which do not deliver the broad range of functional objectives.

Stage 5: develop / review channel management plan and specifications

A successful channel management plan or intervention needs to:

- achieve the required functional objectives in an efficient and cost-effective way
- minimise adverse impacts on any other functional objectives
- ensure the plan or intervention can be implemented safely both in terms of operational access and work, and the public
- work to design out safety issues and mitigate any remaining risks through design and operational processes
- avoid creating unnecessarily onerous maintenance requirements
- where possible, work with rather than against natural geomorphological and hydrological processes
- be appropriate for the type of channel to which it will be applied

- ensure that all relevant legislation is complied with, for example, by ensuring that there is no deterioration in water body status, impediment to fish passage, or impacts upon protected species
- ensure that there is no unacceptable increase in flood risk or reduction in land drainage
- where possible within operational and budgetary constraints, seek to achieve environmental enhancements (for example, additional mitigation measures identified in the RBMP)

Stage 6: carry out channel management activities

When planning management interventions for a channel (including routine maintenance and one-off interventions), it may be necessary to apply for relevant consents and licences from the statutory regulators.

Stages 7 & 8: monitor and review / record the outcomes

Post-intervention monitoring should be undertaken regularly to ensure that:

- The effectiveness of management interventions in delivering the required performance objectives can be evaluated.
- Changes in the channel can be identified, including responses to management and natural variation.
- There is an appropriate dataset on which to base the ad hoc or periodic review of the management decision.
- Management decisions can be changed and/or management interventions amended to ensure continued effectiveness as part of a programme of adaptive management.

Channel Management Checklist

The handbook also includes an interactive checklist tool that supports the decision making process by leading users through the Adaptive Channel Management Framework. The checklist provides clear links to the appropriate sections of the handbook to inform each stage of the decision making process. The checklist also acts as a template for recording channel management decisions and provides an auditable summary of the supporting information and reasoning behind decisions made at each stage of the process.

Further information

For further information on the Channel Management Handbook, guiding principles for channel management, the decision framework and the checklist, please contact the Evidence Team at:

fcerm.evidence@environment-agency.gov.uk

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

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This handbook is dedicated to the memory of Nigel Holmes whose contribution to research and development and the river restoration community was invaluable to the development of the river sediments and habitats work that underpins this handbook.

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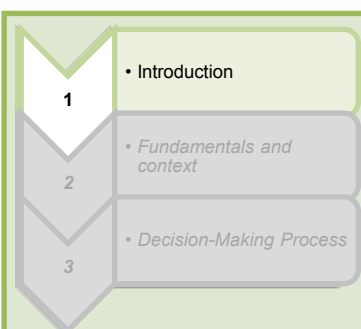
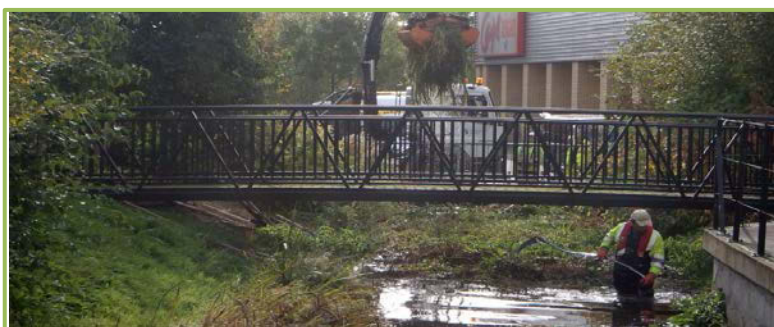
1 Introduction

This handbook will guide you through the process of deciding when and how to carry out channel management for the purpose of managing flood risk and land drainage. The handbook does this by helping you to develop an understanding of channel performance in terms of its ability to convey water and how this can affect flood risk and land drainage. The handbook will help you understand the effectiveness of maintenance on channel performance, while taking account of the environmental and legislative contexts, and the channel's other functions.

This handbook is a strategic, high-level guide that presents the understanding required and the effective process to make informed decisions. This will help to ensure good channel management to achieve flood risk management and land drainage objectives.

The handbook does not tell you which management technique to use, where to apply it within a channel, or when, where or how to implement it.

Following the process presented in this handbook and consulting the relevant further guidance and information as necessary will allow for appropriate management planning. It is anticipated that ultimately this handbook will enable you to make knowledgeable and appropriate decisions regarding channel management.



Throughout the handbook, this sidebar provides links to elsewhere in the document and links to relevant websites, guidance, references and legislation.

This chapter covers:

- [Background](#)
- [How to use the handbook](#)
- [Target audience](#)
- [Understanding channel performance](#)
- [Understanding channels at multiple scales](#)
- [Why does channel management matter?](#)

1.1 Background

1.1.1 What is a 'channel'?

In the context of this handbook, a 'channel' forms part of a watercourse system along with other associated structures such as sluices, weirs, pumps, locks and culverts. The channel

includes the watercourse bed and banks, and incorporates both natural and artificial channels. It does not include estuaries or those channels affected by tidal regimes.

1.1.2 What is good channel management?

For the purposes of this handbook, good channel management is defined as:

‘A course of action that achieves the needs of humans to manage channels for flood risk and/or land drainage purposes, that has due regard of the needs of ecology and wildlife. In some situations, this can be met by allowing natural channel-forming processes to establish.’

Good channel management works as much as possible with natural processes and supports a broad range of ecosystem functions and services, including fisheries, navigation and amenity, habitats, biodiversity, landscape and water quality, in addition to flood risk and land drainage. When carrying out channel management, all these functions should be considered even if flood risk and land drainage are the primary drivers. For this handbook, channel management encompasses routine maintenance that takes place within a wider programme of channel management and on/off reactive and periodic maintenance. This also includes rehabilitation, restoration and modification works to a channel.

The [guiding principles of channel management](#) as used in this handbook relate to good practice principles that should underpin every channel management decision. This should not be confused with basic scientific principles as used in other documents to mean fundamental scientific facts. These are referred to in this document as [fundamental scientific concepts](#).

The Channel Management Handbook represents a synthesis of previous research studies and established good practice. Important sources are the findings of the [River Sediments and Habitats and the Impacts of Maintenance and Capital Works](#) R&D project (River Sediments and Habitats R&D), and the [Dredging Pilot Studies](#).

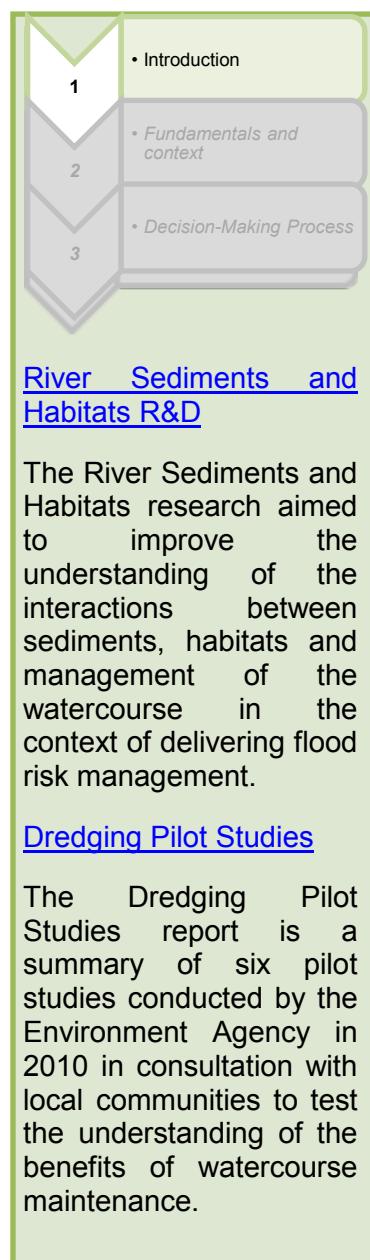


Figure 1.1 illustrates the handbook's structure and how it works together with more detailed guides (where these are available) to support channel management decisions.

Important technical documents

A summary of these technical documents is given in [Technical Support Document D](#). Other support documents that provide more detailed guidance include:

- [Sediment Matters: A Practical Guide to Sediment and its Impacts in UK Rivers](#)
- [Aquatic and Riparian Plant Management Guide](#)
- [Blockage Management Guide](#) (publication due 2015)

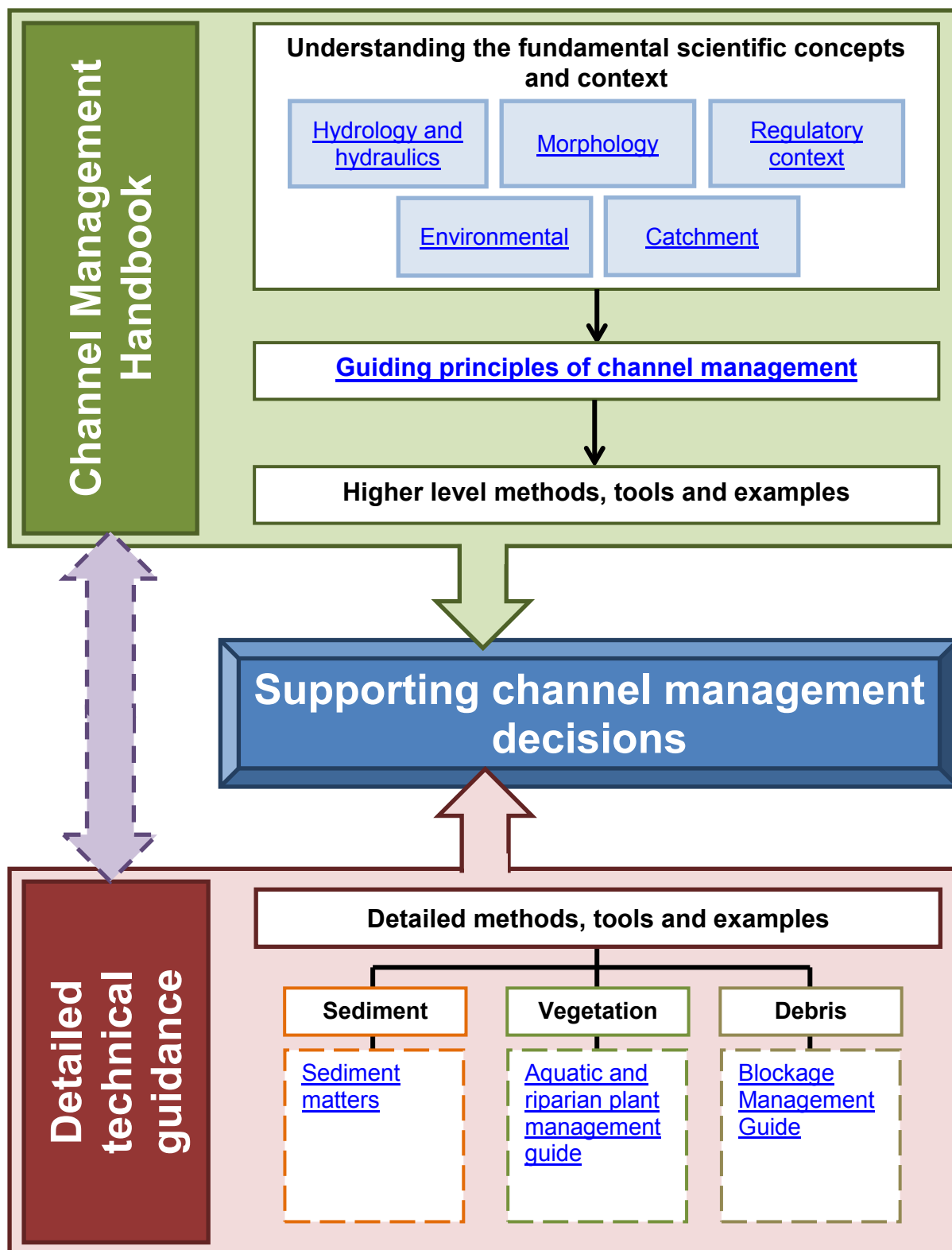


Figure 1.1: Channel Management Handbook organisational diagram

1.2 How to use the handbook

This handbook is designed to help you understand best practice channel management and how it should be undertaken in different channels.

Read [Section 1.1](#) to understand the background and scope of this handbook.

Read [Chapter 2](#) to understand the fundamental scientific concepts and legislative contexts of your system. This is an essential step before you begin the decision-making process regarding if, how or when you carry out channel management.

Building on what you have learnt in [Chapter 2](#), use [Chapter 3](#) to guide you, your partners and stakeholders through the process of making a well-informed decision on how to manage a channel of interest.

The five technical support documents (A–E) provided as part of the handbook contain more detailed information on:

- [channel typologies](#)
- [management intervention selection matrix](#)
- [management intervention options](#)
- [management considerations and governing legislation](#)
- [techniques for assessment](#)

In addition, to help users there is a [list of abbreviations](#) and a [bibliography](#) listing the documents suggested in the handbook as sources of further information. This alphabetical list by document title includes the web addresses used in links to the document or details about it.

Purpose of the Channel Management Handbook

- Help the user recognise that channel performance can be supported by promoting natural form and environment (that is, consistent with [good channel management](#)).
- Help the user select an appropriate approach to managing a channel, including whether intervention or review of current maintenance practice is necessary.
- Make it easier for the user to develop and record an evidence base to support the decision to undertake, change or cease channel maintenance.
- Guide the user through the legislative framework within which channel management has to be carried out and signpost the user to supporting good practice.
- Help the user understand the potential implications of various management techniques (for example, through case studies).

1.2.1 [Channel Management Handbook Checklist](#)

The checklist is an interactive tool designed to be used in conjunction with the handbook. The checklist takes you through a logical process to make the required channel management decision, linking to appropriate sections of the handbook for guidance at each stage.

The checklist also acts as a template for recording your channel management decisions and the evidence they are based on. It refers back to specific sections of the handbook for further information.

Checklist layout

The checklist is set out to provide a clear, step-by-step guide that allows the user to establish the requirements and suitability of management within a channel. The checklist provides a space to record all the supporting evidence as answers to the channel management questions.

The checklist sidebar provides a summary of each question stage and points the user in the right direction for further information.

Checklist output

By using this interactive tool, each stage in the decision-making process is highlighted. Printing or saving of the checklist will store the information underpinning your decisions which can then be shared or used for future reference.

1.3 Target audience

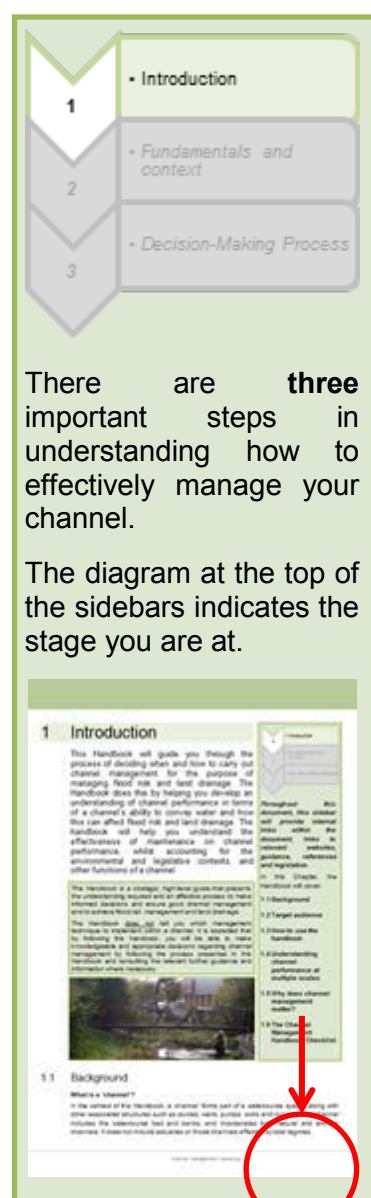
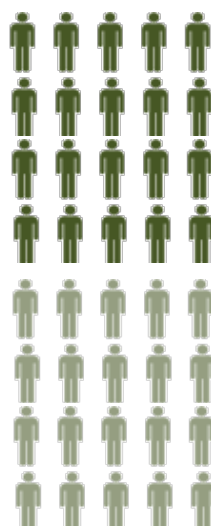
The main aim of the handbook is to advise management authorities on how to manage a channel for land drainage and flood risk benefits. The handbook is therefore structured with flood risk management and land drainage authorities in mind. A much wider range of stakeholders with an interest in channel management for other purposes will also find the handbook useful.

Primary audience

- Environment Agency
- Internal Drainage Boards (IDBs)
- Lead Local Flood Authorities (LLFAs) and other local authorities
- Natural Resources Wales
- Consultants working on behalf of the above authorities

Secondary audience

- Natural England
- Canal & River Trust
- Rivers trusts
- Other charitable trusts
- Riparian landowners
- Community stakeholder groups



1.4 Understanding channel performance

A channel's ability to convey flow is a measure of its performance for flood risk or land drainage purposes. This may be influenced by a variety of factors. Three factors that affect channel performance need to be considered. They are:

- [sediment](#)
- [vegetation](#)
- [debris](#)

The usual measure of establishing channel performance in terms of its land drainage or flood risk management function is whether the design water levels are achieved at the design flows.

1.4.1 Sediment

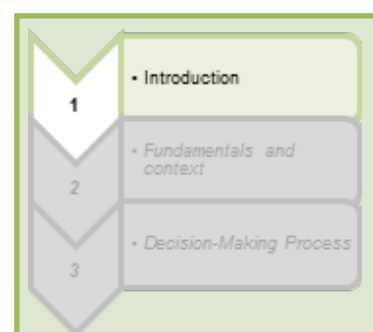
Sediment and its movement is a natural part of aquatic systems, essential for hydrological, geomorphological and ecological functioning. Sediment forms a variety of habitats, which directly and indirectly support a broad range of flora and fauna.

Sediment may need to be managed for a number of reasons including:

- sediment removal or addition to restore/improve channel capacity or to improve its self-cleansing ability for flood risk management and land drainage purposes
- sediment removal or reinstatement for fisheries interest
- navigation
- aggregate extraction

Other sources of sediment management guidance

- [Sediment Matters Handbook](#)
- [Land Use Management Effects on Flood Flows and Sediments: Guidance on Prediction](#)
- [Farming and Watercourse Management Handbook \(PDF, 1.34 MB\)](#)
- [Sediment Management \(SEPA Good Practice Guide WAT-SG-26\)](#)



Further information

Go to [Section 2.4.2](#) for more information on **conveyance**.

Go to [Section 3.6.1](#) for more information on **sediment** management.

Go to [Section 3.6.2](#) for more information on **vegetation** management.

Go to [Section 3.6.3](#) for more information on **debris** management.



River Dove at Egginton, Staffordshire
©Royal HaskoningDHV

1.4.2 Vegetation

Vegetation is a natural part of channel ecosystems. It provides shade and cover, promotes bank stability, enhances physical in-channel features and flow diversity, provides an input of woody debris, filters sediment and serves as a source of nutrients to support fauna and flora. However, excessive vegetation growth can influence channels in a number of ways, including:

- blocking culverts
- increasing channel roughness and flow capacity
- reducing conveyance
- increasing water levels



Other sources of vegetation Management guidance

- [Aquatic and Riparian Plant Management Guide](#)
- [Drainage Channel Biodiversity Manual](#)
- [Riparian Vegetation Management \(SEPA Good Practice Guide WAT-SG-44\)](#)

1.4.3 Debris



Some types of debris are a natural part of a channel ecosystem, providing important habitat for fish and invertebrates and creating diversity in flow. In-channel debris can reduce the channel capacity in isolation or in conjunction with other debris such as anthropogenic debris.

Debris is often more critical to channel conveyance where it has the potential to be moved to the immediate upstream of channel constrictions such as culverts or where the size of the debris accommodates a large proportion of the natural channel cross-sectional area.

When considering removing debris from a channel, think about the wide range of benefits and other functional objectives that having debris in the channel may provide. The removal of urban debris is usually an essential requirement to support the flood risk and recreational objectives of the channel. However, more natural items such as woody debris can have significant ecological benefits and warrant careful consideration (see [Section 2.3.5 – The importance of woody debris](#)).

Other sources of debris management guidance

- Trash and Security Screen Guide
- [Culvert Design and Operation Guide](#)
- [Blockage Management Guidance](#) (publication due in 2015)
- [Managing Woody Debris in Rivers, Streams & Floodplains \(PDF, 1.03 MB\)](#)

1.5 Understanding channels at multiple scales

Figure 1.2 highlights how the factors that affect channel performance (see [Section 1.4](#)) might manifest within the catchment at varying scales.

While a channel performance issue might manifest itself at a particular location within the channel, it is important to seek to understand the source of the problem and the mechanisms creating it (that is, not just the visible symptom). The most sustainable and cost-effective approach to addressing the issue may lie elsewhere (that is, the 'cause' and not the symptom). It may be necessary, where practicable, to manage the surrounding banks, upstream and downstream watercourses and, potentially, the wider catchment.

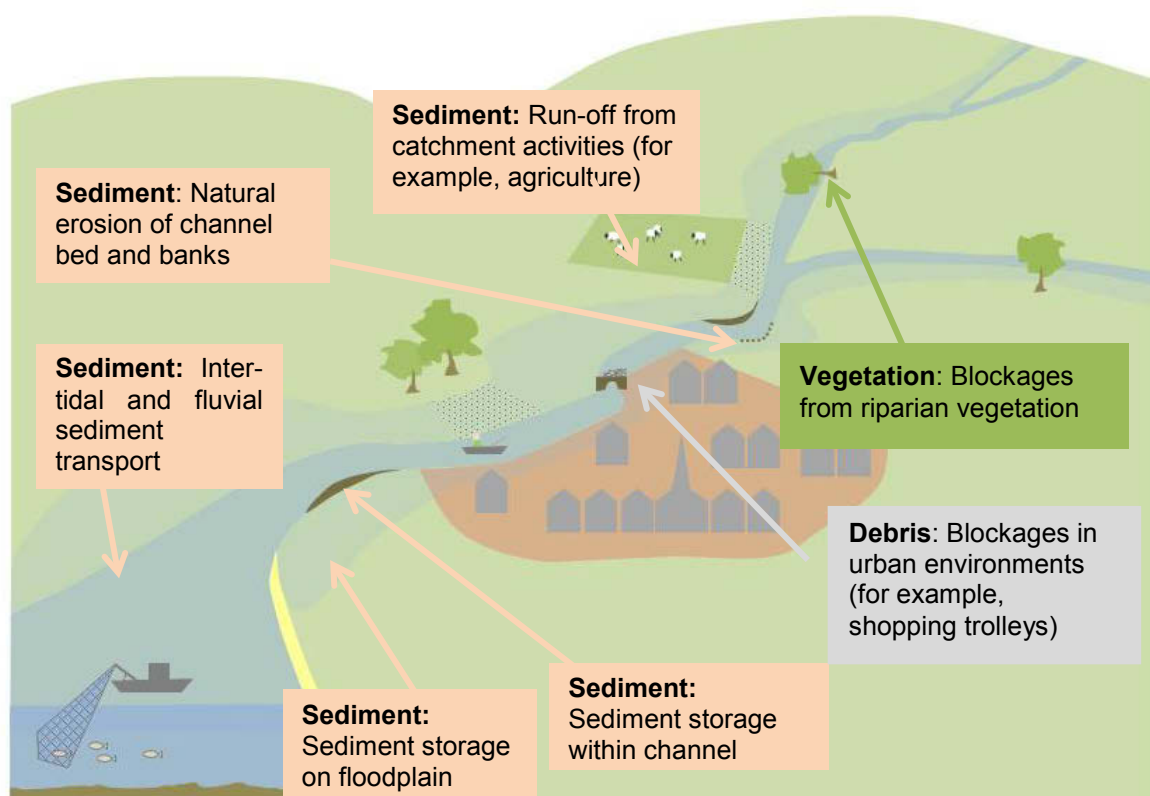


Figure 1.2: Effects of channel performance factors at multiple scales

1.5.1 Extent of channel management at multiple scales

Channel management takes place at multiple scales. At the site of interest it is first important to understand the channel itself. This includes how water level regime and sediment are moving, how the bed and banks are being shaped, and what other local influences there are.



The reaches upstream and downstream are also important. For example, sluggish flow and sediment deposition in the channel's reach may reflect flow restrictions downstream, or increased sediment inputs further upstream. As well as considering factors from elsewhere that impact upon the channel, it is essential to also consider the effects that the channel is having on those other areas and our requirements of them (see [Section 1.6](#)). For example, sediment removal in the channel may increase flood risk downstream due to increased rate of flow during flood events.



Broadening your focus even further, you should consider the channel in the context of its catchment. This includes land uses, geology and soils, and other issues considered in catchment plans such as actions set out in catchment flood management plans (see [Section 2.2.1](#)). In addition, you need to consider changes over time on a local and broad scale, identifying changes within the catchment that have occurred and considering potential future changes.

Land-use management

Channel management is put in place at the local and reach scales, but should be planned and programmed with an understanding of processes at work at the catchment scale.

At a catchment scale, land use and its management will have a strong influence on the performance of the channel reach you need to manage.

Work to influence land-use management practice may be the most sustainable channel management solution in the long run such as working within Catchment Flood Management Plans on where to store water, where to speed up flows, where to improve risk management activities or where to relax them for the wider catchment benefits and land use considerations.

Further information

See [Section 2.3](#) and [Section 2.4](#) for more information on factors to consider at the **local** and **reach** scales.

See [Section 2.2](#) for more information on factors to consider at the **catchment** scale.

1.6 Why does channel management matter?

A channel can perform multiple functions and services, each of which is influenced by management actions (or inaction). Deciding how to achieve and balance these requirements is an important part of channel management. This requires:

- effective understanding of each relevant function and the services it provides
- engagement and co-creation of solutions and management plans with the relevant stakeholders and functional experts

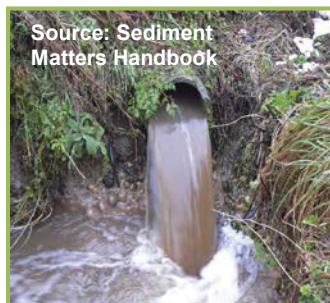
It is important that the following functions and services are considered across the entire catchment:

Flood risk management

Conveyance of flood flows and associated reduction in water levels to achieve a required tolerance of flood risk may be influenced by a variety of factors within channels such as sediment, vegetation and debris, or impoundments caused by on-line structures such as weirs.

Land drainage

Land drainage allows the free flow of water through the soil to typical root depth. Therefore water levels in the channel need to be below the field drain outfall level. The ability of the channel to drain surrounding land may be restricted if the channels connecting terrestrial and aquatic zones are constrained or blocked.

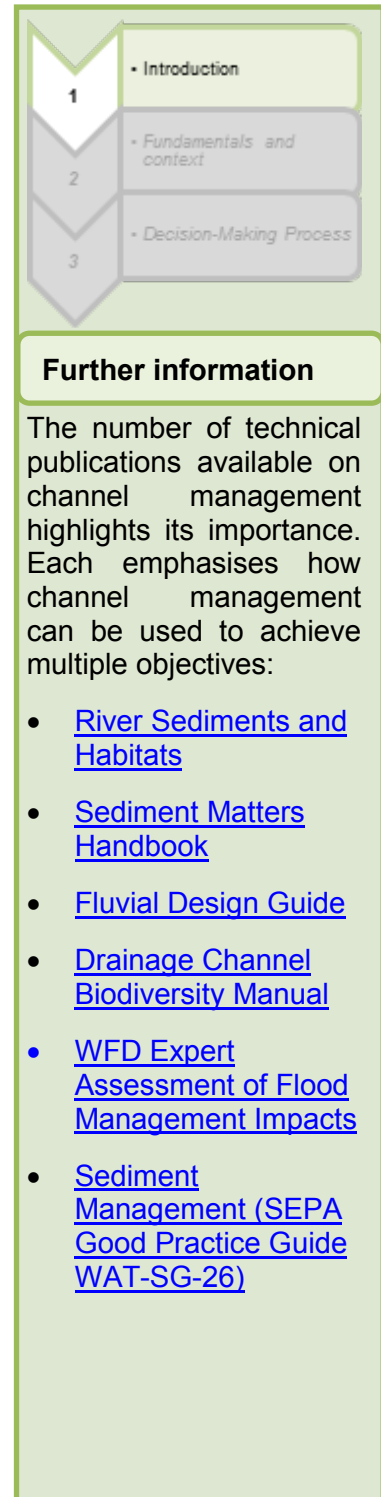


Nature conservation/ecology

Channels and their floodplains support a great variety of habitats for wildlife. These habitats and wildlife provide crucial ecosystem services to people and the economy, such as the provision of drinking water. Both the quality of habitat available in a channel, and individual species themselves, may be impacted by inappropriate channel management, such as the works interrupting breeding or nesting seasons, or the extent of vegetation cutting. Statutory drivers afford channels protection from inappropriate management and set objectives for the improvement of watercourses. Certain sites, species and habitats also have protection.

Fisheries

Fish communities are intrinsically linked to sediment and changes in sediment regimes, because sediment can both directly and indirectly impact populations. For example, the direct effects of smothering of habitat or provision of spawning areas or the impacts of



sediment on fish gills, and the indirect effects of changes in sediment on vegetation cover which may be of benefit to fish.

Water supply

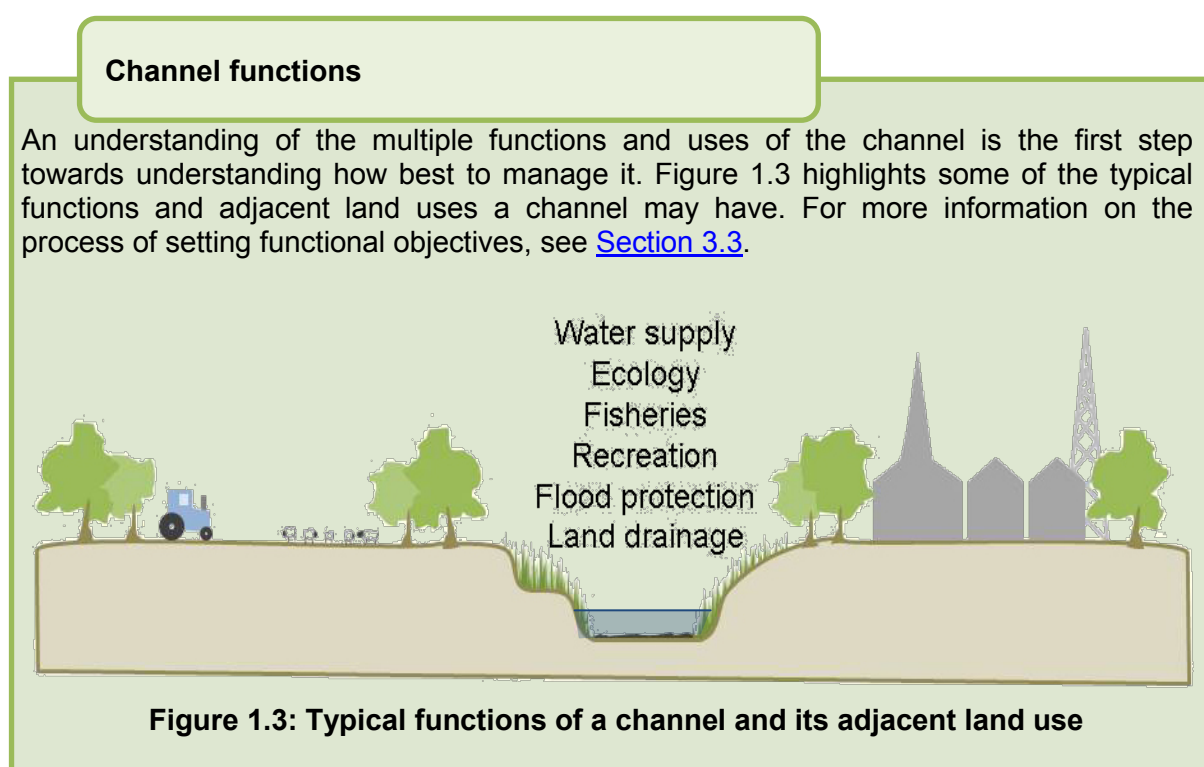
Water supply and quality may be affected by debris and blockages upstream (for example, at structures), restricting flow and hence reducing water availability for the channel.

Navigation

Sediment deposition or dense aquatic vegetation growth within a channel can reduce the available capacity for navigation.

Recreation

Well-managed channels can provide significant recreational opportunities. These activities may be disrupted by functional, aesthetic and health and safety factors such as man-made debris blockages in urban areas. However, intrusive channel management can also diminish the aesthetic value of the channel.



Good channel management to meet the sometimes conflicting demands of various stakeholders is complex. Interactions will exist between:

- catchment 'control' factors (that is, overarching regulating elements of the channel)
- reach scale factors (that is, localised aspects of the channel)
- local channel factors (that is, immediate channel conditions)

[Section 2.2](#) explains these scales further.

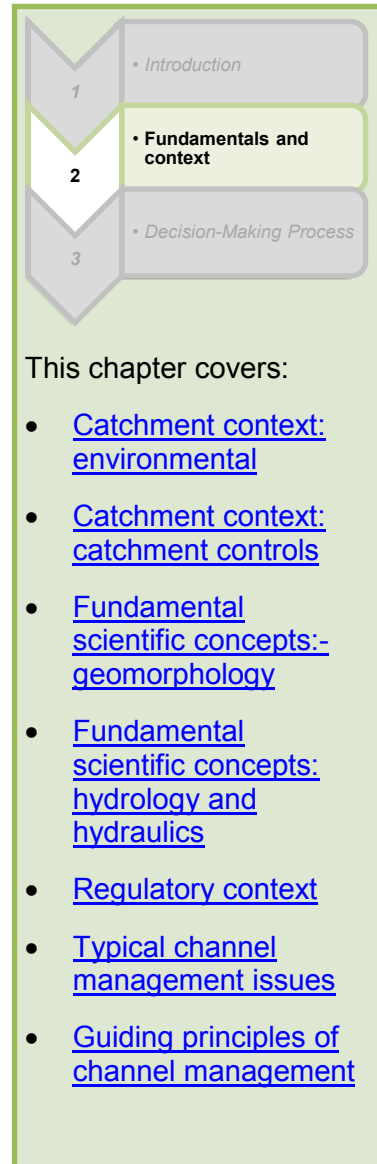
Factors at all these three levels influence the behaviour of the channel and must be appropriately understood so as to determine the right approach to management.

Appropriate channel management will help the channel maintain its essential role, despite having more than one function. These can often have apparently conflicting requirements (for example, both nature conservation and flood risk management systems).

2 Fundamentals and context

Before deciding what, when and how to manage a channel, you must first understand the channel within its wider catchment context. As part of this, you need to understand the fundamental scientific concepts that control the behaviour of channels and their response to management action. You also need to understand the legislative, strategic and local catchment context within which any management needs to occur. Together, these will enable you set appropriate objectives and make channel management decisions that are based on sound science and fit your catchment context.

[Sections 2.1, 2.2, 2.3, 2.4](#) and [2.5](#) describe the fundamental scientific concepts along with the catchment and regulatory contexts. [Section 2.6](#) describes typical channel management issues for which channel management may be required. Addressing these issues requires a good understanding of the above considerations. [Section 2.7](#) presents the guiding principles of channel management, which bring together the requirements for good channel management decisions based on an understanding of the above considerations and their complex interactions.



2.1 Catchment context: environmental

2.1.1 The components of a channel ecosystem

The hydraulic and geomorphological conditions of a channel are strongly linked with the quality of the natural environment. These conditions determine the range of physical habitats that are found in a channel, and by extension, determine the species that can be supported within and adjacent to the channel.

The ecosystem often exists in a delicate balance. Any changes to the physical (abiotic) characteristics of the channel can alter this balance and cause a fundamental change to the biological (biotic) community that can live there (Figure 2.1).

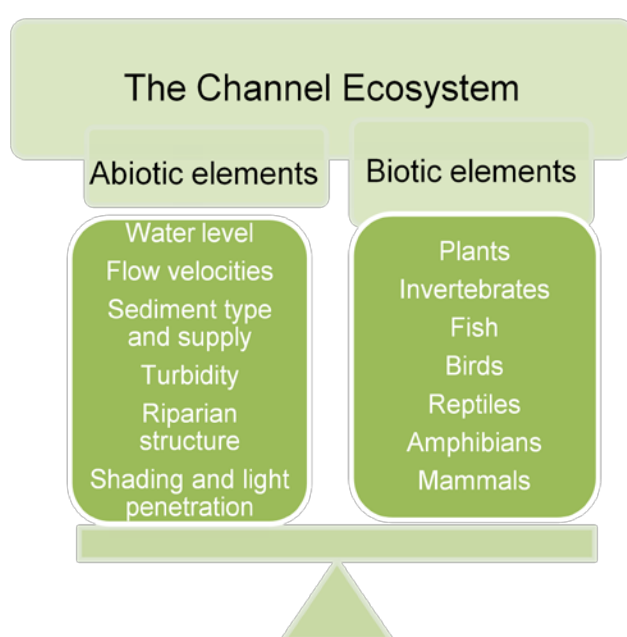


Figure 2.1: Balance between physical channel characteristics and living things in a channel ecosystem – the abiotic and biotic elements

The degree of ecosystem response to a physical change to some extent depends on the type, spatial extent and duration of impact. Some management activities can cause short-term impacts that can be recovered from quickly, while others require longer time periods before the ecosystem can fully recover. In some cases, management activities may have irreversible effects, i.e. the ecosystem is unable to recover from the impact without further intervention. The way in which the channel is managed and how management interventions are undertaken is therefore of considerable importance from an ecosystem perspective.

2.1.2 Minimising impacts

The impacts of channel management activities should be minimised through careful site characterisation, planning and the inclusion of reasonable avoidance, mitigation and compensation measures. These considerations can lessen the likelihood of an activity being in contravention of environmental legislation such as the [Water Framework Directive](#), Habitats Directive, [Wildlife and Countryside Act \(as amended\)](#). In particular, it is vital that the

1

• Introduction

2

• Fundamentals and context

3

• Decision-Making Process

Further information

Further information on the balance between channel management and environmental benefits can be found in:

- [WFD Expert Assessment of Flood Risk Management Impacts](#)
- [Working with Wildlife: Guidance for the Construction Industry](#)

following factors are considered (you may have a Biodiversity team who can help you with this):

- The **location** of management interventions should, where possible, avoid direct impacts on sensitive habitats such as fish spawning grounds, nursery areas, and the habitats of protected species such as water voles, bats and otters.
- You must check whether protected or priority species are present (e.g. water voles, white clawed crayfish, nesting birds, bats) (see Technical Annex D). This might include searching local records (e.g. www.magic.gov.uk) or by contacting your local records centre. You may need to get an ecologist to survey the site for you in advance of works in order to advise on how works can avoid impact to these species, and prevent you committing a wildlife offence. Different species have particular **seasons** during which surveys can be carried out most effectively or reliably. Page 120 of the [Drainage Channel Biodiversity Manual](#) has tables of when surveys can be conducted. Where protected species are affected by works you may need to apply for a licence from Natural England, which will require you to include mitigation and compensation for impacts.
- You must check whether your works will impact on a protected site or priority habitat. This can find the location of these sites at www.magic.co.uk or by contacting your local records centre. You may need to seek permission prior to undertaking works on or adjacent to a protected site.
- The **type** of management intervention should also be selected so as to avoid impacts on sensitive habitats and species. Techniques that work with natural processes are typically less likely to have adverse impacts than traditional 'hard' engineering solutions, for example, creation of multi-stage channels to increase conveyance for flood flows while enabling self-cleansing and habitat diversity during 'normal' flow would be more beneficial over the long-term for wildlife than a single-stage concrete channel. See the [Manual of River Restoration Techniques](#) and [Working with Natural Processes to Reduce Flood Risk](#) for additional techniques.
- You must include mitigation for the impacts of your management intervention, for example, if de-silting a channel you should leave a margin of vegetation at the foot of the bank as refuge for species. Your Biodiversity colleagues (where appropriate) will be able to advise.
- The implementation of management interventions should be **carefully timed** and ensure that disturbance to key species and habitats is **avoided** as far as practicable. Where species or habitats may be affected by works, management interventions must be timed to avoid disturbance to species. Tables 2.1 to 2.3 present high and low risk periods for typical management interventions

Sediment and debris removal

All year round considerations

1. Works require checks for protected species such as water voles, white clawed crayfish and otters prior to works. Seek ecological advice.
2. Lamprey ammocoetes can be found for most of the year in sediment. Any sediment management needs to be checked with Environment Agency Fisheries.

Seasonal considerations

3. Check for nesting birds prior to work (March - September).
4. Salmonid spawning period (October to May). For further advice contact Environment Agency or Natural Resources Wales Fisheries.
5. Coarse fish spawning period (March to July). For further advice contact Environment Agency or Natural Resources Wales Fisheries.
6. Lamprey spawning period (April to July). For further advice contact Environment Agency or Natural Resources Wales Fisheries.
7. Dredging and de-silting are best timed during winter months when the temperature is low enough to sustain dissolved oxygen levels and prevent the killing of fish and invertebrates.

Low risk	Work can be programmed during this period, although you must still check for protected species before commencing works.
High risk	Work should proceed with caution during this period, as sensitive species may be spawning, breeding or roosting. Seek expert ecological advice prior to works.

Table 2.1: Ecological consideration timetable

Species	January	February	March	April	May	June	July	August	September	October	November	December
1. Check for protected species												
2. Lamprey ammocoetes check												
3. Nesting birds												
4. Salmonid spawning period												
5. Coarse fish spawning period												
6. Lamprey spawning period												
7. Low water temperature												

Vegetation management (tree, bank and in-channel)

All year round considerations

1. Works require checks for protected species such as water voles, white clawed crayfish and otters prior to works. Seek ecological advice.
2. Trees must be checked for bats and bat roosts, and otter holts at all times of year prior to work (Bats and otters are protected species). Seek ecological advice.

Seasonal considerations

3. Check for nesting birds prior to work (March – August for bank side vegetation management activities)
4. Check for nesting birds for all in-channel vegetation management work March – September for in-channel activities). Be careful of nesting birds when removing debris for example, coots, grebes etc. Do not disturb if present.
5. Avoid tree management works during September/ October as many trees are not dormant at this time of year and may be susceptible to damage.

Low risk	Work can be programmed during this period, although you must still check for protected species before commencing works.
High risk	Work should proceed with caution during this period, as sensitive species may be spawning, breeding or roosting. Seek expert ecological advice prior to works.

Table 2.3: Ecological consideration timetable

Species	January	February	March	April	May	June	July	August	September	October	November	December
1. Check for protected species												
2. Check for bats and otters before tree management												
3. Nesting birds (bankside activities)												
4. Nesting birds (in-channel activities)												
5. Trees susceptible to damage												

2.2 Catchment context: catchment controls

The overall behaviour of a channel depends on the complex interaction of a range of physical, climatological and human controls. These interact with local factors at a reach scale to determine how a channel behaves and responds to different pressures and management interventions. [Section 1.5.1](#) illustrates this complexity of factors which can affect other elements at varying scales and, in turn, be affected by other variables at varying scales.

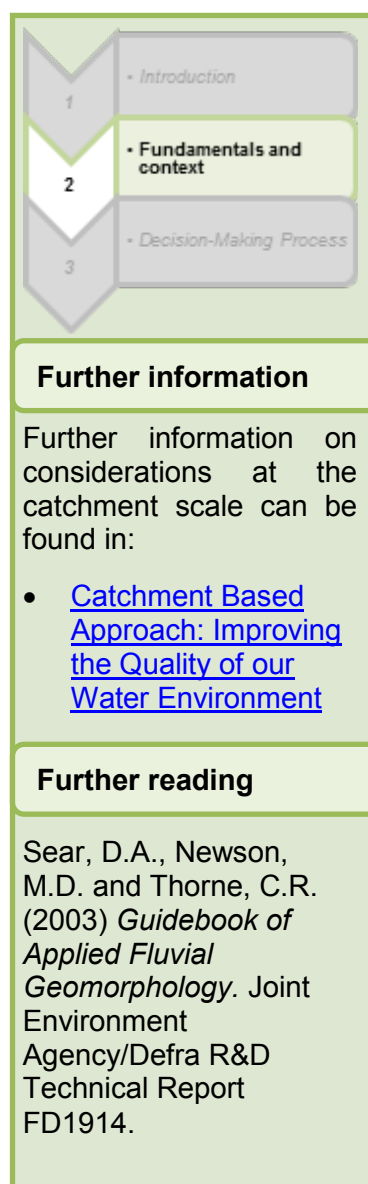
The catchment scale and reach scale controls that influence channel behaviour and local hydraulic factors are detailed below.

Catchment scale controls

- The underlying **geology** and **soils** influence how the channel responds to rainfall and baseflow inputs, control how a channel erodes, and provide a source of sediment.
- The **topography** (or **geomorphology**) of the catchment influences the energy of flows, how rapidly the channel responds to rainfall, and the amount of erosion and deposition that takes place – ultimately dictating the **sediment regime**.
- The **hydrology** of the catchment influences how much water there is in a channel, and how frequently and how rapidly water levels change.
- The **land use** of the surrounding catchment influences how quickly water enters the channel and how much sediment and debris is supplied.

Reach scale controls

- The **channel morphology** (that is, the physical form of the channel), which is determined by the primary catchment controls, influences how water and sediment move through a channel (see [Section 2.3](#)).
- Local **modifications**, including flood and erosion risk management structures, can alter the local hydraulics and therefore the responses of a channel to any changes in the catchment or reach scale controls.
- The local **hydraulic regime** of the channel describes how and when water levels vary. It is determined by the catchment geology and hydrology, alongside its geometry.
- The local **sediment regime** describes how much sediment is in a channel and how, when and where it is eroded, transported and deposited.
- The **location** (position in the catchment) and **dimensions** of a channel determine its energy and responsiveness.
- The **ecology** of the channel is dependent on the geomorphology and hydrology, and can impact on channel function.



2.2.1 Relationship to catchment scale plans

A review of broader catchment plans will provide you with more information regarding the channel, the wider catchment aims and any recommended, and in some cases required, measures.

There is a need for local decisions to be made within the context of understanding the catchment and its controls and systems. Some of the most relevant catchment plans are discussed below as examples of plans and documents where catchment and system level studies and information may be available to steer/inform management approaches. These are of importance when considering the process in [Section 3.2](#).

Catchment flood management plans (CFMPs)

CFMPs consider all types of inland flooding from rivers, ground water, surface water and tidal flooding. They also take into account the likely impacts of climate change, the effects of how the land is used and managed, and how areas could be developed sustainably. There are also lists of actions in CFMPs which set out in more detail how a policy direction is taken forward. An overall policy direction for an area may not be applicable everywhere, so these actions should be referred to for more detail. There is also likely to be a section on catchment hydrology and geomorphology within these plans, which can be a valuable source of information to support understanding of catchment context.

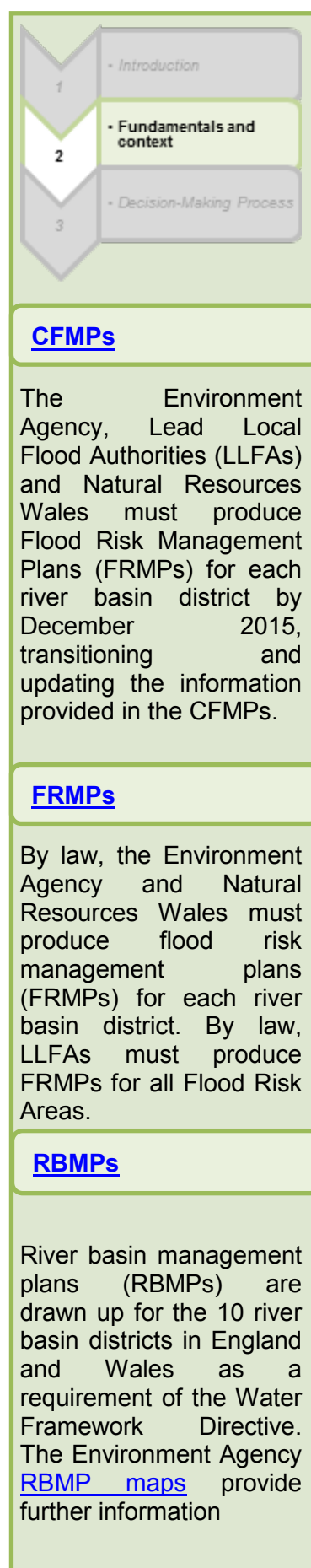
Flood risk management plans (FRMPs)

The European Floods Directive has formalised flood risk management planning. The Flood Risk Regulations 2009 implement the directive and require Lead Local Flood Authorities (LLFAs), the Environment Agency and Natural Resources Wales to prepare and publish FRMPs on a six-year cycle (aligned to that of RBMPs). FRMPs highlight the hazards and risks of flooding from all sources and set out how Risk Management Authorities (RMAs) work together with communities to manage flood risk.

River basin management plans (RBMPs)

Under the Water Framework Directive (WFD), all river catchments are assigned by Member States to administrative river basin districts which are required to prepare RBMPs. These are designed to prevent deterioration and to improve aquatic ecosystems to achieving at least good ecological and chemical status.

RBMPs contain lists of actions, some water body scale and some catchment scale, which are designed to elevate the water bodies to good ecological status or potential. Any channel management needs to recognise the aims of these actions. The directive stipulates that an activity that prevents the achievement of good ecological status or potential is as



bad as an actual deterioration in status itself.

River basin management is a continuous process of planning and delivery. The WFD introduced a formal series of six-year cycles. The current cycle began in 2009 and ends in 2015, when revised RBMPs will be published.

Watercourse catchment and system management plans

Flood Risk Management Authorities use various forms of management plans to direct the management of their watercourse catchments and systems. These plans are usually underpinned by catchment and system studies and assessments. These are often supported by varying levels of details of risk-based assessments of the benefits and costs of strategic management approaches and standards of service. These documents, where they exist, are useful sources of information about the catchment or system context which your management needs to account for.

[The Protocol for the Maintenance of Flood and Coastal Risk Management Assets](#) describes the approach the Environment Agency follows in implementing policy guidance on maintenance. Specifically it describes how the Environment Agency will engage with landowners and other affected parties where it has decided to stop maintaining uneconomic flood defences for the long term. It applies to situations where the costs are greater than the benefits, and it is becoming uneconomic to continue current works. The protocol explains the sequence of actions that the Environment Agency will follow to ensure that the impact on individual landowners and other affected parties is minimised, and that they have sufficient time to make alternative arrangements. The Environment Agency may also consider stopping maintenance where an approved high-level plan such as a CFMP or shoreline management plan (SMP) is in place; this would be used to help inform the decisions on future maintenance. The maintenance of asset systems is carried out using a risk-based approach so that investment is made where activities contribute most towards reducing the potential for damage, and where it is economically and environmentally justified.

Environmental Stewardship

[Environmental Stewardship](#) is a land management scheme that provides funding to farmers and other land managers in England to deliver effective environmental management on their land. It has three levels:

- Entry Level Stewardship (ELS), including Uplands ELS: simple and effective land management agreements with priority options
- Organic Entry Level Stewardship (OELS), including Uplands OELS: organic and organic/conventional mixed farming agreements
- Higher Level Stewardship (HLS): more complex types of management and agreements tailored to local circumstances

When planning channel management, existing land management agreements should be considered carefully. The management practices of adjacent land will have an impact on what can be achieved in the channel regarding access and the riparian zone, and what can be maintained and when in terms of bankside vegetation.

Glastir is the sustainable land management scheme, through which the Welsh Government offers financial support to farmers and land managers.

Glastir pays for the delivery of specific environmental goods and services aimed at:

- combating climate change
- improving water management
- maintaining and enhancing biodiversity.

It is designed to deliver measurable outcomes at both a farm and landscape level in a cost effective way.

Glastir is funded by the [Rural Development Plan for Wales 2007-2013](#). This is financed by the Welsh Government and the European Union.

<http://wales.gov.uk/topics/environmentcountryside/farmingandcountryside/farming/schemes/glastir/?lang=en>

Water level management plans

Water level management plans should be considered where they exist. Although strictly 'local' plans, they are important for Site of Special Scientific Interest (SSSI) wetland sites and for other areas where water level management is crucial, for example, where landowners may have entered agri-environment agreements to support wetland wildlife.

Whether or not there is a formal plan, the flood risk manager or land drainage engineer must recognise that the channel forms part of a functioning system.

2.3 Fundamental scientific concepts: geomorphology

2.3.1 Channel geomorphology

Geomorphology is the shape and physical characteristics of a channel. The geomorphology of a channel (a secondary control of channel dynamics) is the product of catchment scale controls and local scale controls.

What controls geomorphology?

- **Catchment scale controls** (including underlying bedrock, topography and hydrology): These factors help to determine how much water is in a channel, its energy and the types of sediment that can be supplied to it.
- **Local scale controls** (including channel hydraulics, slope, bed and bank cohesiveness, vegetation growth and land use): These factors help to determine how much energy a channel has and how easily it can erode and deposit sediment.

Geomorphological controls affect channel factors such as form, deposition and erosion. There is a need to understand and work with natural processes instead of simply fighting the symptoms, which can be very costly in the long term.

Different types of channel can have varied management requirements as a result of the diverse geomorphological processes that operate in them. This is a particularly important point to consider at different scales (see [Section 1.5.1](#)). Understanding the unique geomorphological concepts in a specific channel is therefore paramount in determining how a channel behaves and how it can be managed effectively.

In the context of channel management, landforms (that is, the channel, floodplain and valley) are a function of the interaction of water and sediment, which in turn determines geomorphology (see Figure 2.2).

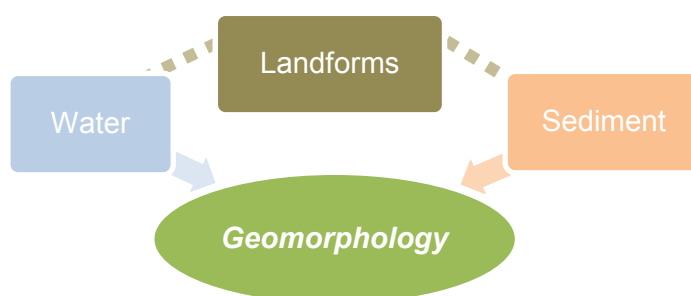
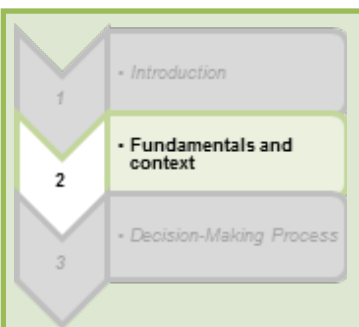


Figure 2.2: Factors that determine geomorphology



Further information

For more information on **working with natural processes** refer to [Section 3.6.5](#)

There are many publications on geomorphology and its potential to influence decisions on channel management, including:

- [Key Recommendations for Sediment Management: A Synthesis of River Sediments and Habitats](#)
- [Working with Natural Processes to Manage Flood and Coastal Erosion Risk \(PDF, 6.24 MB\)](#)
- [Manual of River Restoration Techniques](#)

Further reading

Sear, D.A., Newson, M.D. and Thorne, C.R. (2003) *Guidebook of Applied Fluvial Geomorphology*. Joint Environment Agency/Defra R&D Technical Report FD1914.

2.3.2 Basic geomorphological components

The geomorphology of a channel can be broken down into a number of key components as illustrated in Figure 2.3.

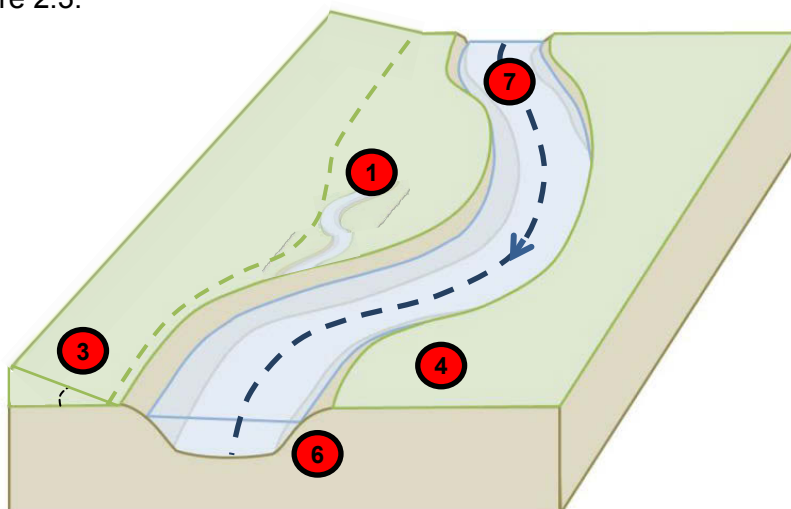
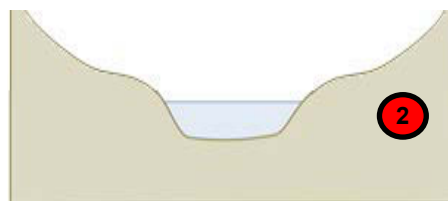


Figure 2.3: Key geomorphological components of a channel

1 Drainage network: The network of channels and drainage features that drain into a channel from the upstream catchment. The higher the drainage density, the more opportunity a channel has to transfer water and sediment through the catchment from upstream to downstream.

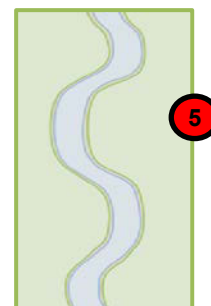
2 Valley form: The cross-sectional shape of the valley (which ranges from a narrow V to a wide, shallow U) in which the channel is located determines the connectivity between the channel and its floodplain. This connectivity influences how the channel floods and deposits sediment on the floodplain, influencing sediment carried in flow and erosion.



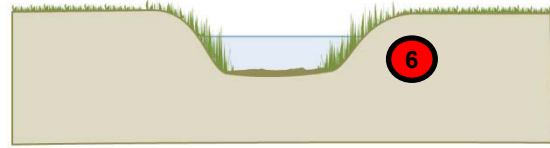
3 Valley slope: The slope or long profile (or gradient) of a valley influences how much energy a channel has; the steeper the slope, the more energy the channel is likely to have. Slope is therefore an important control on where sediment is likely to be eroded, transported and stored within a channel.

4 Floodplain: The floodplain is the part of the valley floor that is inundated during overbank flows. The connectivity of a channel with its floodplain is important for many reasons, such as being a potential control of flood risk, its influence on how sediment is deposited and the development of transitional habitats.

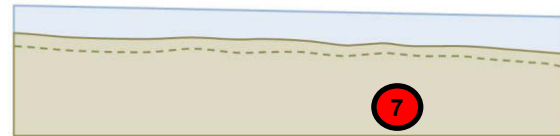
5 Channel planform: The shape of the channel when viewed from above as, for example, in aerial photography. This is an important control on channel behaviour, helping to determine the local gradient (see channel long profile, below) and flow patterns within the channel. These in turn influence where sediment is eroded and deposited, and the distribution of habitats within a channel. Planform is indicative of the dominant processes that are currently operating in the channel and is useful for determining channel type. For further information on channel types see [Section 2.3.6](#).



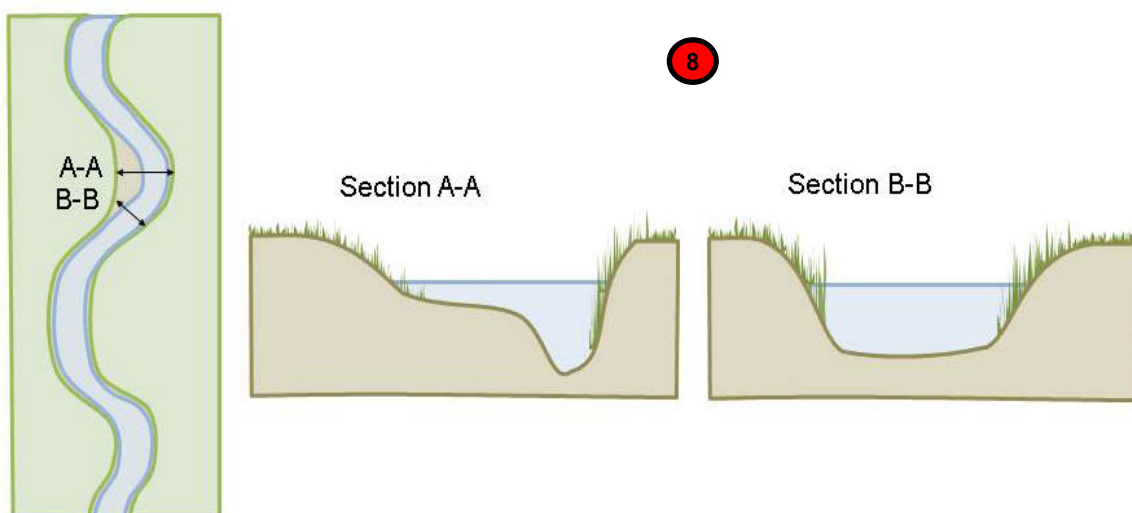
- 6 Channel cross-section:** The shape of the channel in cross-section at a given point. The cross-section reflects the balance between erosion and deposition on the channel bed and banks, and is influenced by the flow patterns which in turn are determined by the planform. Channel cross-section is usually described in terms of width, depth, area and overall shape.



- 7 Channel longitudinal profile:** The local slope of the channel, which determines localised flow conditions and where sediment is eroded and deposited. This interacts with the planform and cross-section to determine the type and distribution of landforms such as pools, riffles, bars and other features within a channel.



- 8 Meanders:** Flow patterns in a bend (Section A-A below) naturally differ from those that occur in straighter sections of channel (Section B-B below). In a straight channel, the line of maximum flow depth (known as the thalweg) occurs within the central portion of the channel. On a bend, however, the thalweg deviates out of the centre and moves towards the outside of the bend. This creates an area of faster, higher energy spiral flows on the outside of the bend and slower, lower energy flows on the inside, resulting in a broadly triangular cross-section. It is therefore natural to have areas of preferential sediment deposition on the inside of a bend, and areas of preferential scour on the outside. The presence of deposition on the inside of a bend or scour on the outside of a bend therefore occur in response to natural processes and only need to be actively managed if they are causing an additional issue in the channel. If management interventions are required, these should work with natural processes to create a solution that is sustainable over long timescales. For example, it may be more sustainable to move an outfall away from a location in the inside of the bend which requires regular sediment removal to removal to enable discharge than to carry out frequent sediment removal.



When should geomorphology be considered?

Geomorphology is an important factor in determining the current form and features of a channel. It is therefore likely to influence the particular issues for which management is contemplated. When seeking to understand the causes of issues, geomorphology should be considered in the first instance to understand underlying causes and whether these are self-limiting or part of a broader geomorphological response. This will enable the development of a solution that is sustainable and works more with natural processes, as well as understanding the likely impact of any management option.

Any changes to the key controls or components of a channel (for example, through management activities such as bed raising or weir removal) have the potential to cause a geomorphological response (for example, altering channel cross-section) and subsequently, water levels.

It is therefore important that channel geomorphology is considered whenever any work is undertaken or planned in or near to a channel. Channel management activities have the potential to:

- impact on the discharge and/or sediment load of a channel
- alter the physical characteristics and structure of a channel or its floodplain
- change the composition, structure or form of the channel boundary conditions including bed and bank material, vegetation, and local slope and topography



Further information

Sear, D.A., Newson, M.D. and Thorne, C.R. (2003) *Guidebook of Applied Fluvial Geomorphology*. Joint Environment Agency/Defra R&D Technical Report FD1914.

2.3.3 Importance of geomorphology in channel management

Different types of channel can have different management requirements as a result of the different geomorphological processes that operate in them. For example, 'restoration of geomorphological features' in heavily reinforced urban channels will vary significantly from those in natural channels. As such, it is vital that the overall behaviour of the channel is considered on both a site-specific and a wider catchment basis when management interventions are planned, implemented and monitored.

2.3.4 Importance of sediment

Sediment is particulate material, ranging in sizes from clays to boulders. It is an important part of geomorphology, driving the form and function of a channel and the range of habitats it supports (Figure 2.4).

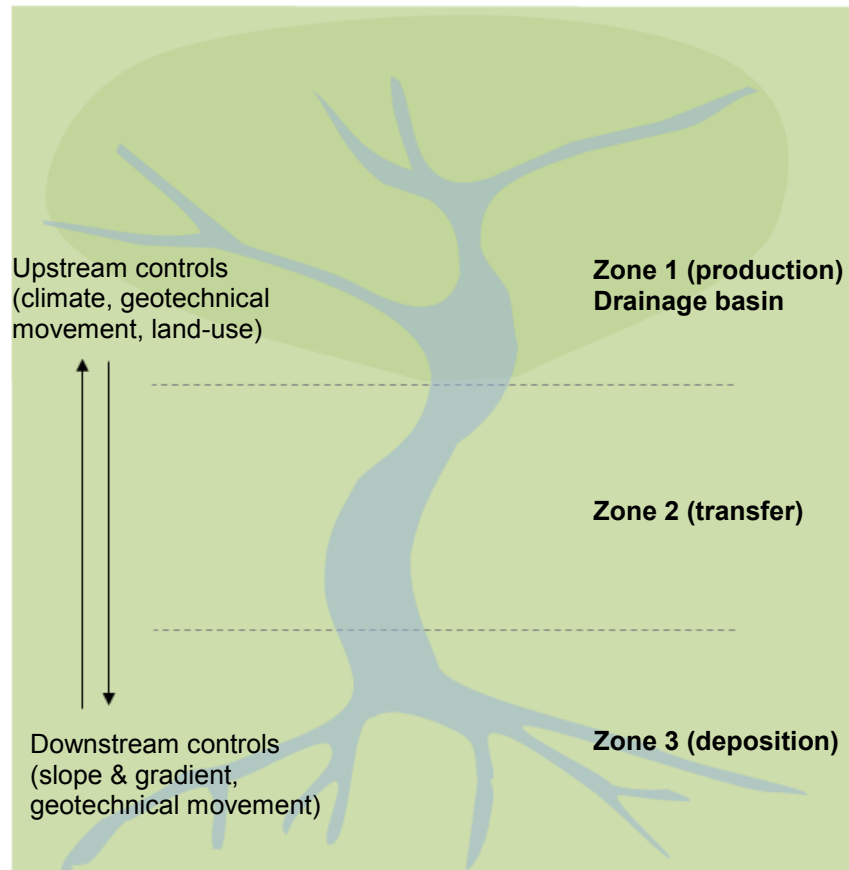


Figure 2.4: Sediment dynamics on a catchment scale

Notes: The drainage basin can be divided into three zones. Different stages of sediment movement can be broadly mapped into these zones, although they generally overlap. These processes all influence each other; even when focusing on part of a channel, all the processes operating upstream and downstream must be considered.

Erosion

Sediment can be eroded from catchment sources (for example, the land that surrounds the channel and upland slopes via mass movement) and from the bed and banks of the channel. Erosion is dependent upon the water in the channel having critical stream power to dislodge and entrain particles from the channel boundaries. This in turn is influenced by the grain size and cohesiveness of the sediment; more energy is required to entrain cohesive sediment and large particles than smaller particles.

Transport

Once entrained, sediment is intermittently transported downstream through the drainage network. Depending on the size of the particles and the available stream power, sediment can be suspended in the water column (suspended load) or it can slide, roll or bounce along the bed (bedload). In some circumstances, sediment may only move a very short distance.

Suspended load moves with the water and once entrained in the flow it can be transported several kilometres during a flood. Hence it carries fine grained material (clay, silt and fine sand) from upstream sources to lowland reaches, where it is deposited in the channel and, particularly, on floodplains provided these are connected. Deposition of fine grained, suspended sediment is promoted where dense vegetation growth, channel modifications or in-channel structures damp turbulence and create low energy conditions. It is therefore important to consider the quantity of suspended sediment supplied to the channel and how its transport and deposition will be affected when appraising options for channel management.

Bedload consists of coarser sediments (coarse sand, gravel, cobbles and occasionally boulders) that create and sustain many geomorphic features (for example, shoals, bars and riffles) that provide important habitats. Bedload moves infrequently and may only travel a few tens of metres, if at all, during a flood. Movement of coarse sediment is highly sensitive to changes in coarse sediment supply and stream power. It is therefore important to consider bedload fully when planning, undertaking and monitoring channel management.

Deposition

Deposition occurs when the stream power available to transport sediment through a channel decreases to an extent that it is no longer capable of transporting the entire load supplied from upstream and local sources. Deposition will occur naturally due to falling discharge after the peak of a flood or a downstream reduction in channel slope, but it frequently occurs in response to excess sediment input due to land uses that accelerate soil erosion in the catchment. Channel management actions that may also trigger or exacerbate deposition include:

- installation of an impounding structure or undersized culvert that obstructs or impedes flow within a channel to create a backwater effect
- channel enlargement or dredging that significantly increases its cross-sectional area, reducing velocity and sediment transport capacity



Implications of channel management

The sediment regime (that is, the behaviour of sediment within a channel, including erosional sources, transport and depositional sinks) is highly sensitive to disturbance. It therefore requires careful consideration when planning, undertaking and monitoring channel management. Some examples are given below.

- Removing sediment from a reach can locally lower water levels and increase conveyance. Increased conveyance in normal conditions can reduce flow velocity resulting in local deposition. In the short term, this could reduce sediment output to the next downstream reach and, potentially, trigger increased erosion and channel instability in that (downstream) reach. Increasing the cross-sectional area of a channel by reprofiling can also reduce flow velocities, leading to sediment deposition and the need for recurring and costly management. Therefore, it is important that sediment is managed carefully to avoid disturbing the sediment regime sufficiently to create significant imbalance between sediment input and output at the reach scale.
- If sediment accumulation is leading to a significant loss of conveyance that is impeding land drainage or increasing flood risk unacceptably, consideration should also be given to managing the root cause of the sediment problem as well as its symptoms. In this context, it is useful to determine whether sediment is accumulating due to excessive supply from the catchment or channel upstream (could the problem be controlled at its source?) or due to a local reduction in sediment transport capacity that has changed the geomorphology of the channel in the problem reach (for example, choking by vegetation growth or backwatering by an in-channel structure). This will aid identification of the best management actions.
- Allowing natural erosion and deposition to adjust the morphology of the channel to match the sediment regime should allow the channel to become self-regulating, but this can locally increase water levels compared with a previous managed condition. However, it also allows channel geomorphology to operate more naturally, recovering multiple functions, more diverse features and habitats. If the increase in water levels is an issue, its impact can often be mitigated locally using multi-stage channels.
- Vegetation management can also have a pronounced effect on the channel's sediment regime. Excessive in-channel vegetation growth should be managed to avoid choking that promotes sedimentation. However, removing too much in-channel vegetation makes the channel vulnerable to bed scour and bank erosion. As an alternative, allowing riparian vegetation to grow sufficiently to buffer and shade the channel can reduce sediment input due to local run-off and shade out aquatic weeds avoiding, or at least minimising, in-water work and disturbance.

2.3.5 Importance of woody debris



In many channels, woody debris is an essential part of the natural geomorphology. Woody debris may cause localised blockages and/or change flow patterns, and encourage localised erosion and deposition of sediment. It is therefore an important driver of geomorphological diversity and change, and is important in terms of in-channel habitats.

Although woody debris can pose a significant flood risk in some channels, this may not be the case in many channels. It is therefore important to consider the need to manage woody debris on a site-specific basis, and that any management is proportionate to the level of flood risk. In some cases, flood risk issues can be addressed without the need for removal, for example, by anchoring woody debris securely to the channel bed or banks. Such a solution addresses flood risk, while at the same time allowing the woody debris to have a natural impact on in-channel processes. Additional information on woody debris management can be found in [Technical Support Document C3 Debris management](#).

2.3.6 How channel type influences channel management

The geomorphology of a channel is a result of the complex interaction of a range of local and catchment scale factors. The dominant geomorphological processes that operate in a channel control how it behaves and how it is likely to respond to management interventions. These dominant processes are often similar in different locations with similar their characteristics (for example, steep uplands or shallow lowlands). This creates groups of channels that behave in the same way and, as such, can be grouped together for management purposes. These groups are called 'channel types'. A channel typology categorises a channel, factoring in channel aspects such as substrate, depositional features, bank modifications and flow characteristics to distinguish between types.

Channel typology

The simple channel typology developed for this handbook is based on a typology developed as part of the [Aquatic and Riparian Plant Management Guide](#) which in turn was developed from the Montgomery and Buffington (1993) typology. It can help management by allowing channel managers to assess potential management options based on their channel type; for example, the erosion control measures that would work well in a drainage channel are unlikely to be successful in an active meandering channel. The typology includes the following river types:

Natural or modified natural channels

- Step pool channel
- Bedrock channel
- Plane bed channel
- Wandering channel
- Active meandering channel
- Pool riffle channel
- Inactive single thread channel
- Tide-locked channel

Artificial or extensively modified channels

- Small unreinforced drainage channel
- Large unreinforced drainage channel
- Reinforced drainage channel
- Canal
- Natural channel (high modification)
- Natural channel (significant modification)

A full description of the main geomorphological characteristics of each of these channel types is provided in [Technical Support Document A](#).

2.3.7 Influence of channel type on prospective management options

The variation in dominant geomorphological processes between each channel type means they can behave in different ways in response to the same pressure or management intervention. As such, there is often a need to manage different channel types in different ways.

A good understanding of channel type can therefore help you limit the range of options feasible for use in your channel. Three important parameters that can be used to help differentiate between channel types are:

- **slope**, which influences the energy of flows within the channel
- **substrate size**, which influences how easily sediment can be entrained and transported
- **degree of modification**, which can be used to differentiate between natural and artificial channels

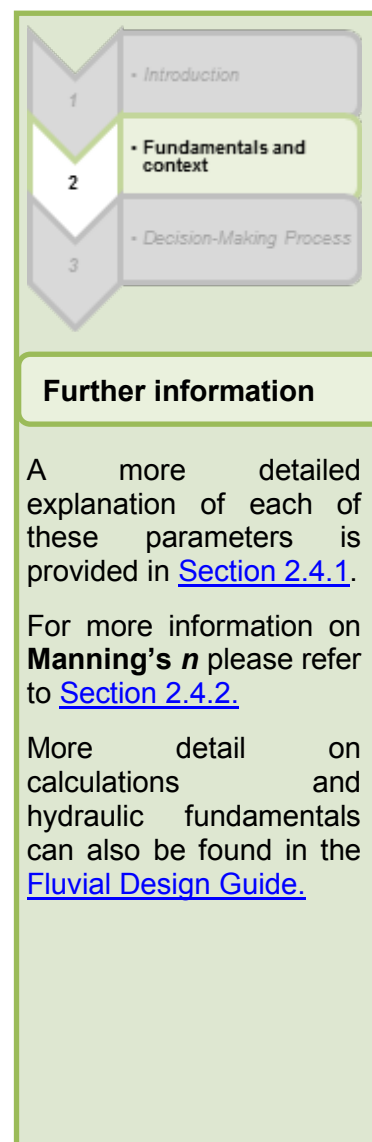
Influence of channel type on roughness

There are a range of channel types that have different geomorphological characteristics and therefore need to be managed in different ways. Channel roughness (as expressed in terms of Manning's n , which is specific to each channel type) can be highly variable between different channel types, reflecting the bed sediment characteristics and vegetation communities.

Variations in channel characteristics mean that some management options can be effective in some channel types and ineffective in others. Furthermore, it may be possible for some management options to have unwanted side effects in some channel types. It is therefore paramount to consider channel type during the planning and implementation of management interventions. Figure 2.5 links channel type to the important characteristics outlined above and provides examples of the implications for sustainable channel management.

Important note: channel typologies

Channel typologies are not a substitute for understanding the various processes acting on the channel. The handbook recommends these typologies are used as a 'guide' to aid discussion rather than as an aspect of the decision-making process. It further recommends consulting a geomorphologist to aid selection of appropriate management techniques.



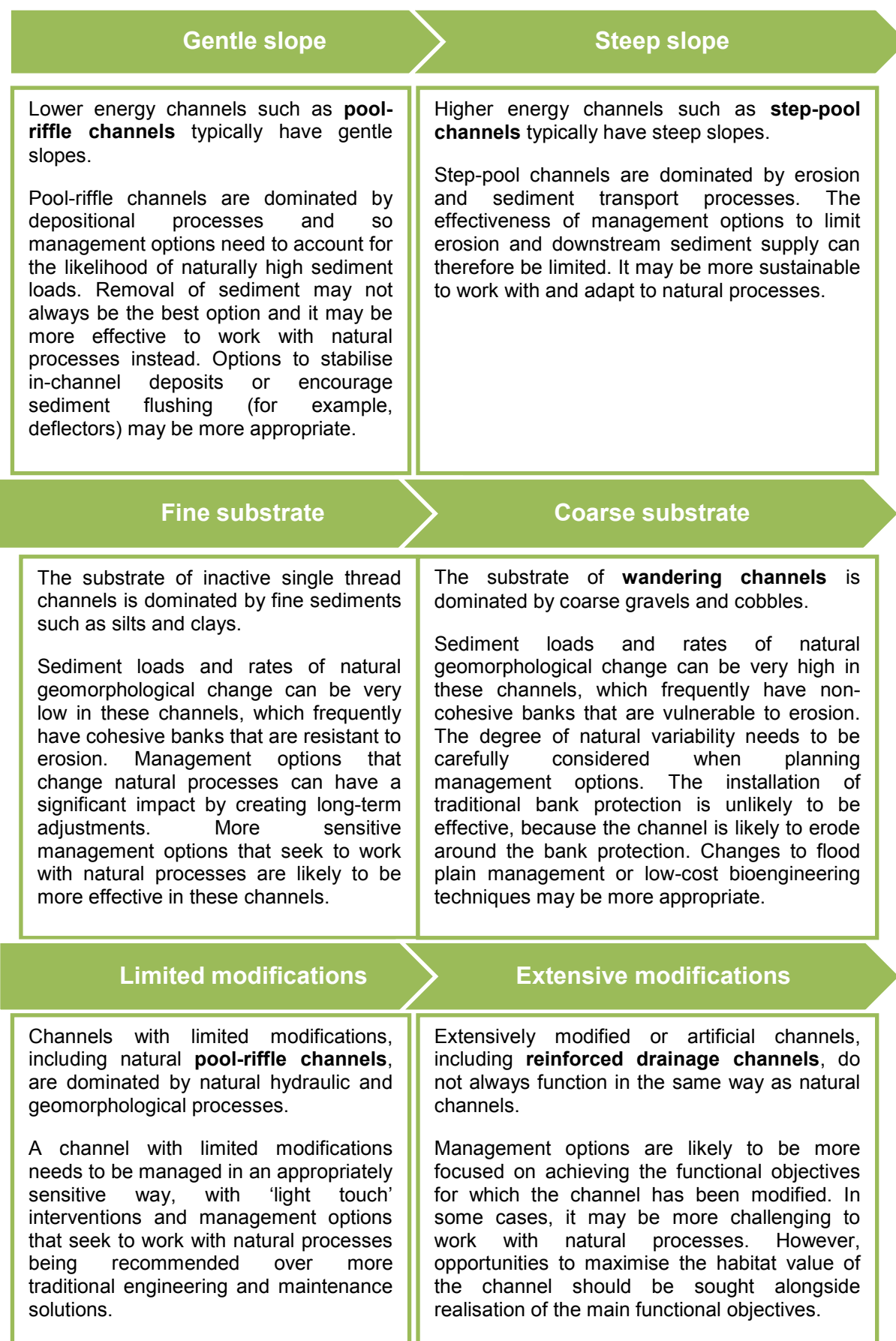


Figure 2.5: Key characteristics defining channel type

Selecting an appropriate value of channel roughness coefficient Manning's 'n' is an important step. Table 2.2 suggests a range of Manning's n values that are likely to be suitable for each channel type; the [Roughness Advisor](#) within the Conveyance Estimation System (CES) provides further advice on how to do this.

Table 2.2: Manning's n roughness values in relation to channel types

Channel type		Manning's n roughness value		
		Recommended value	Upper value	Lower value
Natural or modified natural channels	Step pool channel	0.06	0.075	0.04
	Bedrock channel	0.055	0.07	0.035
	Plane bed channel	0.03	0.02	0.04
	Wandering channel	0.045	0.055	0.03
	Active meandering channel	0.038	0.05	0.03
	Pool riffle channel	0.038	0.07*	0.025
	Inactive single thread channel	0.03	0.055*	0.02
	Tide locked channel	0.025	0.05	0.02
Artificial or extensively modified channels	Small unreinforced drainage channel	0.025	0.06*	0.018
	Large unreinforced drainage channel	0.02	0.055*	0.018
	Reinforced drainage channel	0.018	0.05	0.015
	Canal	0.015	0.017	0.012
	Natural channel (high modification)	0.03	0.055*	0.02
	Natural channel (significant modification)	0.025	0.05*	0.015

*These higher values can be influenced by vegetation, which will influence the roughness.

2.3.8 Cumulative impacts

A channel affects, and is affected by, a wide range of contrasting factors from anthropogenic changes in the catchment such as land use to local scale changes in sediment dynamics (for example, via bank erosion). So as to identify appropriate intervention or maintenance options, the impacts these factors have independently and also collectively on your channel should be considered.

The cumulative impact of multiple factors can play a significant role in channel dynamics. For example, sediment inputs upstream of a channel may not significantly impact conveyance, but this factor coupled with excessive vegetation growth or blockages downstream may, in turn, result in a conveyance issue.

When attempting to obtain an all-encompassing picture of your channel and catchment so as to identify cumulative impacts, the following influences should be considered.

- **Actions of surrounding land owners:** This includes recognising the type of management and/or maintenance implemented by riparian owners upstream and downstream. For example, if a surrounding land owner is not dealing with blockages appropriately then this factor, in conjunction with factors such as high sediment loading, may have significant resultant cumulative impacts within a

channel. Management may therefore aim to address this factor first as it could be considered the focal point of the issue.

- **Surrounding land uses:** This consists of determining if local and catchment scale land-uses can have a cumulative impact that is propagated within a channel. For example, high energy flows with implications of excessive erosion within a channel may be the result of upstream urban environments providing flashy flood flows due to high surface run-off. Potential management may therefore seek to address this issue at source by means of reducing the rate of run-off input from urban areas via, for example, increased riparian planting or installation of sustainable drainage systems.
- **Surrounding catchment factor:** This involves gaining an understanding of the primary and secondary control factors (see [Section 2.2](#)) that potentially affect the dynamics of a channel. For example, excessive sediment deposition within a channel may be the result of geology and soil types within the catchment, which in turn interact with complex hydraulic processes to create an issue within a channel.

Sources of information can be consulted to gain information on cumulative impacts include the following.

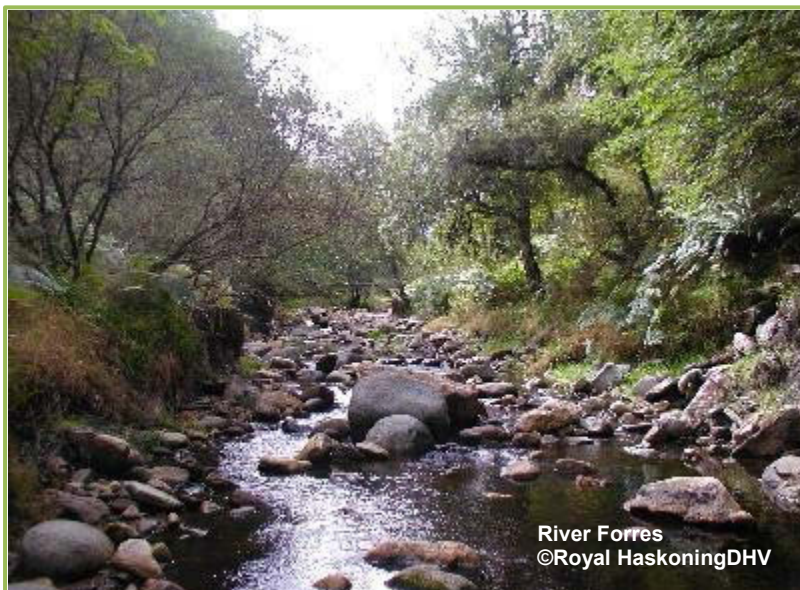
- Consultation with local landowners offers an opportunity to gain an insight into the actions of individuals that may impact on your channel. Public consultation meetings or information from local councils may provide this evidence.
- Surrounding land uses can be assessed via aerial photography (for example, Google maps), or site walkovers and assessments.
- Catchment factors may be established by acquiring data on catchment controls from information held by specific bodies. For example, the management authority channel monitoring programme can provide an indication of water levels.

You should also consider potential changes in the cumulative impacts on your channel. This includes identifying changes to existing surrounding conditions or other factors that may impact on a channel within the catchment.

2.4 Fundamental scientific concepts: hydrology and hydraulics

2.4.1 Relationships between channel characteristics and water levels

The water level in a channel will vary in response to changes in run-off, groundwater and surface inflows. The rate at which the water level rises or falls in response to a severe storm or period of dryness will reflect the hydrological response of the catchment (including the antecedent conditions, such as how moist the soil is). For example, in steep valleys such as shown in the photograph below), the water level is likely to respond more quickly to rainfall than in lowland chalk watercourses sustained by groundwater.



In the fluvial environment, hydraulic concepts are principally considered in the context of open channels and structures, or features that either constrain or control the flow of water. In all cases, however, the change in the water level (WL), and hence the performance of the channel and its ability to meet the flood risk and land drainage objectives for a given land use, will be governed by the hydraulic characteristics of the channel. These are:

- conveyance capacity
- afflux at structures
- very local reductions in flow area (for example, due to trees falling into the channel or bank slippages)
- erosion and deposition of sediment as determined by stream power and sediment size

An overview of the important hydraulic factors governing each of these (interrelated) issues is given in Figure 2.6.

1

• Introduction

2

• Fundamentals and context

3

• Decision-Making Process

[Fluvial Design Guide](#)

The Fluvial Design Guide provides more detail on the hydraulic principles that control channels.

See [Chapter 7](#) for comprehensive coverage of the theory and practice of hydraulic analysis and design as applied to works in rivers and streams. After brief introductory sections the rest of the chapter is divided into three main parts: basic hydraulic concepts; fundamental hydraulic principles; and the practical application of hydraulic modelling.

See [Chapter 8](#) for guidance on the planning, design, construction and maintenance of a wide range of works that may be found in rivers.

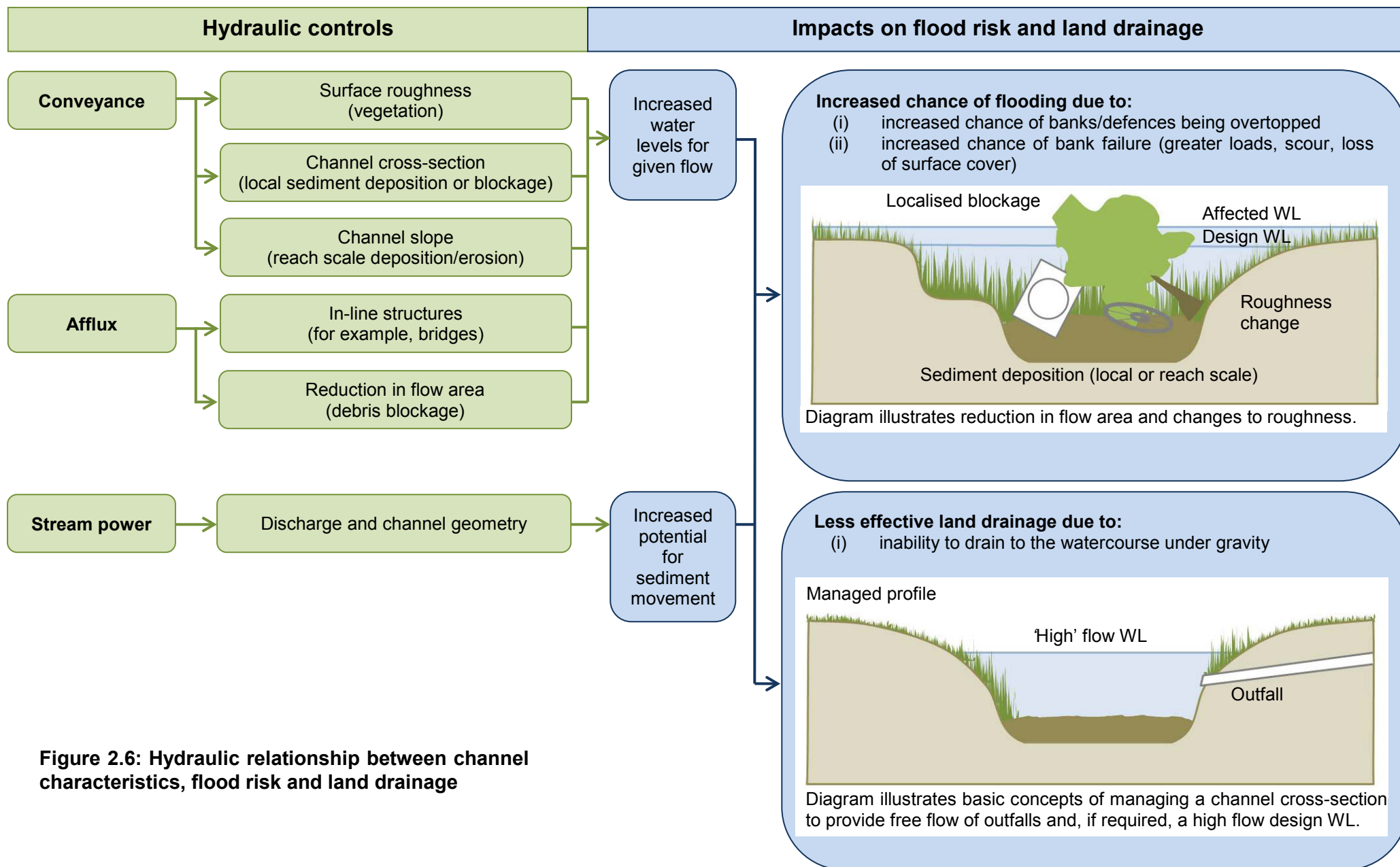


Figure 2.6: Hydraulic relationship between channel characteristics, flood risk and land drainage

2.4.2 Conveyance of the channel

Understanding the discharge (Q) and flow velocity (V) of the channel, and the interaction between them, is a prerequisite to understanding how water levels in the channel are likely to change in response to a management action.

The fundamental of conservation of mass relates discharge and velocity simply as:

$$V = Q / A$$

This relationship demonstrates that, if the discharge (Q) remains constant but the area (A) through which it flows is reduced, the velocity of the flow will increase (and vice versa). A reduction in velocity will cause water levels to rise (increasing the area, A) and may encourage sediments to deposit and limit the ability of the channel to self-scour (that is, stay in regime). An increase in velocity and water levels in the channel will decrease as the required area, A, decreases, but may increase channel erosion and scour.

Conservation of mass alone does not provide the whole story as it focuses on a two-dimensional channel cross-section. To understand the hydraulic characteristics that influence velocity along a reach, it is useful to consider Manning's equation which defines the mean channel velocity as:

$$V = (1 / n) R^{2/3} S^{1/2}$$

By combining Manning's equation with the fundamental of conservation of mass, an expression discharge for [steady uniform flow](#) can be derived as:

$$Q = A (1 / n) R^{2/3} S^{1/2}$$

Conveyance formulae

Fundamental of conservation of mass $V = Q / A$

Hydraulic radius calculation - $R = A / P$

Manning's equation - $V = (1 / n) R^{2/3} S^{1/2}$

Steady uniform flow - $Q = A (1 / n) R^{2/3} S^{1/2}$

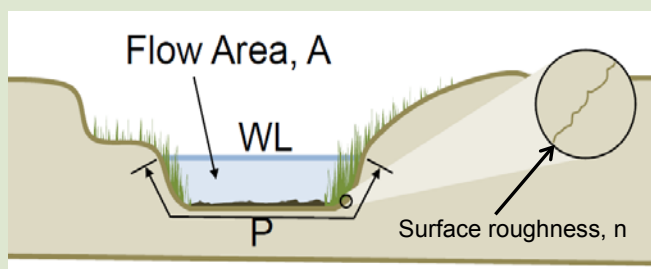


Figure 2.7: Diagram illustrating channel terms

Definition of terms

Mean flow velocity (V) is the speed at which water moves through a channel (m/s). It depends on how much water is in contact with the bed and banks of the channel, and hence the efficiency of the channel in overcoming friction.

Discharge (Q) is the volume of water that passes through a channel cross-section in unit time, normally expressed in m³/s and often simply referred to as 'flow'.

Cross-sectional area (A) is the shape of the channel at a given point (m²). It can determine how much water is in contact with the channel bed and banks.

Slope (S) can often be approximated by the gradient of the channel bed gradient or water surface. The steeper the slope, the greater the velocity will be.

Wetted perimeter (P) is a measure of how much water is in contact with the bed and banks of a channel at any one time (Figure 2.7).

Hydraulic radius (R) is a measure of how efficient a channel is at conveying water and increases as a channel becomes larger. R is cross-sectional area of the flow (A) divided by the wetted perimeter (P). The greater the hydraulic radius, the more efficient the channel is at conveying water and eroding sediment.

Manning coefficient of roughness (n) accounts for channel energy losses due to friction and turbulence in the flow. The value of *n* varies according to the bed material, vegetation growth, channel irregularities and shape and size of channel. For example, *n* = 0.003 for straight channels with no riffles, deep pools or vegetation; for very weedy reaches, the value of *n* may be as high as 0.1.

Local channel controls such as weirs or effects of local blockage or local/reach scale sediment deposition influence the behaviour of the channel upstream and downstream. The nature of influence will reflect the nature of the flow regime (that is, if it is normal, super or subcritical flow). For example, for subcritical flows (typical of lowland channels) downstream changes in flow depth impact on water levels upstream (the **backwater profile**, also illustrating slope; see Figure 2.8). The distance upstream before the normal depth is re-established is known as the **backwater length**. A first-pass approximation of the distance upstream that may be influenced by this so-called **backwater** effect is given by:

$$L_b = 0.7H_d / S$$

where H_d = flow depth [at structure] and S = slope.

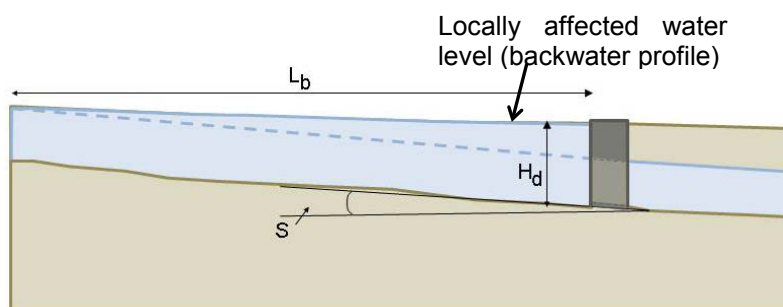
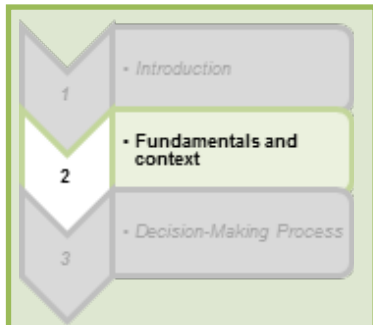


Figure 2.8: Diagram illustrating the backwater effect

Backwater effects

Backwater effects can be both positive and negative in terms of water level. For example, if sediment, vegetation or debris is removed the water level is likely to be reduced upstream too. Thus the benefits of techniques such as dredging are often found in communities upstream of the dredging site. Recognising backwater effects is an important consideration because:

- It enables the upstream influence of works in a river channel to be determined.
- The backwater length may extend far upstream, potentially causing inundation in areas remote from the study reach.
- Flow gauging stations should not be located within reaches influenced by backwater effects.
- The backwater profile is useful for the operation of land drainage pumps to avoid frequent switching on and off, leading to increased wear and tear and hence reduced operational life.
- In lowland areas where channel slopes are very small, backwater issues tend to be a core consideration as the backwater length tends to be long and small changes in water levels can affect drainage functions.



Conveyance and Afflux Estimation System (CES/AES)

The Environment Agency's [Conveyance Estimation and Afflux Estimation System](http://www.river-conveyance.net) (www.river-conveyance.net) provides a more rigorous analysis of backwater effects.

In particular, the CES enables variation in cross-sectional roughness to be captured.

It also enables simple **backwater effects** (the increase in upstream water levels due to a restriction in the downstream conveyance capacity) to be estimated.

When the channel flows are unsteady, more complex hydrodynamic modelling is likely to be required. This can be provided through appropriate industry standard river modelling software (as listed in the [Fluvial Design Guide, Section 7.5, Table 7.6](#)).

2.4.3 Issues that influence conveyance

The design water level is the water level (WL) that needs to be maintained to allow a channel to perform its function. Depending on the channel's functional objectives, this could be a minimum level (for example, for water resources, biodiversity or navigation) or a maximum level (for example, for flood risk management and land drainage). Channels are frequently managed to maintain the design water level. The simplified equations presented in [Section 2.4.2](#) provide an approximate means of estimating the discharge and flow velocity for any given water level in any channel. They also encapsulate the way the hydraulic characteristics of the channel interact and hence the issues that influence conveyance, afflux and related water levels; these are illustrated below:

Local channel features that influence conveyance

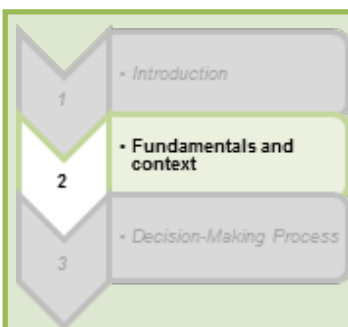
- **In-channel debris:** When part of the channel is restricted by debris the available cross-sectional area (A) to convey flow is reduced. This reduced conveyance capacity increases water levels for a given flow. Hence, managing partial blockages can make a useful contribution to managing water levels.



In-channel debris relates to multiple typical channel management issues associated with sediment, vegetation and debris. For example, debris from outside of the channel can be entrained in the channel during flood flows and result in blockages. See [Section 2.6.3](#) for further information.

- **Surface roughness:** In the absence of a blockage, surface roughness provides the primary resistance to the flow. Assuming all other parameters are the same a greater resistance will result in a slower flow and higher water level. Managing roughness at the local and reach scales can result in appreciable changes in flow velocity and hence water levels.

Surface roughness relates to the typical channel management issues of sediment deposition, too much debris and in-channel vegetation whereby sediment deposition is encouraged, for example, slowing flows due to increased resistance. This can lead to bed aggradation. See [Section 2.6.1](#) for further information.



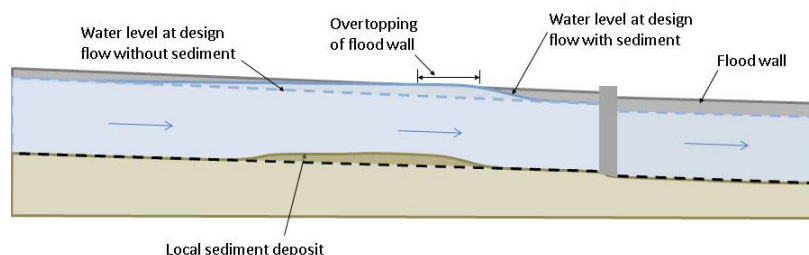
The degree of 'roughness' provided by the managed or unmanaged channel is represented by the 'n' in Manning's equation. Selecting an appropriate value of 'n' is therefore an important step. If you are unsure how to do this, the [Roughness Advisor in the CES](#) provides advice.

Further information

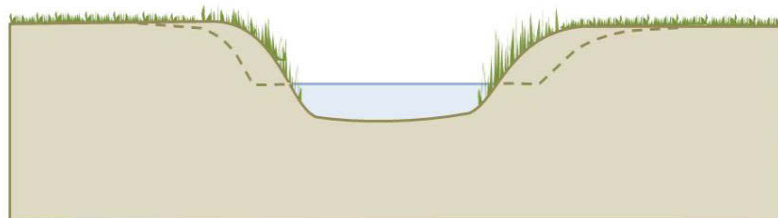
For more on the issues that influence conveyance see:

- [River Sediments and Habitats](#)
- [Sediment Matters Handbook](#)
- [Fluvial Design Guide](#)
- [Drainage Channel Biodiversity Manual](#)
- [WFD Expert Assessment of Flood Management Impacts](#)
- [Conveyance Manual \(PDF, 4.5 MB\)](#)
- [Culvert Design and Operation Guide](#)
- [Land Use Management Effects on Flood Flows and Sediments: Guidance on Prediction](#)

- **Sediment deposition (local scale):** Sediment deposition at a local scale can act in a similar way to a blockage and reduce the cross-sectional area of the channel and hence its conveyance capacity. During higher flows this loss of channel capacity may result in higher upstream water levels and consequently increased flood risk. However, the channel cross-section will tend to match the discharge and sediment budget naturally, where in flood flows sediment may become remobilised.



- **Channel cross-section:** Changing the channel cross-section to increase the hydraulic radius can increase the efficiency of the channel and its conveyance capacity. Increasing channel capacity by creating a multi-stage channel, rather than a wholesale enlargement, may allow the channel to continue to be self-cleansing at low flows while creating the extra capacity required during higher flows.



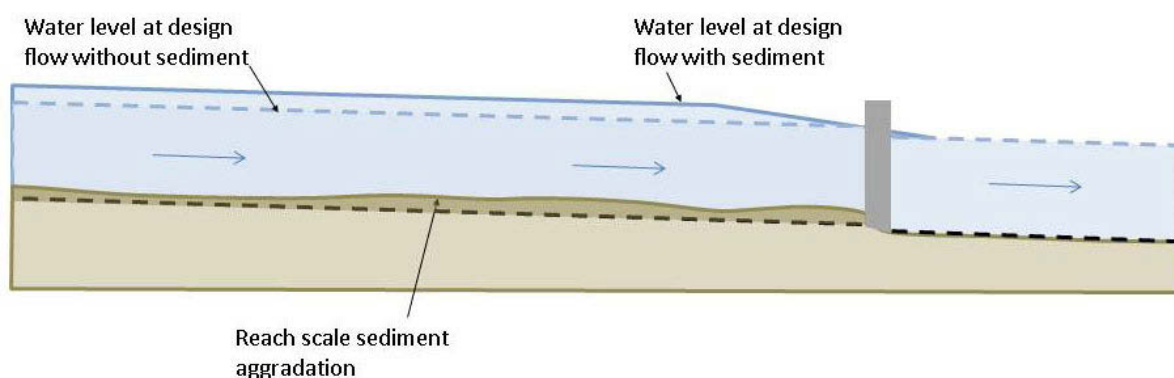
Reach-scale features that influence conveyance

- **Sediment deposition (reach scale):** Unlike a shoal or local scale deposition, widespread deposition of sediment can, in some settings (for example, lowland reaches and estuaries), act to reduce the bed slope of the channel, in turn slowing the flow (reducing its stream power) and hence increasing water levels for a given flow. In middle and upland reaches, reach scale deposition may have limited impact on slope and hence little impact on stream power. However, it will reduce the bankfull cross section and may cause the banks to overtop more frequently at that particular location. Managing the slope of channel at a reach scale is a difficult task as it depends on the wider topographic setting and geomorphological processes. At a local scale, modification of the bed slope is unlikely to have a significant impact to flow/water levels.

Sediment deposition relates to multiple typical channel management issues such as direct effects of sediment deposition, aggradation of the channel bed, or the creation of shoals and banks which can become stabilised by vegetation over time. See [Section 2.6.2](#) for further information.

The cross-sectional area of a channel will influence most of the typical channel management issues. For example, excessive vegetation growth will significantly lower the channel cross-section and influence sediment deposition where flow slows down. See [Section 2.6.1](#) for further information.

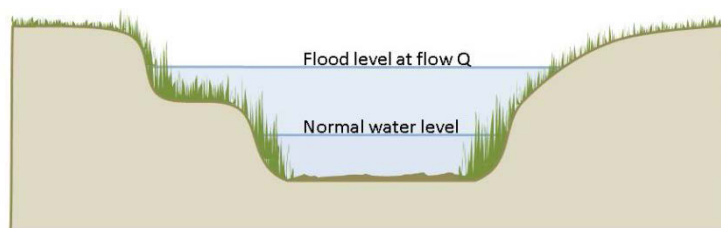
Reach scale sediment deposition relates to multiple typical channel management issues, such as sediment deposition resulting in aggradation of the channel bed, and the creation of shoals and banks. This issue is common where upstream sediment supply has changed due to increased erosion or changes in land management practises. See [Section 2.6.1](#) for further information.



- **Excessive vegetation growth:** The ability of a channel to convey flows can be significantly affected by vegetation if not managed correctly.

The following series of diagrams present an example of how excessive vegetation growth, sediment deposition and debris may reduce channel cross-sectional area, reduce flow velocities and hence reduce conveyance.

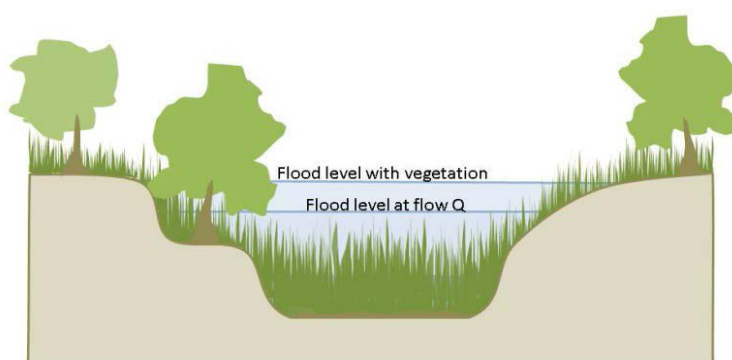
(i) Limited vegetation – low surface roughness, high conveyance, low water level



The diagram shows a channel cross-section which is able to convey high water levels during flood events and hence helps achieve flood risk objectives. The vegetation cover provides some protection to the channel bank and toe, while having minimal resistance to flow.

Water levels within channels can be designed to reflect the range of discharges that need to be conveyed by the channel, related to its functional objectives.

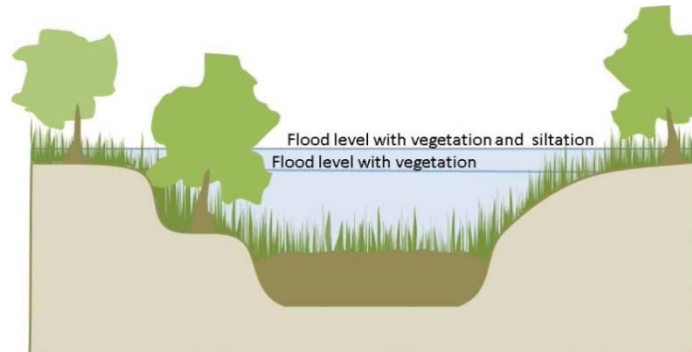
(ii) Increased vegetation – increased surface roughness, lower conveyance, higher water level



The diagram shows the impact of heavy vegetation on water level and flow capacity of a channel when vegetation acts to reduce the cross-sectional area (A) and increase the roughness of the channel.

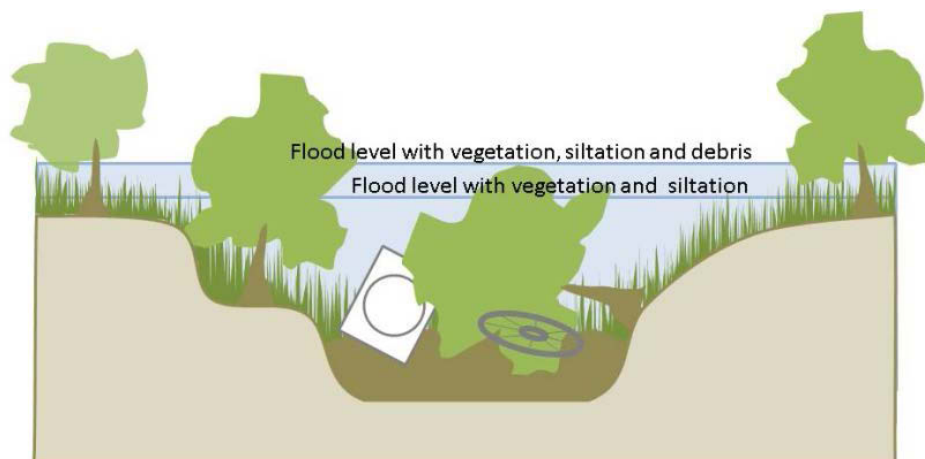
Vegetation can significantly reduce conveyance and raise upstream water levels. This image shows impoundment effects where the channel has become choked with vegetation.

(iii) Local sediment deposition (encouraged by the presence of excessive vegetation) can reduce cross-sectional area and lead to higher water levels for a given flow



Vegetation growth within the channel can reduce stream power (see [Section 2.4.5](#) for more detail) and encourage the deposition of sediment on the channel bed. This can further reduce channel capacity and will also lead to further increases in water levels. The slowing of flow in the upper catchment may reduce flood risk further downstream.

(iv) Debris within the channel can reduce cross-sectional area and lead to higher water levels for a given flow



The series of diagrams above highlights the impact on water levels associated with excessive vegetation growth. These include too much vegetation in the channel, the promotion of local deposition of sediment and blockages. These impacts are greater in narrower and flatter channels. See [Section 2.6](#) for further information.

2.4.4 Afflux

The rise in water level above the normal surface of water in a channel that is caused by a partial obstruction, such as a bridge or culvert is referred to as afflux (Figure 2.9).

Afflux is caused by localised energy losses at high flows through bridges and culverts. It can be made significantly worse if debris further constrict the openings.

Afflux does not necessarily only occur at structures. Highly localised blockages within channels (such as a tree falling into a channel and restricting flow area by its branches and leaves or debris) can also cause afflux (see Figure 2.9).

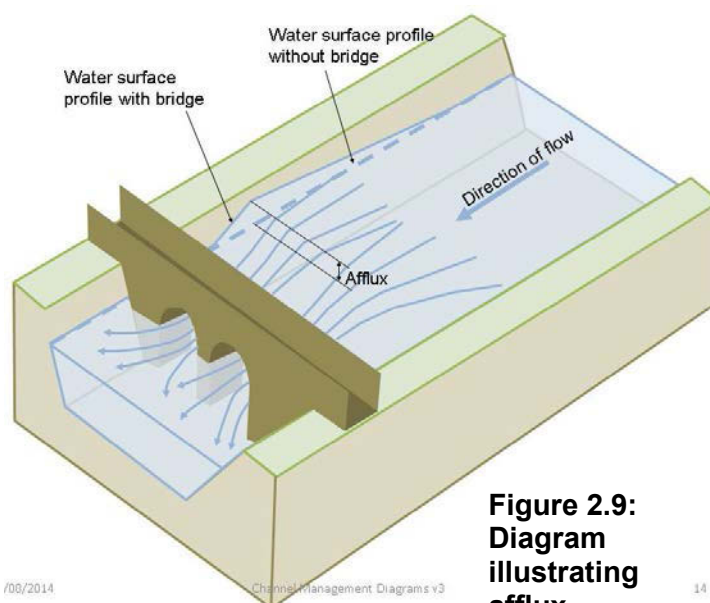


Figure 2.9:
Diagram
illustrating
afflux

Blockages, for example, as a result of debris, change the channel cross-sectional area and locally decrease channel capacity, thus reducing conveyance and increasing water levels.

Afflux is associated with several typical channel management issues such as flow restrictions and blockages via sediment, vegetation and debris at structures. See [Section 2.6](#) for further information.

From a flood risk management perspective, the channel must have sufficient capacity at design water level to convey flows of a given discharge. From a land drainage perspective, the water level must be low enough to allow outfalls to discharge freely during 'normal' flow conditions.

The [Environment Agency's Conveyance and Afflux Estimation System](#) (free to download) enables an estimate of the likely increase in water levels upstream of structure to be estimated.

[Chapter 7](#) of the Fluvial Design Guide provides comprehensive coverage of the theory and practice of hydraulic analysis and design as applied to works in rivers and streams, including a specific discussion on afflux.

2.4.5 Stream power and sediment erosion and deposition

Stream power reflects the rate at which energy is dissipated (against the bed and banks of a channel) as the flow moves downstream through the watercourse. The stream power is estimated as:

$$\omega = \rho g Q S / B$$

where ω is the stream power unit (W/m^2), ρ the specific weight of water (kg/m^3), g the acceleration due to gravity (m/s^2), Q the bank-full discharge (m^3/s), S the water surface slope (m/m) and B is the channel width (m) at bank-full.

The rate of change in the stream power can be used to provide an initial view of how a channel might be affected by processes of erosion or deposition. Although only a crude guide, stream power can be used to provide a reasonable high level indicator as to whether or not more sediment deposition within the channel may present an issue and whether or not more detailed sediment modelling is required.

The **critical stream power** is the threshold above which flows have sufficient energy to entrain and transport particles of a given size. Larger or denser particles typically have a higher critical stream power than smaller or lighter particles, which means that more energy is required to transport them.

Changes in the energy of flow within a channel can mean that this threshold is crossed and erosion or deposition starts to occur. For example, a reduction in energy due to a blockage in a channel can result in a decrease in stream power and the initiation of deposition, while the removal of this blockage can result in an increase in stream power and the initiation of erosion.

Stream power is therefore a good indicator of whether erosion or deposition is likely to occur in a reach, and as such can be a useful tool to help determine the most appropriate management options.

Turbulence is a chaotic, highly irregular type of flow that is characterised by the formation of unsteady vortices and rapid changes in velocity and pressure. This encourages water to mix and become homogenised. Turbulent flows dissipate rapidly unless there is a constant source of energy to maintain them.

The 'examples' box on the next page illustrates the influence of stream power on sediment dynamics.

Examples

As stream power increases, erosion is more likely. The photograph on the right shows overbank flow on the River Adur during a flood event, where high stream power resulted in scouring and erosion of banks.



The photograph on the right illustrates bank erosion on the River Teme where scouring and slumping of the river bank has resulted from excessive flow energy for the vegetated bank to withstand.



The photograph on the right shows a sediment shoal on the Cod Beck. In reaches where the stream power decreases (typically below 35 W/m^2), some of the smaller sediments carried by flow are likely to settle and deposition is more likely.



Further reading

The [Fluvial Design Guide](#) provides a more detailed discussion of the issues and methods highlighted in this section.

[Practical Channel Hydraulics](#) also provides an excellent technical reference guide and instruction text for the estimation of flood and drainage water levels in rivers, waterways and drainage channels. It is written as a user's manual for the openly available [CES / AES](#) software, with which water levels, flows and velocities in channels can be calculated and the impact of factors influencing these levels and the sensitivity of channels to extreme levels can be assessed.

2.5 Legislative context

Awareness of the main legislative drivers is crucial to appropriate channel management. These acts, regulations and subsequent national policies place significant duties and responsibilities on those working to achieve flood risk and land drainage objectives to have due regard for conservation and enhancement of the environment.

Important legislative drivers you need to be aware of, and what they mean for your channel, are summarised below. There may be some pieces of legislation that apply to only one organisation, e.g. the Environment Act 1995 confers duties on the Environment Agency. These have not been summarised here for purpose of brevity. A full discussion of all legislation relevant to channel management is presented in [Appendix D](#).

Water Resources Act 1991

This act provides a general structure for the management of water resources, standards for controlled waters and pollution, and flood defence mitigation information. Any works to or close to a main river may require the consent of the Environment Agency or Natural Resources Wales. Early engagement is beneficial.

Land Drainage Act 1991 (as amended 1994)

This act requires that a watercourse be maintained by its owner through liaison with Internal Drainage Boards (IDBs) or Lead Local Flood Authorities (LLFAs) in such a condition that the free flow of water is not impeded. Any works within to or close to an ordinary watercourse (non-main river) may require the consent of the LLFA or IDB as a result of this act or associated byelaws. Early engagement is beneficial.

Floods Directive / Flood Risk Regulations 2009

Practical interpretation of the [Floods Directive](http://ec.europa.eu/environment/water/flood_risk/) (http://ec.europa.eu/environment/water/flood_risk/) is more applicable to the UK interpretation given in the Flood Risk Regulations 2009. Associated information from FRMPs, the first of which will be published by the end of 2015, can provide a useful context for your channel management.



The Environment Agency has the power to bring criminal charges against people or companies responsible for crimes concerning water. More: [Water Resources Act 1991](#) (www.legislation.gov.uk/ukpga/1991/57/contents)

If a riparian owner fails to carry out their responsibilities under the Land Drainage Act, or if anyone else causes a watercourse to become blocked or obstructed, county and district councils and Internal Drainage Boards have powers of enforcement by serving a notice under the act. More: [Land Drainage Act 1994](#) (www.legislation.gov.uk/ukpga/1994/25/contents)

The directive requires Member States to consider flood impacts on environmental, social and economic factors. It makes clear the need to integrate its delivery with that of the WFD.

Flood and Water Management Act 2010

This act, which applies specifically to England and Wales, aims to reduce the flood risk associated with extreme weather events, placing a duty on all flood risk management (FRM) authorities to co-operate with each other for a catchment-based approach.

The act gives more power and responsibility to the Environment Agency and local authorities to plan food defences co-ordinated across catchment areas. Contact your LLFA for details regarding your channel. More: [Flood and Water Management Act 2010](http://www.legislation.gov.uk/ukpga/2010/29/contents) (www.legislation.gov.uk/ukpga/2010/29/contents)

Conservation of Habitats and Species Regulations 2010

These regulations designate sites important for habitats and species in order to secure their conservation such as Special Areas of Conservation (SACs) and Special Protection Areas (SPAs). Ramsar sites, classified under the [Ramsar convention of 1971](http://www.legislation.gov.uk/ukpga/1971/63/contents), have the same protection as SAC and SPA sites.

[List of Ramsars, SACs](https://www.gov.uk/check-your-business-protected-area) and SPAs (https://www.gov.uk/check-your-business-protected-area)

These regulations also provide certain animal and plant species with levels of protection from disturbance and harm. Known as European Protected Species, these are listed within the Annexes. Annex II species are protected through the designation of SACs, whereas Annex IV species receive what is known as full protection. For more information see JNCC website: <http://jncc.defra.gov.uk/page-1747>.

Any channel management within a designated site must be discussed with the competent authority (Natural England) and a management agreement entered into. More: [The Conservation of Habitats and Species Regulations 2010](http://www.legislation.gov.uk/uksi/2010/490/regulation/41/made) (www.legislation.gov.uk/uksi/2010/490/regulation/41/made)

A licence from either Natural England/Natural Resources Wales will be needed where protected species are likely to be impacted by works.

Water Environment (Water Framework Directive) (England and Wales) Regulations 2003

The [Water Framework Directive](http://ec.europa.eu/environment/water/water-framework) (http://ec.europa.eu/environment/water/water-framework) imposes legal requirements to protect and improve the water environment. It expands the scope of water protection to all waters and sets out clear objectives (for example, ecological and chemical standards) that must be achieved. Achievement of the WFD's environmental objectives depends on the current ecological status or ecological potential (for heavily modified water bodies and artificial water bodies) of the water body.

You can obtain information about your water body and its objectives and targeted action by finding your channel on the relevant management authority website and looking in Annex B of the RBMP.

Nature conservation legislation such as the Habitats and Birds Directives impose legal requirements to conserve important species and habitats. Wider environmental legislation provides protection for landscape, heritage and fisheries. Physical works that occur in and

around channels could potentially conflict with these legal requirements and/or cause harm to the water environment.

The channel manager must secure compliance with the requirements of the WFD and meet its other environmental duties when carrying out physical works in channels and issuing consents/licences for others to do so.

An applicant applying for a consent or licence to undertake physical works in or around a channel may be required to provide the appropriate management authority with information to demonstrate that the proposed works meet the requirements of the WFD and wider environmental legislation.

The Eels (England and Wales) Regulations 2009

These regulations deal with the passage of eels, such as obstructions and eel passes and also screening at abstractions, which will aid downstream migration. In December 2008, the UK produced 15 eel management plans (EMPs) which have been approved by the European Commission. The EMPs are based on the river basin district as defined in the WFD.

Eel management plans relevant to your channel of interest can be obtained online. To identify your river basin district, use the Environment Agency's [What's In Your Backyard](http://apps.environment-agency.gov.uk/wiyby/default.aspx) (<http://apps.environment-agency.gov.uk/wiyby/default.aspx>) website.

Once you have identified the relevant river basin district, EMPs specific to your channel of interest can be found on the [Managing freshwater fisheries web page](http://www.gov.uk/government/policies/managing-freshwater-fisheries/supporting-pages/increasing-eel-stocks) (www.gov.uk/government/policies/managing-freshwater-fisheries/supporting-pages/increasing-eel-stocks).

Salmon & Freshwater Fisheries Act 1975

This act is aimed at the protection of freshwater fish, particularly salmon and trout. Offences under the act include direct mortality, barriers to migration and degradation of habitats. The owner or occupier of a watercourse frequented by salmon or migratory trout is obliged to provide a mechanism for the free passage of these species beyond any obstructions which act as a barrier.

To comply with the act, it is necessary to ensure that the structures in your channel are passable by salmon and migratory trout and the overcutting of reeds is minimised. More: [Salmon and Freshwater Fisheries Act 1975](http://www.legislation.gov.uk/ukpga/1975/51/contents) (www.legislation.gov.uk/ukpga/1975/51/contents)

Natural Environment and Rural Communities Act 2006

This act places a duty on all public bodies (i.e. the intended audience of this document) such that *"in exercising its (our) functions, (we should) have regard... to the purpose of conserving biodiversity"*. Therefore, public bodies must assess how proposals could protect, restore or enhance nature conservation and include this as part of our decision making process when considering management interventions.

Wildlife and Countryside Act 1981 (England and Wales) (Amendment) Regulations 2004

These regulations provide protection to native species; control the release of non-native species and enhance the protection of SSSIs. The regulations apply to channels situated adjacent to or within sites designated as a SSSI under the regulations, or where species listed within the legislation are present at the site.

[Find a list of SSSIs](http://www.gov.uk/check-your-business-protected-area) (www.gov.uk/check-your-business-protected-area).

Countryside and Rights of Way Act 2000 (CRoW)

[The CRoW Act](#) amends the [Wildlife and Countryside Act 1981](#) via Schedule 9 to increase the responsibilities of public bodies towards SSSIs. It also strengthens wildlife enforcement legislation. The amendment obliges public bodies to notify NE/NRW when authorising or undertaking activities that might affect SSSIs.

Any channel management within a designated site must be discussed with the competent authority (Natural England) and a management agreement entered into. More: [Wildlife and Countryside Act 1981](http://www.legislation.gov.uk/ukpga/1981/69) (www.legislation.gov.uk/ukpga/1981/69)

Environmental Assessment of Plans and Programmes Regulations 2004

These regulations implement the Strategic Environmental Assessment Directive in England and Wales. The aim of this directive is:

‘to provide for a high level of protection of the environment and to contribute to the integration of environmental considerations into the preparation and adoption of plans and programmes with a view to promoting sustainable development’.

Requirements for your channel include the preparation of an environmental report in which the likely significant effects on the environment of implementing your plan or programme are identified, described and evaluated. More: [Strategic Environment Assessment Directive: Guidance](#)

2.5.1 Waste disposal / management

Any material excavated and requiring disposal off-site will need to be characterised and disposed of in accordance with the Landfill Regulations 2002 (as amended) and, where applicable, the Hazardous Waste Regulations 2005. Any material classified as hazardous waste will require pre-treatment prior to disposal to either reduce the volume requiring disposal or to reduce the hazardous nature of the material. Other wastes will also require some form of pre-treatment prior to disposal.

Any soils imported to the site will need to be tested and verified to ensure they do not pose a risk to human health or controlled waters. They will also need to be accompanied by all relevant duty of care documentation.

2.5.2 Health and safety

The Health and Safety at Work Act 1974 (Health and Safety at Work (NI) Order 1978 in Northern Ireland) and its subordinate regulations such as the Construction (Design and Management) Regulations 2007, the Provision and Use of Work Equipment Regulations

1998 and the Workplace (Health, Safety and Welfare) Regulations 1992 are all relevant to channel management works.

The main health and safety (H&S) issue associated with completing works to manage channels is the requirement to maintain, through a number of provisions, the safety of the public and operatives working on the site – both day and night, in high and low flow conditions.

A fundamental activity that is required before planning or delivering any channel management activity is a health and safety risk assessment. The risk assessment should identify all hazards associated with the feasible options. The option development, design and construction planning process should seek to remove the identified hazards or reduce them as far as practicable.

A record should be kept of the hazards identified and how these have been eliminated through the design or management process. Any residual hazards should also be identified, recorded and communicated appropriately so that relevant parties can be made aware of them. These hazards should also be recorded in the health and safety file for the asset, where this exists, or in an appropriate format and location such that it is easily accessible to those who need to operate, maintain, upgrade or remove any part of the works.

There are a number of hazards associated with working in, on or near to watercourses. The most obvious hazard is the risk of drowning. This may be due to slips or falls, strong currents and, in extreme circumstances, machines falling into the water. Adverse weather such as heavy rain, severe winds or icy conditions is likely to increase the danger and working conditions can change quickly, particularly in times of flood.

During channel management, common significant injuries or accidents have occurred due to a number of causes including:

- the overturning of plant and access platforms during operation (including pontoons and excavators) due to overloading, unbalanced loads or poor ground conditions
- flying debris from cutting works or unseen debris on the ground
- the striking of buried or overhead services
- accidents during movement of plant
- accidents involving the lack of segregation of pedestrians and plant
- skin irritation caused by certain species of plant (for example, giant hogweed)
- becoming stuck in soft silt

It is also necessary to consider the health implications of working within water. The water could be polluted (for example, when working near sewage discharge points) and there is a risk of contracting leptospirosis (Weil's disease) from water contaminated by rat urine.

When planning any channel management operations, it is essential that:

- safe systems of work are in place based on a thorough risk assessment
- operatives and, where used, volunteers, are properly trained and instructed, and provided with appropriate personal protective equipment (PPE)

Other health and safety implications that you may need to consider when planning any aquatic and riparian plant management include:

- lone working

- use of tools and machinery
- use of chemicals such as herbicides
- working adjacent to highways, railways and other infrastructure
- presence of overhead power lines, buried services
- presence of livestock and other animals
- public safety

When planning works adjacent to a watercourse, the following should be considered and planned before works begin.

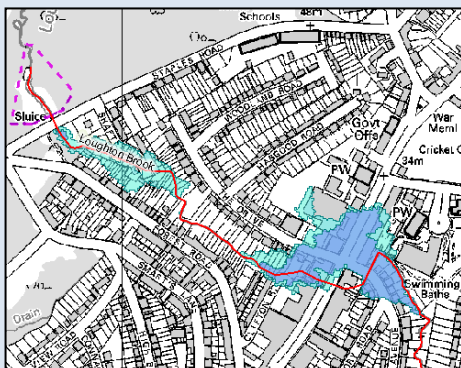
- Prepare an emergency response procedure.
- Know how to raise the alarm and the location of rescue equipment.
- Wear a life jacket or buoyancy aid if there is a risk of falling in.
- Ensure all rescue equipment is inspected and maintained regularly.

H&S case study: Loughton Brook, Loughton

Case study details

Loughton Brook is managed to convey a design discharge of approximately 1:10 year floods. The watercourse is linked to a flood storage area, attenuating up to 1:75 year flood events.

The watercourse must be cleared regularly due to man-made and natural debris often restricting flow and increasing flood risk. The 'debris rota' is implemented on a bi-monthly basis to identify blockages. In addition, the site is attended following a rainfall event to inspect the channel for blockages. The trash screen is cleared if rainfall exceeds 10 mm. It is not possible to access the channel if rain is forecast and therefore work (such as strimming of vegetation) is programmed during low risk, low rainfall months.



Flood map of the Loughton Brook
©Easimap

Title: Loughton Brook Maintenance Programme

Location: Loughton

'Typical' channel management issue: vegetation and blockage issues affecting conveyance

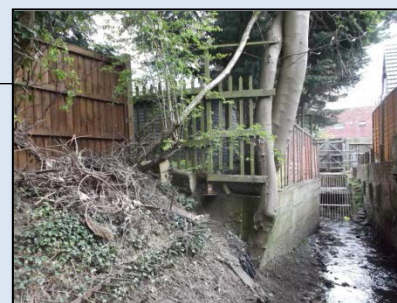
Management technique(s): vegetation and blockage management

How it was delivered: Environment Agency

Health and safety

Trash loading (especially anthropogenic debris) is a significant issue. Access is extremely limited and, where possible, very restricted. Management must therefore reduce the need for access by increasing the frequency of checks for blockages at the trash screen and adapting the trash screen to allow for easier and safer access.

Restricted access on the Loughton Brook
©Environment Agency



The Construction (Design and Management) Regulations 2007 (for England, Scotland and Wales) and in Northern Ireland the Construction (Design and Management) Regulations (Northern Ireland) 2007 (CDM 2007) apply to all construction works carried out in Great Britain. Section 4 of the regulations in particular sets out the duties during construction, but there are obligations throughout the feasibility, design, operation and maintenance phases.

The CDM regulations may apply to the following activities:

- sediment removal and management
- reshaping and reprofiling of channels
- vegetation management works necessary to maintain:
 - a flow rate within the channel
 - a channel structure such as flood defences or an artificial channel

Although the CDM regulations apply to all construction work, definitions of which are given in the [Approved Code of Practice](#), the extent of obligations under the regulations will depend on whether a scheme is notifiable or not. A scheme is notifiable if it is envisaged that the construction phase will last for more than 30 working days or will involve more than 500 person days. Therefore, the CDM regulations may not necessarily apply to minor maintenance works such as horticultural works though it is best to consult a competent person to confirm whether this is the case.

Construction Design and Management Regulations (CDM)

Advice on CDM and other health and safety issues can be obtained from the [Health and Safety Executive \(HSE\)](http://www.hse.gov.uk) (www.hse.gov.uk).

CDM 2015

Updated CDM regulations, replacing CDM 2007, are expected in 2015. The main changes are likely to include:

- significant simplification of the regulations to make them easier to understand
- replacement of the Approved Code of Practice with targeted guidance
- replacement of the CDM co-ordinator role with a 'principal designer'
- replacement of competence requirements with a specific requirement for appropriate skills
- inclusion of construction works for domestic clients
- changes to the threshold of notification of construction works

2.6 Typical channel management issues

The main management issues in many channels are typically related to **sediment**, **vegetation** and/or **debris**. Although each of these factors can cause management issues in isolation, more typically management is required as a result of the interaction between two or more of the factors, for example:

- sediment may not become a channel management issue unless vegetation or debris reduce flow energy and encourages deposition
- vegetation can provide a significant source of debris (both live and dead material) into a channel, increasing the potential for blockages occurring.

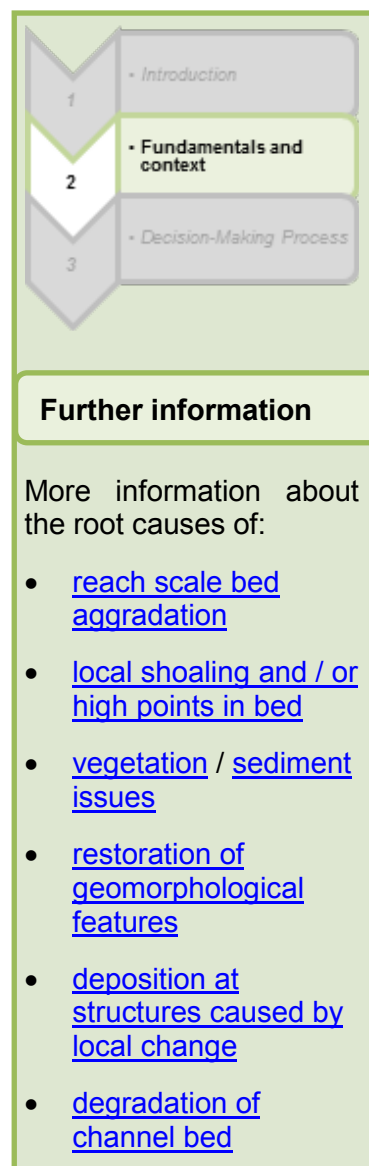
Details of several commonly occurring management issues related to sediment, vegetation and debris are provided in Sections 2.6.1 to 2.6.3 below. These issues may also occur due to man-made interventions to the channel such as excessive vegetation growth due to nutrients from farming or excessive deposition due to an over-widened channel.

2.6.1 Typical management issues: sediment

Channel management interventions, changes in land management practices and extreme storms can all increase or reduce sediment supply. These can affect flood management and land drainage objectives by changing the quantity of sediment in a channel and altering the way it behaves. Some examples are given below.

Sediment issues

- The cross-sectional area of a channel reduces if there is **more sediment** reaching a stretch of watercourse than flows are able to carry. This can reduce the ability of the channel to convey flows, resulting in increased water levels. Shoals and banks typically form when the energy of the flow reduces (for example, as a result of a reduction in flow volume or velocity in response to channel enlargement) or when sediment supply from further upstream increases. This can be a temporary effect while the channel changes to assume a narrower cross-section which is more natural for the amount of sediment supplied and the flows being passed. This issue is common in areas where sediment has been artificially removed as flows have been reduced. Also, it is common where sediment supply upstream has increased because of vegetation management, increased erosion or changed land management practices.
- Shoaling and erosion around bends are natural morphological phenomena and often not an issue – these habitats may provide ecological value (for example, fish spawning areas). However, an issue may arise if there are adjacent structures or land-uses that restrict the creation of the natural balance of erosion and accretion.



Deposition at structures caused by localised change

- Localised deposition can also occur when **structures** reduce flow energy and limit the amount of sediment that can be transported. These deposits may become permanent unless the structure can be operated to increase flows. Sediment deposition upstream of structures that become permanent may subsequently become vegetated and act to trap debris. This can consequently create conveyance issues in the upstream channel.
- Localised deposition can also occur at **over-widened channels**. This issue is likely to occur when a channel has been over-widened to cope with large flood flows leaving the channel too wide during lower flows. Flow energy is reduced and the amount of sediment that can be transferred is lower (as above), leading to sediment deposition, increased vegetation and resulting in higher maintenance costs.
- In-channel sediments can become **stabilised by vegetation growth**. Over time, these deposits can continue to grow and may eventually become part of the banks and floodplain (for example, in the case of vegetated bars), therefore preventing sediment remobilisation. This creates potential environmental benefits such as the creation of biodiverse transitional zones, and may also impact upon water levels and the rate of channel erosion.

Aggradation

- **Sediment deposition** can lead to aggradation (raising) of the channel bed. In engineered channels this can reduce conveyance capacity and can also reduce the capacity of structures to pass flows. This will increase water levels in relation to adjacent land and increase flood risk – assuming the elevation of the floodplain remains the same. Larger flows may remobilise this sediment, so this issue may not affect conveyance capacity as much as expected.

Degradation of channel bed

- Increased bed and bank scour can occur if there is **less sediment** reaching a stretch of watercourse than flows are able to carry. This occurs when the energy of the flow increases (for example, as a result of an increase in flow volume or velocity in response to a reduction in channel capacity) or when sediment supply from further upstream decreases. This can be a temporary effect while the channel changes to assume a wider or deeper cross-section that is more natural for the amount of sediment supplied and the flows being passed. This issue is common downstream of areas where sediment has been artificially removed, or where natural bank erosion has been prevented.
- **Bed and bank scour** can lead to degradation of the channel bed elevation. This may have a minor impact on the flow regime of natural channels (depending on how uniform the incision is), but can increase the conveyance capacity of engineered channels during periods of lower water levels (assuming that the elevation of the floodplain remains the same).

2.6.2 Typical management issues: vegetation

Vegetation provides important provisioning and regulating services for both habitat and water quality. However, too much or too little vegetation can have significant impacts on flows and affect flood management and land drainage objectives. Some examples are given below.

Vegetation issues

- The growth of in-channel or overhanging vegetation could reduce the cross sectional area of the channel where it is within the flow envelope and become a point around which further debris accumulates, reducing flow velocities. If there is **too much vegetation**, this can reduce velocity and increase water levels in the channel.
- By reducing flow, vegetation can reduce the amount of sediment that is able to be carried, as well as directly trapping sediment (very common in small channels). This can temporarily promote **local deposition of sediment** as the channel adjusts to decreased flows, resulting in a further reduction in channel capacity and an increase in water levels.
- If there is relatively **too little vegetation** in a channel due to factors such as aggressive removal, large floods, channelisation or disease, conveyance increases and water levels may locally reduce. However, downstream water levels may increase as a result of increased conveyance. This may temporarily cause channel widening or deepening through erosion as the channel adjusts to increased flows.
- The **root networks** of trees and larger plants can promote preferential drainage pathways through channel banks and embankments and also affect the integrity of structures. However, if correctly managed, root networks provide significant environmental benefits and promote working with natural processes.
- Vegetation and root networks can also provide an effective protection against bank erosion by reducing flow velocities and increasing bank stability. The removal of this protective vegetation cover can therefore **increase erosion** of the bed and banks.
- Trees growing within a channel and woody debris in the channel can be carried downstream during high flows to accumulate at and restrict/block flows through constrictions in the system such as culverts. This can cause a **blockage** and raise upstream water levels.

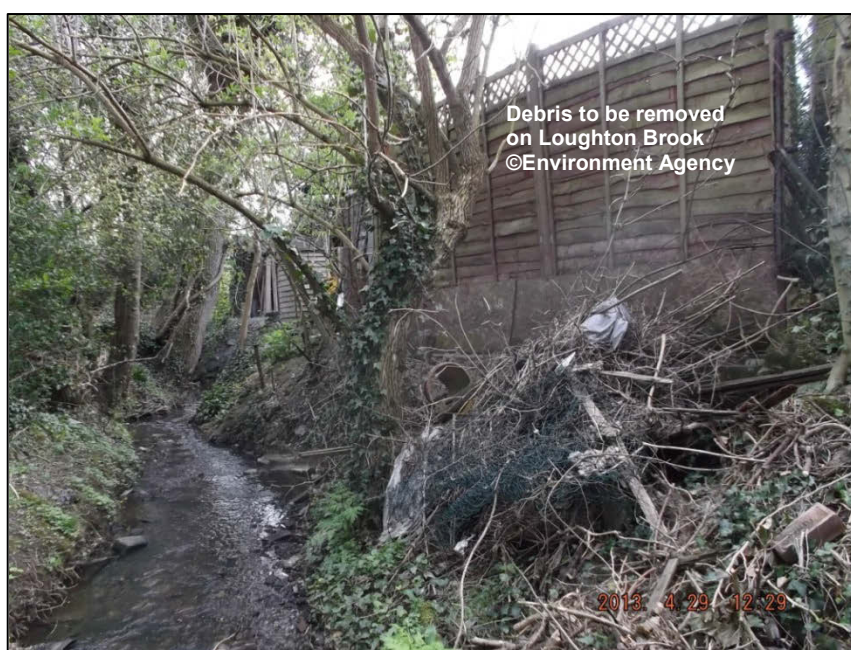


2.6.3 Typical management issues: debris

Debris from natural sources is an integral component of a channel system, encouraging geomorphological diversity and providing important habitats for aquatic life. However, too much or too little natural debris and debris from human activities can have significant

impacts on flows and affect flood management and land drainage objectives. Some examples are given below.

- **Too much debris** in a channel can directly reduce the cross-sectional area of a channel and increase water levels upstream. Debris can also increase the roughness of the channel bed, which temporarily increases sedimentation locally and over a period of time can cause further increases in water levels in the channel.
- If debris accumulation is allowed to continue, this could result in a **blockage** and cause an increase in upstream water levels, scour of the adjacent channel bankside and localised head loss downstream of the blockage.
- **Debris accumulation at structures** can also increase water levels upstream and create localised head loss, increasing the potential for increased flood risk.
- The **removal of debris** can cause rapid changes in channel capacity. This can increase flows and locally decrease water levels as well as temporarily causing erosion locally as the channel adjusts to increased flows. Although this may be desirable in many engineered channels, it can result in increases in downstream water levels. It is often desirable to **retain debris** from natural sources in a natural channel. The amount, distribution and location of retained debris should be assessed so as to balance habitat requirements with flood management and land drainage objectives. Debris from human sources should typically be removed from all channels.



2.7 Guiding principles of channel management

The form and behaviour of channels and their response to management are very complex. The dynamic interaction of geomorphological, hydrological and hydraulic conditions coupled with external influences (for example, human) gives rise to a regime of sediment behaviour, vegetation growth and debris. This regime affects the water levels in a channel for a given flow and the habitats and ecology it supports. A watercourse allowed to reach its natural equilibrium creates and supports its own habitats and ecology over time. While channel management may improve some functions positively, it may also impact others negatively, and in some cases lead to permanent damage or loss of those functions or services.

[Section 2.6](#) describes a number of channel management issues relating to sediment, vegetation and debris and their potential to impact on some desired functional requirements of a channel. Although these issues may lead to the need for channel management, it is also important to recognise that non-intervention may benefit other functions or services, including flood risk management. For example, decreased conveyance capacity at one location may lead to strategically selected localised overbank flooding with associated reduction in flood risk downstream. This type of thinking over medium spatial scales may provide significant flood management benefits.

To develop a channel management plan for a channel or to decide on the need for, or form of, intervention that may be necessary to address a channel management issue, it is important to take proper account of:

- the fundamental scientific concepts that govern channel behaviour
- the potential opportunities of delivering multiple functional benefits
- the potential harm or adverse impacts of action or inaction

Channel management can be costly, so when deciding on appropriate management, it is essential that the benefits of carrying out management activities outweigh the cost and effort involved.

The realisation of the complex interaction of functions, users and their respective requirements demand early and continued engagement with the local community, all relevant stakeholders and functional experts. This is necessary to understand the wider requirements, impacts, opportunities and constraints, both in determining the current state and in developing and agreeing a preferred solution or management plan.

The guiding principles of channel management, detailed in **Figure 2.10**, are intended to guide and inform the planning and provision of channel management.

Agree and define success criteria

- Recognise that a channel may have multiple functional objectives to provide consensus benefits, with potentially conflicting requirements.
- Engage with experts associated with the other associated functions to ensure that flood risk or land drainage objectives are not outweighed by other considerations.
- Engage with relevant partners, riparian owners and the community as appropriate.
- Set clear, realistic and auditable targets and agree these with relevant stakeholders.

Challenge the need for intervention

- Only intervene if channel is demonstrably not performing against desired objective(s).
- Any decision to intervene must be evidence-based. Simply relying on past activities to guide future actions is not a sufficient basis on which to make a decision. However, past activities may provide indicators as to required intervention(s).
- Regularly review decisions and plans to reflect potential changes in evidence collected from monitoring or observations, changes in policy and funding.

Act in proportion to the risk

- The level of management intervention or maintenance performed should be proportionate to the level of risk that is being managed.
- The level of detail required to characterise the channel context and make an informed management decision should also depend on the level of risk.

Recognise that channels form part of a dynamic system

- Understand how the channel in question is changing through time in response to natural geomorphological and hydrological processes.
- Consider how the current state of the channel and a channel management issue of interest reflect catchment, reach and local scale processes.
- Understand the impact that anthropogenic activities may have had (or be having) on these natural processes.
- Engage with experts in geomorphology.

Deal with the cause, NOT the symptom

- Appreciate that management issues may not be manifested at the source of the problem and the most effective solutions may be action in the upstream or downstream channel or elsewhere in the wider catchment.
- Weigh the long-term costs of managing the symptoms against those of addressing the root cause.

Aim to work with natural processes and deliver multiple objectives

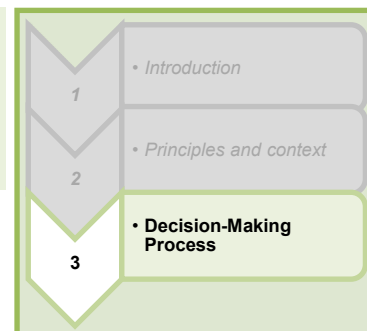
- It is important to work with natural processes rather than against them.
- Recognise that working with natural processes can achieve real management benefits as well as environmental improvements.
- Aim to balance the requirements of multiple objectives to achieve a consensus benefit.
- Use best practice to minimise disruption to the environment.

Learn and adapt

- Ensure that the results of channel management are properly monitored and recorded.
- Use evidence and the results of monitoring to review and, if necessary, amend key decisions.
- Ensure that lessons learned are clearly recorded and used to inform future decisions.

Figure 2.10: Guiding principles of channel management

3 Channel management decision framework



This section describes each step of a decision-making process that will help you apply the guiding principles to your channel management decision. The process will help you understand your channel and catchment of interest, and then decide whether to intervene or not. The handbook will aid the process of planning, designing and implementing the most appropriate management option(s) (if any), as well as monitoring their effectiveness and adapting management if necessary over time.

3.1 How the handbook enables channel management decision making

It is crucial that the chosen approach to channel management reflects the objectives that need to be achieved and is appropriate for the catchment and controls of the channel in question.

This chapter is designed to guide you through a process that will help you to make the best management decision for your channel of interest. The Adaptive Channel Management Framework (ACMF) is presented in Figure 3.1.

The framework addresses the channel's functions and the impacts of management. In practice, however, decisions are also affected by cost and affordability. The framework does not include this aspect explicitly and so should be used alongside situation-specific cost and funding considerations.

Subsequent sections of this chapter will guide you through the management decisions and processes that are required at each stage of the framework.

Overall process of channel management

The Adaptive Channel Management Framework presented in Figure 3.1 forms a vehicle for the guiding principles of channel management presented in [Section 2.7](#). Some of the principles form a clear stage within the framework, while others are realised as part of a stage or across many stages of the framework.

The framework is designed to be used by a channel manager who is seeking to carry out either a programme of works or an isolated activity to enable a channel to fulfil (or continue to fulfil) its desired performance for the functions or services it performs or supports.

This high-level process is adaptive and so changes in the context or responses of the channel can be reflected in subsequent iterations. The process does not provide you with an answer to channel management, but if followed with an input and support of evidence, expertise and data, it will guide you down the path to selecting and supporting an appropriate management decision.

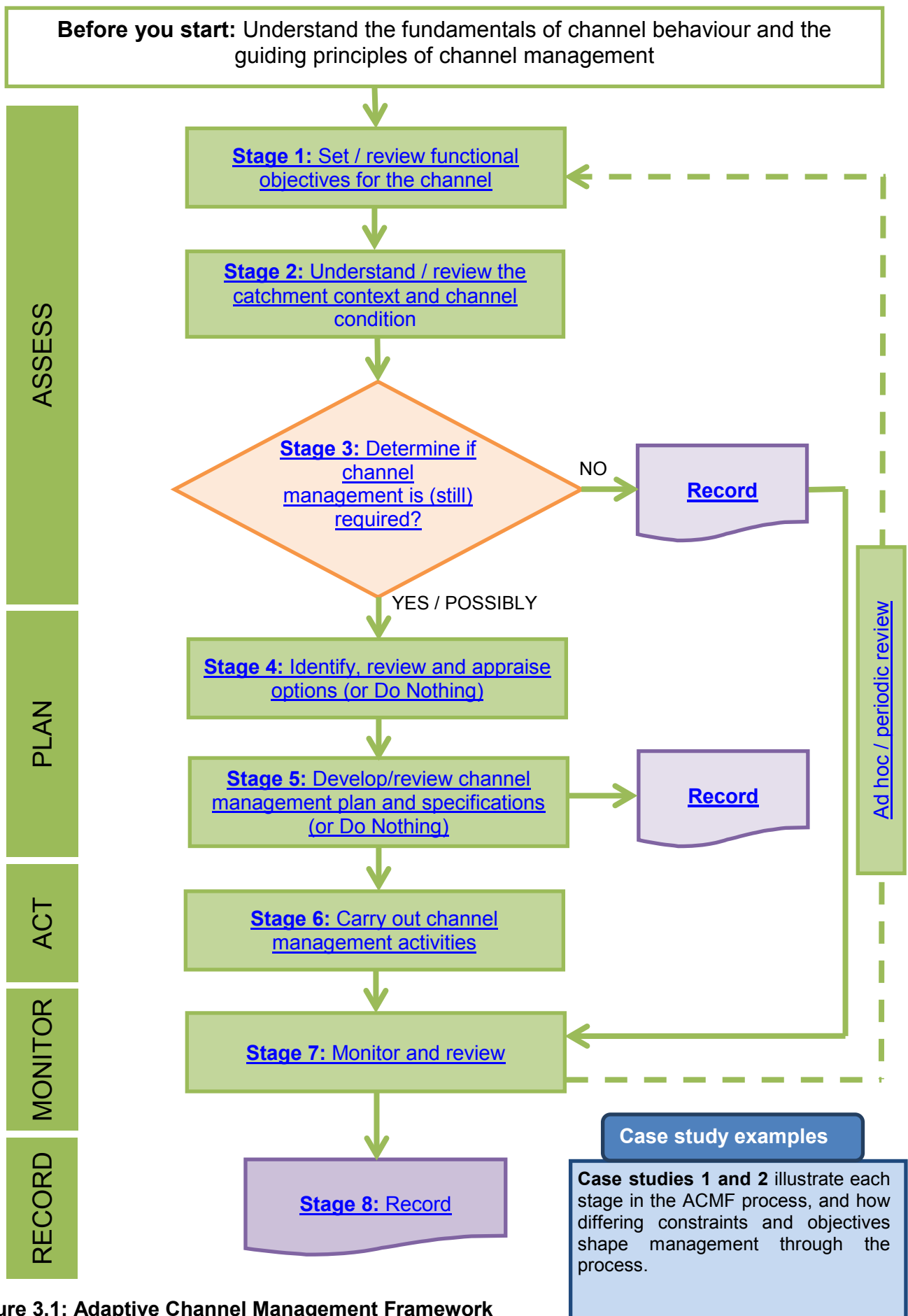


Figure 3.1: Adaptive Channel Management Framework

Case Study 1: Dagenham Brook, Leyton

Case study summary

Dagenham Brook is a highly constrained urban channel that passes through a dense area of housing via culverts and open channels. It is linked to the Lee flood relief channel at three separate intervals, and also to a flood storage area. It is assessed that, in a 1:100 year flood, approximately 500–1000 properties are at risk. It is therefore crucial to maintain conveyance through certain sections of the watercourse.



Flood map of the Dagenham Brook © Environment Agency



Open channel of the Dagenham Brook © Environment Agency

Stage 1: Set/review functional objectives for the channel

The flood risk objective is to manage flood flows greater than a 1:25 year flood. There is also a need to manage non-native invasive fauna (Japanese knotweed and Himalayan balsam) on the watercourse. The watercourse is classified as failing status under the WFD due to multiple factors including diffuse pollution and being a heavily modified water body. There is limited opportunity within the management of the watercourse for significant gains in habitat and biodiversity functions.

Stage 2: Understand/review the catchment context and channel condition

The heavily urbanised catchment results in the Dagenham Brook being extremely flashy. If channel maintenance is not carried out, it is estimated that 50–100 properties are at risk from floods with an annual chance of occurrence. The channel condition is frequently assessed during 'debris rotas' where the full extent of the watercourse is walked every two weeks to check for blockages and debris within the channel. It is assessed that the blockages on the Dagenham Brook are roughly half due to anthropogenic activity (for example, man-made debris thrown over fences into the watercourse) and half due to vegetation blockages (for example, accumulation of woodv debris).

Stage 3: Determine if channel management is (still) required?

Channel management is essential to prevent significant flooding of housing within this urban environment. Without regular maintenance and an effective maintenance programme, the flood impact would not be acceptable.

Title: Dagenham Brook Maintenance Programme

Location: Waltham Forest, London

'Typical' channel management issue: Excessive vegetation and debris restricting channel conveyance

Management technique(s): vegetation and blockage clearance

How it was delivered: Environment Agency

Stage 4: Identify, review and appraise options (or Do Nothing)

There are future aspirations to improve the capacity of the river to manage the channel in a more environmentally and ecology sensitive manner. The current maintenance programme has been developed over nearly 30 years, with budget and access constraints limiting options. The 'Do Nothing' option is rejected due to the need for management. Mechanical techniques are discounted due to access limitations. There is potential to manage vegetation via chemical control, however this would leave the banks bare and also be environmentally damaging. Strimming of vegetation is the chosen option.

Stage 5: Develop/review channel management plan and specifications (or Do Nothing)

The maintenance programme is issued to the Environment Agency's Fisheries and Biodiversity (F&B) teams at the start of the year for screening. This involves assessing it before issuing an instruction to evaluate any new issues that may have arisen.

Stage 6: Carry out channel management activities

The 'debris rotas' identify specific areas within the watercourse where debris management is required. The strimming of vegetation and removal of debris is often carried out by contractors and supervised by a member of Environment Agency Operations. The vegetation management involves strimming both banks, leaving it fairly long (cut finish of 100–150 mm) to preserve some habitat on the banks. This is done once in May/June and once at the end of summer.



Vegetation management on the Dagenham Brook ©Environment Agency

Stage 7: Monitor and review

Unless the background information changes, the maintenance programme will stay the same due to its constraints. New modelling could result in a significant change, for example, the intensity of maintenance may reduce if it is found that one cut a year still stops woody debris from developing, as this would half the effort.

Case study 2: Rags Brook, Cheshunt

Case study summary

The Rags Brook is a concrete revetted channel, with some naturalised sections, which flows through an urbanised area. Compared with the Dagenham Brook, the areas affected by 1:100 floods are significantly more localised. The scheme was designed with a 300 mm freeboard. It is assessed that, in a 1:100 year flood event, approximately 50–100 properties are at risk.

Flood map for the Rags Brook
©Easimap



Concrete revetted channel of the Rags Brook
©Environment Agency

Stage 1: Set/review functional objectives for the channel

The flood risk objective is to manage for flood flows up to a 1:70 year flood. Management of invasive Japanese knotweed is also required in some revetted sections of the watercourse. There is also potential for fish migration opportunities. Remodelling has indicated that there is 'capacity' to reduce management intensity and frequency a little to increase habitat and biodiversity benefits.

Stage 2: Understand/review the catchment context and channel condition

Like the Dagenham Brook, the urbanised nature of the catchment results in very flashy flood responses. The channel condition is assessed by being walked once a month to check for obstructions. Within the Rags Brook, the risk of blockage is not great as the channel is quite large and there is only one trash screen and few culverts; only a large accumulation of blockages would result in an issue. Recent modelling indicates that flood flows in excess of 1:50 years will result in out of bank flows.

Stage 3: Determine if channel management is (still) required?

Management is required, but there are opportunities to use techniques that are less intensive and more environmentally sensitive to achieve multiple functional objectives.

Title: Rags Brook Maintenance Programme

Location: Flamstead End, Cheshunt:

'Typical' channel management issue: Excessive vegetation and debris restricting channel conveyance

Management technique(s): Vegetation and blockage clearance

How it was delivered: Environment Agency

Stage 4: Identify, review and appraise options (or Do Nothing)

Like the Dagenham Brook, there are a number of constraints with managing a channel within an urban environment. Do nothing is not an option due to the flood risk. Sediment management such as leaving well established berms (or removing half) and leaving sediment inside bends is an option, as is vegetation management (strimming and spraying invasive species). The techniques must comply with access constraints.

Stage 5: Develop/review channel management plan and specifications (or Do Nothing)

Consultation with the Environment Agency's F&B and Geomorphology teams is required to agree the amount of sediment to be left in the channel. F&B also issues time constraints to mitigate potential ecological disturbance.

Stage 6: Carry out channel management activities

Walking the channel monthly identifies any obstructions, where any debris or blockages larger than a football are removed. Sediment is removed via machines and excavators in the channel grab lorries from the side of the bank, and by hand. Where possible grab lorries are favoured as this method is more sensitive than tracking within the channel. In-channel features are kept where possible, such as by leaving a fringe of vegetation, through concrete sections of the channel as this will aid connectivity and provide habitats for fish and invertebrates. Strimming and emergency tree removal are also carried out; 100-150 height of mm vegetation is left and saplings are removed or cut and chemically treated to remove the stump if in a revetment. Japanese knotweed is managed via annual spraying. The works are often carried out by contractors and supervised by a member of Environment Agency Operations.



In-channel features within the Rags Brook to aid connectivity and ecological value of channel
©Environment Agency

Stage 7: Monitor and review

Reviewing the management plan has resulted in a reduction in the intensity of maintenance in recent years to a level where management still achieves flood risk objectives but also achieves some ecological and environmental benefits.

3.2 Before you start: Understanding fundamental scientific concepts and guiding management principles

Before developing a plan to manage a channel or to plan any intervention to it, it is important that you are prepared to underpin your assessments and decisions with a basic knowledge of the science of channel management and of the legal regulations that can apply to it. This will enable you to gain an appropriate understanding of the wider concepts that determine how the channel behaves and the potential positive and negative impacts of management intervention, or lack of management. This includes concepts that relate to:

- catchment scale factors such as geology, soils, topography, hydrology and land use ([Section 2.2](#))
- reach scale factors such as channel type and morphology, hydrological and sediment regimes, and existing modifications ([Section 2.3](#))
- local hydraulic controls such as channel cross-section, roughness, slope and stream power ([Section 2.4](#))
- legislative and regulatory requirements which may affect the 'if', 'what', 'how' and 'when' of your management decision ([Section 2.5](#))

The complex interaction of these factors can provide answers to why a channel is in its current state. It can also determine how it could respond to change, and thus the type of management interventions that need to be implemented to successfully manage the channel.

[Chapter 2](#) includes a more detailed discussion of the important factors which underpin the behaviour of a channel and how they can be taken into account. The Adaptive Channel Management Framework enables you to apply this information to your channel of interest.

Scale
(see [Section 1.5](#))

Spatial scale plays an important role in determining the behaviour of a channel, the risk associated with this behaviour, the need for management, and the types of management intervention that are suitable for application.

The scale of an issue to some extent determines the responses of a channel and how they need to be managed. For example, multiple large-scale blockages need to be managed differently to a single, spatially confined partial blockage.

It is therefore vital to consider the scale when context is established, risks are assessed and interventions are planned.

What can happen if you don't understand the basic concepts before carrying out channel management?

One of the case studies for the [River Sediments and Habitats project](#) on the Long Eau in Lincolnshire involved leaving large widths of the watercourse uncut to create particular habitats. The outcome showed that, while there were some limited benefits, the type of habitats being encouraged was not appropriate for that type of watercourse. The awareness of the concept that different types of watercourses respond differently to certain types of intervention would have enabled an understanding of the appropriate typology of the channel in question and a check on what type of enhancement options were more appropriate for it.

3.3 Stage 1: Set/review functional objectives for the channel

Once you've used the guidance provided in [Chapter 2](#) to develop a good understanding of how your channel functions, you're now ready to determine which functional objectives are appropriate to your channel. This stage provides guidance on:

- what functional objectives are
- how they should be set
- the importance of considering multiple objectives

3.3.1 What are functional objectives?

Functions are the main uses of a channel, for which management may be undertaken. Functional objectives are specific objectives related to these functions. They must be defined before making any channel management decisions once a broad understanding of the guiding principles and wider catchment context has been developed. The functional objectives will determine what is needed from a channel and why, and will describe them in terms of performance indicators such as [hydraulic requirements](#) and [environmental conditions](#).

Agree clear objectives for your channel

An agreed set of objectives provides focus for the management of a channel. Without this, there is no reference point from which you can make decisions about what you are doing, when and where to do things, and for you and others to assess whether the action has been worth it or not.

How to set the right functional objectives?

The setting of functional objectives needs to be proportional to the risk that is being managed. This is a guiding principle of channel management.

Functions

There are a range of functions that commonly apply to channels:

- flood risk management
- land drainage
- water resources
- fisheries
- nature conservation
- navigation
- recreation

Although the primary functions considered in this handbook are flood risk management and land drainage, it is important that the objectives of other functions are understood and given careful consideration when planning and implementing channel management.

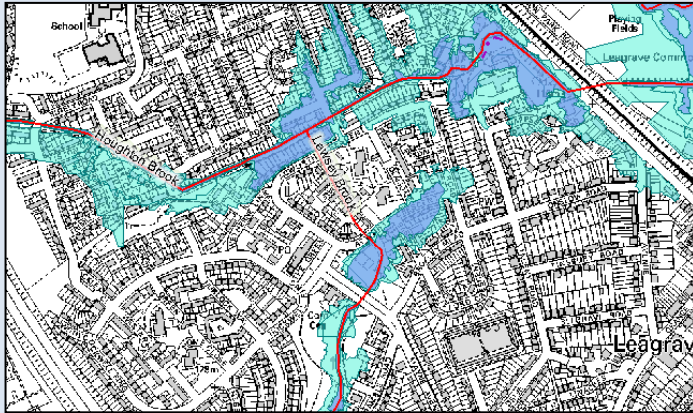
Case study 3: Lewsey Brook, Luton Case study examples

The Lewsey Brook case study illustrates where management has been planned and carried out with a particular functional objective in mind. Following the discovery of water voles on the watercourse, it was established that management had to follow nature conservation objectives as well as flood risk management ones.

Case study 3: Lewsey Brook, Luton

Case study details

The Lewsey Brook is an urban channel. As a result is flashy in its response to rainfall and is very sensitive to blockages. The channel can convey 1:30 year flood events and is managed to this level. The watercourse receives surface water drainage from the M1 and therefore has water quality issues. The previous maintenance programme developed by the Environment Agency was to simply flail both banks to prevent vegetation reducing the cross-sectional area of the channel and subsequently reducing conveyance and increasing flood risk. However, the establishment of a water vole population on the watercourse has led to the adoption of new management techniques. The biggest concern from a maintenance point of view is the propagation of water cress within the channel, as high flows strip out this poorly rooted plant which can then cause significant blockages. Chemical removal trials had limited success and therefore removal of water cress is currently by hand. The maintenance programme has been updated so that, during routine patrols, small amounts of water cress are removed as they occur as opposed to waiting until the channel is choked. Through consultation with the Environment Agency's Fisheries and Biodiversity team, several mitigation measures have been implemented to ensure the protection of water voles. These include cutting vegetation outside of water vole breeding season, keeping out of the channel as much as possible, implementing staggered cutting of opposing banks (that is, strimming one bank in early summer and then waiting a minimum of six weeks before strimming the other bank, therefore providing a food reserve for water vole and minimal disturbance) and having an ecological watching brief during the works on an annual basis.



Flood map of the
Lewsey Brook
©Easimap

Title: Lewsey Brook Maintenance Programme

Location: Luton

Management authority: Environment Agency

'Typical' channel management issue: vegetation and blockage issues affecting conveyance

Management technique(s): vegetation and blockage management

How it was delivered: Environment Agency

Stage 1: Set / review functional objectives for the channel

Historically flood risk has been the primary function in managing the Lewsey Brook. This is still very important as around 250 properties are at risk in the instance of a blockage on the Lewsey Brook. However, over 10 years ago, the presence of water voles was established on the watercourse. Following consultation with Fisheries and Biodiversity, professional partners and local interest groups, it was decided that the management of the Lewsey Brook must consider nature conservation an important objective given the presence of this protected species. The management of the Lewsey Brook has been altered by including functional objectives to achieve both of these interests. The channel is now managed in a way that maintains the conveyance to minimise flood risk, but maintenance is carried out in a manner sensitive to the local water vole population.

Water cress on the
Lewsey Brook
©Environment
Agency



Guiding principles of channel management

The setting or review of functional objectives requires agreeing and defining success criteria in consultation with relevant stakeholders. This process should be conducted with actions in proportion to the risk of not managing the channel.

Agree and define success criteria

- Recognise that a channel may have multiple functional objectives to provide consensus benefits, with potentially conflicting requirements.
- Engage with experts associated with the other associated functions to ensure that flood risk or land drainage objectives are not outweighed by other considerations
- Engage with relevant partners, riparian owners and the community as appropriate.
- Set clear, realistic and auditable targets and agree these with relevant stakeholders.

Act in proportion to the risk

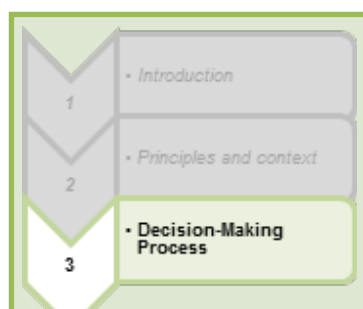
- The level of management intervention or maintenance performed should be proportionate to the level of risk that is being managed.
- The level of detail required to characterise the channel context and make an informed management decision should also depend on the level of risk.

The important role played by the functional objectives of a channel in determining why it is managed means it is vital that they are set appropriately and agreed with relevant stakeholders for the channel in question. It may be necessary to seek expert assessment to identify and prioritise the functions of the channel (for example, to ensure that they are in line with the rest of the catchment).

3.3.2 Managing multifunctional channels

The majority of channels are multifunctional. Each function has its own stakeholders and set of performance requirements. However, these may relate to design standards derived as part of a previous scheme or management plan. It is important to check that the reasons behind these standards are still relevant. The performance requirements might also relate to achieving favourable conditions or targets which can often be managed or regulated by multiple organisations. For example, the Water Framework Directive (see [Section 2.5](#)) sets specific biological and chemical standards for surface water bodies which channel management must seek to achieve.

The functional objectives of your channel must be carefully developed with all functions in mind. It is vital to identify the relevant functions of the channel as well as their individual requirements. This will often require engagement with other channel users, other functional experts or organisations with legislative roles relevant to the channel. It is important that requirements for all relevant functions feed into the performance objectives and that these are known and agreed by all relevant stakeholders.



The need for review

The functional objectives identified at this stage should not be regarded as permanent, fixed targets. They should be reviewed later in the process, and regularly as the asset management plan is operational, to establish if they are still relevant or appropriate. This will allow the way the channel is managed to adapt in response to changing priorities and conditions within the channel. This review will generally be a much shorter process than setting functional objectives.

There may be significant opportunities for the achievement or enhancement of multiple functions or avoidance of damage to other functions, often at no additional cost, that can be missed if only one function (of primary interest to the channel manager) is taken into account. For example, lengths of watercourses designed for specific purposes such as artificial land drainage channels or flood relief channels may over time develop into important navigation waterways or support diverse habitats.

While the driver for management may be to fulfil the initial objective for which the watercourse was created (where this is the case), there is still a clear requirement (in many cases, legislative) to give due regard to the other functions.

This consideration of multiple objectives can help to ensure that better, more effective management solutions are developed and implemented. As such, the consideration of multiple objectives should be an integral part of the objective setting process for all channels.

3.3.3 How do you set/review and agree functional objectives?

Functional objectives should be developed by a group with local knowledge about the channel and its uses, and the relevant range of functional perspectives and expertise. Ideally this would occur at a well-facilitated workshop at which all relevant functions are represented.

Where the scale of works and interests are limited and well-known, or where it is a review of existing functional objectives, the functional objectives could be developed by someone with good local knowledge of the channel and its associated system. However, identified stakeholders and functional representatives or experts should be consulted.

It is important that the set of objectives is agreed by all relevant functions.

Functional objectives can be set or reviewed for channels using the following steps:

1. Identify/review the relevant functions of the channel of interest. Ensure all relevant uses and functions are covered.
2. Identify/review the legislative or regulatory status or requirements relating to your channel of interest, including the important habitats or ecology they support. Understand the requirements, constraints or opportunities these place on channel management.
3. Identify/review the performance requirements for each of the functions. These may be legislative or based on previous studies, schemes, higher level plans or strategies, or existing agreements.
4. Check each performance requirement for validity and relevance in terms of current risks and context, such as changes to channel, land use, policy or legislation.
5. Align the performance requirements for each function into a set of functional objectives for the channel. Address within these areas of common interest, conflicts, opportunities and constraints. The focus should be on achieving 'win-wins' for the individual performance requirements.
6. Review and agree the set of functional objectives for the channel. Ensure they are as **Specific Measurable Achievable Realistic Time-scaled (SMART)** as practicable.

3.3.4 A useful assessment for functional objectives

In setting and finalising your objectives (particularly for items 5 and 6 above) it is worth making the following assessments.

- Do the objectives cover the important local and strategic issues? It is crucial in realising the wider catchment outcomes and local relevance that the objectives cover both. Think of the main problems, constraints and opportunities from your problem definition and engagement to date. Are these covered?

- Are the objectives unnecessarily restrictive? Narrow objectives will lead to narrow solutions that may miss opportunities for broader multiple benefits.
- Do your objectives presuppose the solution? Asking the 'why' question can lead you away from those that prejudice solutions toward less restrictive ones. For example, if you are thinking of removing obstruction or deposition, 'why' may lead you to achieve a particular flow discharge or a particular water level required for land drainage. This allows your options to look at broader ways of achieving this objective, including upstream and source management solutions. A further 'why' may lead you to question the reason for requiring that standard and probably realise the original reason is no longer relevant due to a land-use change or some works carried out further upstream.

3.3.5 What does a set of functional objectives for a channel look like?

Example 1

The channel needs to be managed to reduce local flood risk (where increased flow downstream is not desirable due to an existing flood risk downstream) and to achieve good ecological potential (due to lack of bankside habitats, fish spawning areas and impounding structures that prevent mammal and fish movement).

- To maintain flow conveyance and storage that allows $10\text{m}^3/\text{s}$ flows to be conveyed with a maximum water level of 4.5 m above Ordnance Datum (AOD) within the study reach (or at a particular point).
- To avoid action that prevents the achievement of good ecological potential of the channel.
- To enhance the channel ecological potential through actions to encourage marginal vegetation, remove restrictions to ecological migration, and improve fish spawning and refuge areas.

Example 2

The channel needs to be managed for land drainage (where increased vegetation in the channel is not desirable due to the need to convey flows for agricultural purposes) and achieve good ecological potential.

- To maintain flow conveyance that allows $10\text{m}^3/\text{s}$ flow to be conveyed with a maximum water level of 2mAOD within the study reach (or at a particular point).
- To avoid action that increases the risk of spreading invasive species further downstream.
- To enhance the channel ecological potential through actions that encourage in-channel sedimentation and establishment of in-channel vegetation in appropriate locations that will improve fish spawning areas downstream.

Are your functional objectives clear?

An unclear set of functional objectives leaves room for conflict and raises assessment issues. The objectives are what management options will be developed to achieve and the benchmark against which channel performance will be measured.

3.4 Stage 2: Understand/review the catchment context and channel condition

The aim of this stage is to develop a specific understanding of the issues affecting the channel and the wider catchment context. This stage applies the general concepts outlined in [Section 3.2](#), and supported by [Chapter 2](#), to provide a more detailed understanding of how a particular channel functions. It then seeks to understand the condition of a channel in terms of the indicators that relate to the functional objectives. Where this is being carried out for the first time, this process includes the development of performance indicators that relate to the functional objectives which will be the focus of future condition assessments.

3.4.1 Why is it necessary to understand the catchment context?

Before any decisions on management are made, it is important to apply the principles explored in the earlier stages to develop a detailed understanding of catchment context. A channel reach does not exist in isolation, and as described in [Section 2.2](#), the form, function and behaviour of a channel to some extent depend on a range of physical and hydrological controls and the behaviour of upstream and downstream reaches. It is vital that this context is understood so that the most appropriate management options for each type of channel can be identified.

3.4.2 Defining catchment context

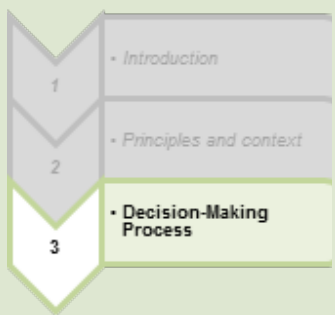
There are a wide variety of tools that can be used to help you:

- define the context of your channel
- identify the channel type
- inform the development of appropriate management interventions

These tools can be divided into two broad groups:

- high level techniques that provide overall context
- more detailed techniques which can help refine the conceptual understanding of a channel

A pragmatic, proportionate approach is recommended in which the high level techniques are first used to provide a broad definition of the site context and the more detailed techniques are used only if more information or further understanding is necessary. A selection of potential techniques is provided below, along with indicative costs categorised as low (£), medium (££) and high (£££). An explanation of the proportionate use of these techniques is given in Table 3.1.



The diagram illustrates a three-stage process flow for a risk-based approach. It consists of three numbered boxes connected by arrows. Box 1 is labeled 'Introduction', Box 2 is labeled 'Principles and context', and Box 3 is labeled 'Decision-Making Process'. The boxes are arranged in a descending staircase pattern from top-left to bottom-right.

Risk-based approach

It is vital to adopt a risk-based approach to appraising your site and catchment to determine a proportionate level of investigation for your 'issue'.

[Section 3.6.4](#) offers advice on risk-based decision-making.

Advice to help you to decide what techniques might be right for your catchment is given in:

- [Technical Support Document E](#)
- [Sediment Matters Handbook](#) – see page 89 for a summary table and pages 90–119 for details of the different techniques

[Chapter 7](#) of the Fluvial Design Guide lists some of most common modelling techniques and software used and provides help in choosing a model depending on:

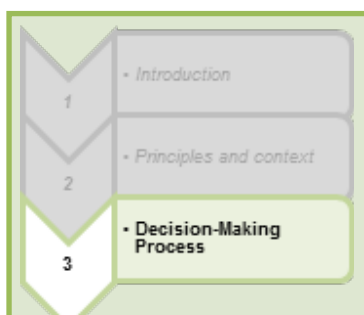
- level of complexity
- storage and flow control
- accuracy
- available data
- time and resources available

High level context

- Expert judgement based on known conditions (£)
- Desk-based assessment of archive hydraulic data, mapping and any other relevant data (£)
- Field-based walkover survey (£)

Detailed characterisation

- Expert judgement based on previous high level assessments (£)
- Detailed hydraulic monitoring using repeat measurements of factors such as water levels, discharge and channel cross-section where possible (££)
- Detailed geomorphological monitoring using techniques such as fluvial audit, physical biotope mapping or geomorphological dynamics assessment (££–£££)
- Detailed survey or monitoring of bed and bank erosion or sediment accretion (£–££)
- Channel hydraulic modelling using one-dimensional packages such as ISIS, HEC-RAS and MIKE 11, or links with two-dimensional packages such as TuFLOW, MIKE FLOOD, SOBEK or JFLOW+ where necessary to assess the potential responses of a channel to changes in flows, morphology or management practices (££–£££)



Further information

- [WFD Expert Assessment of Flood Risk Management Impacts](#)

Simple, low cost techniques (£) may be useful if:

- an improved overall understanding of the channel and its catchment is required
- For example: You suspect there is a management issue but have not identified causes, mechanisms or impacts.

More complex low to medium cost techniques (£–££) may be useful if:

- an improved understanding of specific channel characteristics or management issues is required
- the channel or its functions are sensitive to change
- For example: You suspect there is a management issue but have insufficient evidence to take mitigation action.

Complex medium to high cost techniques (££–£££) may be useful if:

- a detailed understanding of specific channel characteristics or management issues is required
- the channel or its functions are particularly sensitive to change
- For example: You want more certainty about the underlying cause of the channel management issues in order to persuade others to change their behaviour and/or to carry out costly mitigation action.

Table 3.1: Proportionate use of investigation techniques

Case study 4: Tame De-Silts

Case study details

The River Tame is the main arterial watercourse within the Birmingham conurbation. Much of the river is heavily modified, consisting of man-made concrete channels beneath the elevated carriageway of the M6 motorway. The channels were designed as a flood defence system offering a 1:50 year standard of protection (SOP). To maintain the SOP, an annual programme of channel maintenance is required to provide conveyance capacity and allow safe operational access for ad hoc blockage removal and routine maintenance activities. Removal and disposal of the gravel and silt was the major cost element. Working in conjunction with the Environment Agency's biodiversity officer, the option of retaining the gravels in the river system to reduce costs, retain much needed fish spawning habitat and provide WFD benefits was explored. The location of the site at the downstream extent of the formal defence system meant that the gravels could theoretically be transported and deposited around 0.5 km downstream to an area where the river opens out into a wider natural floodplain. The option of pumping the gravel downstream as opposed to the cost and practicalities of loading the gravel into a dumper, hauling it downstream and tipping it into the open channel was also considered. Haulage was selected as the solution, and a tele-handler and a 20-tonne 3600 excavator were used to load the gravels into a 25-tonne wheeled dumper, haul them downstream and tip them into the open channel. The result was a saving of £25,000 in removal and disposal costs of the gravels, in addition to the retention of fish spawning habitat and reduced environmental impact of pollution from haulage lorries transporting the material to a landfill site 15 miles away. The saving allowed completion of works at two additional sites within the original planned budget.

Gravel and silt accumulations at Chester Road Bridge, beneath junction 5 of M6 motorway
©Institution of Civil Engineers, 2014



Title: Tame De-Silts

Location: West Midlands

'Typical' channel management issue: Restoration of geomorphological features

Management technique(s): Annual de-silting programme

Stage 2: Understand/review the catchment context and channel condition

The River Tame is the main arterial watercourse within the Birmingham conurbation. Much of the river is heavily modified, consisting of man-made concrete channels beneath the elevated carriageway of the M6 motorway.

The channels were designed as a flood defence system offering a 1:50 year standard of protection (SOP). In order to maintain the SOP, an annual programme of channel maintenance is required to provide conveyance capacity and allow safe operational access for ad hoc blockage removal and routine maintenance activities.



Gravel removal at Tameside Drive
©Institution of Civil Engineers, 2014

Deposition of gravels in River Tame
©Institution of Civil Engineers, 2014



Guiding principles of channel management

Understanding the catchment is fundamental to acting in proportion to the risk of not managing the channel. Recognising that the channel context extends further than the location of the specific issue is crucial to understanding how or why the channel should or should not be managed.

Act in proportion to the risk

- The level of management intervention or maintenance performed should be proportionate to the level of risk that is being managed.
- The level of detail required to characterise the channel context and make an informed management decision should also be dependent on the level of risk.

Recognise that channels form part of a dynamic system

- Understand how the channel in question is changing through time in response to natural geomorphological and hydrological processes.
- Consider how the current state of the channel and a channel management issue of interest reflect catchment, reach and local scale processes.
- Understand the impact that anthropogenic activities may have had (or be having) on these natural processes
- Engage with experts in geomorphology.

3.4.3 Assessing the condition of channels and assets

When assessing the condition of a channel and its assets for the first time, it is important to identify a set of performance indicators for the channel that relate to its functional objectives. Inspection and monitoring processes can then be developed to ensure such indicators are appraised as part of a monitoring process to determine the channel condition.

Where an inspection or monitoring process is already in place (see [Section 3.9](#)), use the information here to assess the condition of the channel, including providing the necessary information to make the decision whether or not to intervene (see [Section 3.5](#)).

Condition appraisal: for example...

Modelling has shown that the channel can cope with sediment build-up to a particular level before affecting its objectives relating to flood risk or land drainage. This level, the indicator of performance, can be made visible on-site (for example, by marking it on an outfall, bridge abutment or other appropriate point readily accessible to inspectors), enabling a condition appraisal and performance assessment to be carried out at the same time. Such an approach reduces abortive maintenance effort and associated impacts, and provides the chance for normal morphological processes to address the siltation before it becomes a problem.

The Environment Agency has developed a methodology, set out in its condition assessment manual ([available on request](#)), to ensure that the condition of its flood and coastal erosion risk management (FCERM) assets (including channels and structures within them) is assessed in a consistent way. While the detail in the channel section of the manual is not as comprehensive as for other assets, it is still a very useful and consistent starting point for carrying out condition assessment for channels. However, it is advisable to link it as much as

possible with the appropriate indicators relating to the functional objectives of the channel to strengthen a link from condition to the performance assessment required at the next stage. This handbook recommends that this method is used only as a guide to aid discussion rather than necessarily underpinning the decision-making process. It further recommends consulting geomorphologists, ecologists, drainage engineers and so on as appropriate to aid condition assessment.

The Condition Assessment Manual is used by the Environment Agency as part of a risk-based asset assessment programme in which the highest risk sites are inspected every six months and the lowest risk sites are inspected every five years. Each asset is assigned a condition grade based on a visual inspection:

1. Very good: cosmetic defects only
2. Good: minor defects, no impact on performance
3. Fair: defects could impact upon performance
4. Poor: defects significantly reduce performance
5. Very poor: severe defects, performance failure

Each asset is also assigned a target condition based on the potential consequences of failure. The need for further management interventions or maintenance is determined according to the inspected condition grade in relation to the target condition grade. The results of the inspections are stored in the Environment Agency's Asset Information Management System (AIMS), which also contains a record of historic inspection results.

Channel condition for flood risk management: vegetation

The Condition Assessment Manual describes the following condition grades (CGs) for vegetation growth in channels, based on a visual inspection by a qualified asset inspector.

- CG1 Vegetation is low or of limited extent. It will not therefore affect the performance of the channel from a flood risk management perspective.
- CG2 Vegetation is generally low and sufficiently flexible to become flattened during high flows. It will not affect the performance of the channel from a flood risk management perspective.
- CG3 There is some vegetation growth in the channel, but the extent of stiff or dense vegetation is limited. This could potentially reduce the performance of the channel from a flood risk management perspective.
- CG4 There is considerable growth of stiff or dense vegetation on the channel banks, and this is encroaching on the bed. This could significantly reduce the performance of the channel from a flood risk management perspective and further investigation is therefore required.
- CG5 The growth of stiff or dense vegetation clogs the channel. This fails the performance criteria for flood risk management and further action may be required.

Channel condition for flood risk management: sediment

The Condition Assessment Manual describes the following condition grades (CGs) for blockages in channels, based on a visual inspection by a qualified asset inspector:

- CG1 No accumulation of sediment in the channel (over and above the natural bed deposits). This will not affect the performance of the channel from a flood risk management perspective.
- CG2 Isolated sediment deposits, such as small bars. This will not affect the performance of the channel from a flood risk management perspective.
- CG3 Some sediment accumulation but not occupying entire channel cross-section. This could reduce the performance of the channel from a flood risk management perspective.
- CG4 Significant quantities of sediment occupying most of the cross-section over extended reaches, or limiting flows through structures. This could significantly reduce the performance of the channel from a flood risk management perspective and further investigation is therefore required.
- CG5 Widespread sedimentation not limited to in-channel features chokes the channel. This fails the performance criteria for flood risk management and further action may be required.

Channel condition for flood risk management: blockage

The Condition Assessment Manual describes the following condition grades (CGs) for blockages in channels, based on a visual inspection by a qualified asset inspector:

- CG1 No accumulation of debris in the channel. This will not therefore affect the performance of the channel from a flood risk management perspective.
- CG2 Small quantities of debris in comparison with the channel cross-section. This will not affect the performance of the channel from a flood risk management perspective.
- CG3 Some debris accumulation but not occupying entire channel cross-section. This could reduce the performance of the channel from a flood risk management perspective.
- CG4 Significant quantities of debris occupying most of the cross-section over extended reaches, or limiting flows through structures. This could significantly reduce the performance of the channel from a flood risk management perspective and further investigation is therefore required.
- CG5 Widespread debris accumulation chokes the channel. This fails the performance criteria for flood risk management and further action may be required.

Once you have developed an understanding of the catchment context and channel condition, progress to **Stage 3: Determine if channel management is (still) required.**

3.5 Stage 3: Deciding whether channel management is (still) required

The aim of this stage is to use the understanding of the functional objectives, current behaviour and wider context of the channel developed in the previous stages to reach an informed decision on how the channel should be managed.

3.5.1 Deciding whether intervention is necessary

Where there is already a management plan and the functional objectives on which it is based have been reviewed during Stage 1 ([Section 3.3](#)) for continued relevance, the first part of this process is to:

- determine whether the existing management regime is delivering the required objectives
- decide whether any new or different management interventions are necessary – including ceasing management all together

The decision whether or not to intervene by carrying out management in a channel can often be down to expert judgement or historical precedent. However, the channel, its functions, land use, legislative and regulatory framework will change over time. This decision should therefore always be based on:

- an understanding of the channel's functional objectives (developed from all relevant functional perspectives)
- comparison of the channel's performance on the basis of its current condition with that required by its functional objectives

As such, 'no intervention' should always be considered the default option when deciding whether or not a channel should be managed.

If the investigations made in the previous stages demonstrate that the **performance requirements have been met** for each of the channel's functional objectives, this suggests that the current management plan is achieving its aim and an increase in scale or frequency is not required. Despite this, current management activities should be reviewed to see if other approaches which work better with natural processes, offer more opportunities and/or have less impact in terms of safety, cost or the environment are likely to be feasible and still (or better) achieve the functional objectives.

If a one-off intervention decision is being considered, then a channel management issue being shown not to affect the performance objectives means intervention may not be necessary. It may be appropriate not to intervene in many situations where the sediment and vegetation are not creating a risk and where the channel is trying to adjust to a more natural shape and size. Again, opportunities for working better with natural processes can be assessed.

If the investigations demonstrate **performance requirements have not been met**, it is likely that further management interventions will be required or that the current regime needs to be updated. [Section 3.6](#) deals with identifying and appraising management options.



Intervention decisions: for example...

Where regular de-silting and debris removal upstream of a structure is required to achieve the required conveyance, a review may suggest working with the culvert owner to remove to culvert or to increase its capacity. Both would remove or reduce the long-term cost and impact of silt and debris removal. Another example could be where a channel reach is wider than upstream and downstream reaches due to previous widening activity, and as a result is encouraging silt deposition and high vegetation growth which needs to be cleared regularly to maintain the required upstream water level. A review may suggest investigating the potential for turning the channel into a multistage channel that caters for high flow conveyance as well as being more self-cleaning, with berm levels set to provide optimum habitat creation.

Guiding principles of channel management

This stage of the Adaptive Channel Management Framework encapsulates the guiding principle of channel management shown below.

Challenge the need for intervention

- Only intervene if channel is demonstrably not performing against desired objective(s)
- Any decision to intervene must be evidence-based. Simply relying on past activities to guide future actions is not a sufficient basis on which to make a decision. However, past activities may provide indicators as to required intervention(s)
- Regularly review decisions and plans to reflect potential changes in evidence collected from monitoring or observations, changes in policy and funding

Whatever the outcome of this stage, it is essential to record the reasons to provide an audit trail of the decision. This includes relevant information, assumptions and assessments supporting the decision either to Do Nothing or to intervene. The [checklist](#) can be used for this process.

Where the outcome of this process, either at the channel reach scale or broader asset system scale, suggests that there is no justification or economic case for carrying out (or continuing to carry out) channel management, other options may exist.

What are the implications of not intervening?

If a channel is not maintained, hydrological and geomorphological processes will operate naturally within that reach – subject to constraints from upstream and downstream reaches. The channel may adjust to the prevailing conditions and, depending on these conditions, sediment may accumulate and vegetation may grow. This could potentially be highly beneficial for biodiversity and some functional objectives, in addition to reducing maintenance costs. However, possible negative implications of not intervening in certain circumstances include:

- increased flood risk and water logging
- unbalanced sediment load upstream or downstream leading to erosion or deposition impacts in other places in the catchment
- dominant invasive or non-native species
- poor or deterioration of water quality from increased sediment load or stagnant water
- blockage of screens, structures, culverts and pumps

The implications of environmental legislation: for example...

The requirements of environmental legislation (see [Section 2.5](#)) are often important in determining whether intervention is required or not. Where legislation determines that it is necessary to implement certain management techniques, care must be taken to ensure that the measures instigated meet the legislative requirements.

The decision to remove the gates from Vitbe Sluice on the River Cray to lower water levels, instead of refurbishing the structure, was taken for the benefit of in-channel habitats and water voles. This was enforced by WFD legislation.

Examples of good practice guides to implement legislation include the [Eel and Elver Passes Manual](#) and the [Fish Pass Manual](#).

Case study 5: River Kent pilot study

The River Kent case study showed that reducing intervention in scale and frequency can result in significant benefits such as reduced maintenance and disposal costs, reduced effort and reduced environmental impacts (landfill, carbon, emissions) while still achieving the conveyance requirements.

If you decide that channel management is or may be required, proceed to [Stage 4](#).

If you decide that channel management is not required, record this decision using the guidance provided in [Stage 8](#) and regularly review it using the guidance provided in [Stage 7](#).

Case study 5: River Kent pilot study

Case study details

The reach of the River Kent that was studied forms a high-energy gravel bed river through the centre of Kendal. The river channel has been subject to major changes in the past and now has artificial banks, while the bed level is constrained by a number of weirs. There has been a history of fluvial flooding in the urban area and a flood scheme was implemented in the 1970s. The study investigated the impact of sediment removal and the effectiveness of different strategies for flood risk management objectives.

Sediment yield is from a range sources including over-grazing and poaching, but also mining waste which contributes significant amounts of coarse gravel material in some reaches. As a result of high coarse sediment loads, shoals continue to develop frequently through the flood alleviation scheme in Kendal and are routinely removed. If sediment is allowed to accumulate, it reaches a point where the flood risk standard is compromised.

Monitoring results to date indicate that the partial removal of gravel bars improved conveyance, achieving the flood risk objective through the urban phase. Partial gravel removal allowed some sediment to be remobilised during high flow events and improved connectivity with starved downstream reaches. It significantly reduced maintenance costs and carbon impact, and improved river ecology.



River Kent showing
mid-channel gravel bar
downstream of
Stramongate weir
©Environment Agency

Title: River Kent Pilot Study

Location: Cumbria

'Typical' channel management issue: local deposition affecting flow capacity at bridges and weirs.

Management technique(s): Develop management strategy, conduct sediment management at an appropriate time

See River Sediments & Habitats guidance for more information.

Stage 3: Determine if channel management is (still) required

Historically, the river has been managed on a reactive basis with large gravel shoal removal at specific points throughout the urban phase of the River Kent. This removal impacts the channel's downstream stability and ecology. The frequent large-scale sediment removal is very costly and has significant environmental impacts.

The sediment transfer system is complex with the majority of sediment accumulating in or around in-channel structures such as bridges and weirs. Observations from field monitoring and detailed hydraulic sediment modelling revealed that bar growth within the channel does reach a point where it becomes self-regulating, without compromising the standard of defence. However, this depends on sufficient high flows to reduce the onset of vegetation colonisation, which reduces sediment mobilisation.

Despite the loss of conveyance and channel capacity for flood flows associated with in-channel bar growth, field observations showed that removal of sediment in the upper reaches resulted in sediment starvation for reaches downstream.

Sediment modelling showed that an adaptive management routine, through partial sediment removal at key points, could provide an opportunity for achieving improved ecological status, maintaining the standard of defence, and ensuring the integrity of flood defences in downstream reaches. This option with reduced, but targeted sediment removal was taken forward.

3.6 Stage 4: Identify, review and appraise options

Where the outcome of Stage 3 shows that channel management is or may be required, this stage will help you to identify and assess a range of options for managing the channel. This may be to improve its performance or to address an issue that is preventing achievement of channel's functional objectives. The outcome of this stage is identification of a preferred management intervention or plan.

The option development and appraisal is an objective led process. The options are identified and developed to optimise the achievement of the full range of functional objectives. The option screening and development process involves removal or modification of options which do not deliver the broad range of functional objectives.

It is essential that the initial focus is on identifying the right type of options that fit the channel and its functional objectives (see [Management Intervention Selection Matrix](#)). This shortlist of options can then be appraised against how far they achieve the objectives and their associated benefits, costs and affordability. It is better to carry out the right type of management, even if it is done less frequently than required, than to carry out an inappropriate management with significant negative impacts just because it is cheaper or more affordable.

The option identification, review and appraisal process should be guided by the particular channel management principles set out in the box below:

Guiding principles of channel management

Option selection must be in proportion to the risk of not managing the issue. Appropriate selection of the intervention depends on understanding of the problem and working within the environmental context of the issue.

Act in proportion to the risk

- The level of management intervention or maintenance performed undertaken should be proportionate to the level of risk that is being managed.
- The level of detail required to characterise the channel context and make an informed management decision should also be dependent on the level of risk.

Deal with the cause, NOT the symptom

- Appreciate that management issues may not be manifested at the source of the problem and the most effective solutions may be undertaking action in the upstream or downstream channel or elsewhere in the wider catchment.
- Weigh the long-term costs of managing the symptoms against that of addressing the root cause.

Aim to work with natural processes and deliver multiple objectives

- It is important to work with natural processes rather than against them.
- Recognise that working with natural processes can deliver real management benefits as well as environmental improvements.
- Aim to balance the requirements of multiple objectives to deliver a consensus benefit.
- Use best practice to minimise disruption to the environment.

Different options are likely to have different impacts on the various functional objectives. It is therefore important that the option development and appraisal process involves the relevant

breadth of expertise and stakeholders to ensure opportunities are optimised and negative impacts are avoided or mitigated.

3.6.1 Sediment management

For a detailed technical guide on sediment management please refer to the [Sediment Matters Handbook](#).

What is sediment management?

Sediment may need to be managed for a number of reasons including:

- sediment removal (some refer to this as dredging or de-silting depending on the circumstances) or deposition for flood risk management and land drainage purposes
- sediment removal and reinstatement for fisheries interest
- aggregate extraction

How should sediment be managed?

A number of techniques are available for managing sediment with a view to reducing flood risk and improving land drainage (see [Technical Support Document C](#) for more detail on each intervention technique):

- manage the upstream erosion of sediments
- manage in-channel erosion and deposition
- restore channels

Selecting the most appropriate sediment management option

Sediment deposition or erosion can create problems such as blockages, reduced conveyance and possible increases in flood risk or reduction in land drainage. For sediment management to be effective and sustainable, the appropriate option needs to be selected. This can be done by considering the following factors.

- Where is the source of sediment? Have you considered run-off from land or erosion from upstream? If the problem is at the source then it may be a better to investigate and stop or slow down the source rather than deal with the issue locally. However, that may also still be necessary as a temporary measure or to a much lower scale.
- Is the sediment problem, erosion or deposition being caused by something further upstream or downstream? For example, there may be a change in channel slope, or extra flow from a housing development or a downstream constriction. Use of an experienced geomorphologist can be cost-effective in assessing the cause of the problem.
- If there is no obvious explanation upstream or downstream, has there been a change locally to the channel or floodplain (for example, land use) which is creating a difference to the flow or channel conveyance (for example, a change in the slope or the amount or size of sediment)? If so then this issue should be addressed.
- If there is no other explanation, then assess the extent of the problem at the site. By how much is the sediment increasing flood risk? The amount of sediment

removed should be proportional to addressing the level of risk and understanding the impact upstream and downstream. It is vital to consider if flood risk or erosion/deposition will be affected elsewhere.

- A proportionate approach should be taken in identifying and assessing options. This should consider the risk, expected scale and impact of the issues. For example if there is a clear local deposition upstream of a culvert that clearly has no system-related link, it would be prudent to focus on addressing the problem locally, ideally by removing or altering the culvert or removing the sediment deposit if it is risking the achievement of functional objectives.

Upstream / downstream considerations: for example...

The Rothes Flood Alleviation Scheme is one of five flood alleviation schemes carried out for Moray Council between 2002 and 2014. Rothes was very different to the other schemes as it was at the confluence of three very steep burns with very high sediment transport. These channels regularly deposited large amounts of sediment into the burn at Rothes, causing frequent flooding from channel capacity reduction and blockage at the culverts and bridges. Over 400 properties (80% of the village) were at risk during the 1% annual exceedance probability (AEP) flood event.

The need for geomorphology-led design was identified early in the project. Through fluvial audit and sediment modelling, the solution was based on creating preferential sediment traps at locations along the reach where they caused no flood risk and there was easy access to plant for removal. The channel cross-section through the village was designed to deter deposition near the road bridges and culverts, and coarse screens made of widely spaced logs prevented very large debris from reaching the bridges. A monitoring programme is in place to enable adaptive learning and management.

The alternative to a geomorphology-led design in this case would have given rise to a very heavily engineered channel. This would have worked against the natural processes and required very high sediment management cost, as well as a high residual risk of culvert blockages during large flood events.

3.6.2 Vegetation management

For a detailed technical guide on vegetation management please refer to the [Aquatic and Riparian Plant Management Guide](#).

What is vegetation management?

Vegetation is a natural part of channel ecosystems, providing shade and cover, promoting bank stability, enhancing physical in-channel features, providing an input of woody debris, filtering sediment and serving as a source of nutrients to support fauna and flora. However, vegetation growth can influence channels in a number of ways including blocking culverts, and reducing conveyance. Vegetation management involves controlling excessive growth of vegetation. This can be done through mechanical, chemical or biological means.

How should vegetation be managed?

Where vegetation management is required to maintain the functional objectives of a channel, good practice vegetation management measures support diversity of vegetation, allow natural regeneration and prevent the spread of invasive non-native species. A number of

techniques are available for managing vegetation (see [Technical Support Document C](#) for more detail on each intervention technique):

- manage recruitment of debris
- maintain conveyance
- reduce chance of surface erosion

Selecting the most appropriate vegetation management option

The selection of the most effective vegetation management option can be made through understanding and considering the following:

- What is the flood risk management functional objective of the channel?
- What is the flood risk due to vegetation growth?
- What will happen to the sediment and stability of the channel banks and beds if vegetation is removed?
- How will the vegetation management impact on habitats?
- What is the best time to remove the vegetation, considering regrowth and flora and fauna and sensitive periods such as for spawning or nesting?

Ideally vegetation should be removed from one side or down the centre of the channel to retain habitats and minimise environmental impacts. Guidance on how to do this is given in:

- [Healthy Catchments website](http://www.ecrr.org/RiverRestoration/Floodriskmanagement/HealthyCatchmentsmanagingforfloodriskWFD/tabid/3098/Default.aspx)
(www.ecrr.org/RiverRestoration/Floodriskmanagement/HealthyCatchmentsmanagingforfloodriskWFD/tabid/3098/Default.aspx)
- [Environmental Options for Flood Defence Maintenance Works \(PDF, 1.07 MB\)](#)
- [Environmental Options for River Maintenance Works \(PDF, 1.06 MB\)](#)

3.6.3 Debris management

For a detailed technical guide on debris management please refer to the [Debris and Blockage Modelling Guide](#).

What is debris management?

When considering the removal of debris from a channel or associated structure, the wide range of benefits and other functional objectives that having debris in the channel may provide should be taken into account. For example, the removal of urban debris (for example, supermarket trolleys, mattresses, sofas, vehicles and other waste) is usually an essential requirement for both flood risk, aesthetic, environmental and health reasons. In most cases, such items provide little or no benefit to the ecosystem and can be removed without concern. However, more natural items such as large woody debris can have significant ecological benefits and warrant careful consideration.

How should debris be managed?

Various techniques are available for debris management, involving actions to help prevent blockage (through the upstream management of the recruitment and transport of debris) and removal.

Typically the techniques available can be divided into two categories (see [Technical Support Document C](#) for more detail on each intervention technique):

- planned management of debris recruitment and transport
- reactive trash and debris removal

Selecting the most appropriate debris management option

The appropriate option for blockage management should be assessed and based on the specific site. Aspects which should be considered include the following.

- Management of the surrounding area can be an effective measure to prevent debris at the source. This could include the removal or trimming of riparian vegetation, or community engagement to minimise the likelihood of fly-tipping.
- Enlarging or modifying culverts or structures can allow the passage of debris downstream to a site that is less prone to flood risk. The impacts of this option on downstream locations should be considered carefully; otherwise it could just be passing the debris and possible flood risk to a different location.
- Debris trapping screens can allow the collection of debris at one site for removal. A risk assessment of collection of debris at a location should be undertaken to understand the potential impact on flood risk. The [Trash and Security Screen Guide](#) and the [Culvert Design and Operations Guide](#) contain details on appropriate screen design.

Further information

There are many guidance documents describing the best practice management of sediment, vegetation and blockages. They include the following Environment Agency publications:

- [Sediment Matters: A Practical Guide to Sediment and its Impacts in UK Rivers](#)
- [Aquatic and Riparian Plant Management Guide](#)
- [Environmental Good Practice Guide – Guidance to Help you Maintain your Watercourse in River Maintenance Pilot Areas \(PDF, 1.37 MB\)](#)
- [Debris and Blockage Modelling Guide](#) (publication due 2015)

3.6.4 Risk-based decision making

The need for channel management interventions and the level of intervention depend on the level of risk associated with the location. The benefits of management, including risk reduction, must outweigh its cost and other impacts.

It is vital that the level of management intervention or maintenance performed in a channel is proportionate to the level of risk being managed. The level of detail required to characterise the channel context and make an informed management decision also depends on the level of risk. A risk-based approach to management therefore enables resources to be targeted effectively at the areas that most require them.

To assess the level of risk and determine the most appropriate management interventions, you should ask yourself the following questions:

- **What is the present day risk?**
 - What is the probability of a response occurring?
 - What is exposed to the risk?
 - How vulnerable are existing receptors?
- **What is the future risk?**
 - Would intervention change the risk?
 - What sort of intervention would be most effective?
 - How much would the intervention cost?
 - Is more information required to allow an informed decision to be made?
 - Are there any uncertainties that need to be resolved?



Proportionate activities: for example...

The Hinksey Stream is part of the complex network of watercourses that run through and around Oxford. The draft Oxford flood risk management strategy recommended carrying out de-silting work at Hinksey Stream, allowing the flow of water to be taken away from North Hinksey where there was flooding in 2007. As part of the drainage system for Oxford, plans to clear vegetation and de-silt the channel to improve its capacity were added to the maintenance programme.

A river corridor and walkover surveys were made to minimise environmental impacts. This allowed obstructions to be cleared before an excavator was used to cut the thicker vegetation. Once the channel was accessible, an excavator removed the silt with the machine placed an arm's length away from the watercourse.

Case study 6: Hinksey Stream pilot study

Case study details

Hinksey Stream is part of the complex network of watercourses that runs through and around Oxford. It is an important carrier of water during high flows, taking water from the north of Oxford round to the west of the city. The pilot site starts at North Hinksey, where the Seacourt Stream splits into two forming the Hinksey Stream and the Bulstake Stream.

Channel management is required as part of the Oxford flood risk management strategy work. Obstructions were cleared from the channel using chainsaws and hedge cutters before using an excavator. Vegetation was left on the bank to rot down under the dredgings. The work that has been carried out shows, through the use of the Conveyance Estimation System, that there is an increase in conveyance of approximately 30% as well as a reduction in water level between the pre and post dredging data.

The increase in conveyance will cause more flow to travel down the Hinksey from the main Seacourt channel. This will result in the large area of floodplain adjacent to the Hinksey stream being utilised earlier in a flood event, taking more flow away from the Bulstake stream. From previous knowledge of the interaction of the Hinksey and Bulstake streams, something as small as a tree causing a blockage can increase the flow down the opposite channel. Modelling of the increased flood risk downstream post dredging showed that there is sufficient floodplain to cope with the increased conveyance.



Weed cutting on
Hinksey stream
©Environment
Agency

Title: Hinksey Stream

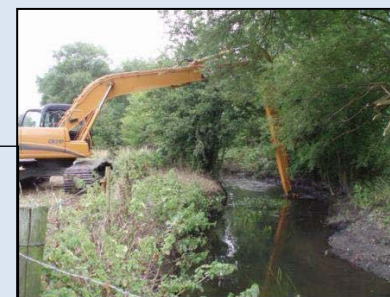
Location: Oxfordshire

'Typical' channel management issue: vegetation and sediment issues affecting conveyance

Management technique(s): de-silting programme

Stage 4: Identify, review and appraise options (or Do Nothing)

The draft Oxford flood risk management strategy recommends carrying out de-silting work at Hinksey Stream to allow the flow of water to be taken away from North Hinksey, where there was flooding in 2007. This part of the drainage system for Oxford was added to the maintenance programme, with the preferred option being to clear vegetation and de-silt the channel to improve capacity. A review of the local condition and flood risk issues confirmed that the strategy requirements were still valid. Further surveys were carried out to determine where management was required at the present time and what other factors could affect its scope. River corridor and walkover surveys were made to better understand the channel and to minimise environmental impacts. Careful attention was paid to the topographical survey, which was carried out before work started. This identified where the silt deposit was deepest and showed how the silt had built up on a number of locations along the stream.



De-silting works on
Hinksey stream
©Environment Agency

3.6.5 Working with natural processes

If it is decided that management intervention is required to achieve a channel's performance objectives, it is vital to consider natural channel processes and forms as far as possible. Optimising natural processes is often a very efficient way to manage a channel, and as such, it is important to determine whether they can be worked with in a way that achieves the channel's functional objectives.

To establish the extent to which natural processes can be worked with, it is necessary to assess the main characteristics and behaviour of the channel and its wider catchment (see [Section 3.4](#)) in the context of its channel type and the functional objectives (see [Section 3.3](#)). It is also important to consider the regulatory context (see [Section 2.6](#)).

In many cases it will be possible to do one or both of the following.

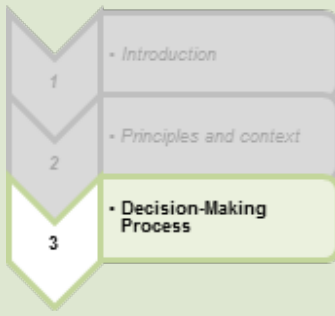
- Enhance or adapt natural processes as an alternative to engineering solutions. For example, it may be possible to change channel geometry to increase flow velocities and promote sediment transport as an alternative to de-silting.
- Allow natural processes to continue when a management solution is planned and implemented. This must, as far as practicable, use green engineering solutions or adopt environmentally sensitive management techniques alongside WFD targets.

Although there may be some instances where natural processes are directly contradictory to the performance requirements of the functional objectives of a channel, the optimisation of natural processes can provide an efficient, cost-effective and environmentally sensitive alternative to more traditional management solutions in most types of channel. This option should therefore be considered as the default management option for all channels.

3.6.6 Selecting appropriate management options

As described in [Section 2.3](#), the way in which a channel is managed should, where possible, reflect the dominant geomorphological processes that determine how the channel will respond.

The Management Intervention Selection Matrix in [Technical Support Document B](#) will help you choose a channel management technique appropriate for the type of channel that you are managing. The matrix works by establishing the type of channel being managed (see [Section 2.3.6](#) and [Technical Support Document A](#)) and providing recommendations for which sediment, vegetation and blockage management techniques are likely to be most effective in delivering the functional objectives of the channel. The handbook recommends use of this matrix as a guide to aid discussion rather than necessarily an underpinning of the decision-making process. Consultation with appropriate stakeholders is also recommended to aid option selection.



1 - Introduction

2 - Principles and context

3 - Decision-Making Process

Further information

It is important that the principles of **working with natural processes** (see [Section 2.3](#)) are considered when looking at whether there is an 'issue' or in the selection of techniques (see [Section 3.6](#)). More information on working with natural processes can be found in 'restoration' and geomorphological guides such as:

- [Rivers, Sediment and Habitats](#)
- [SEPA Engineering in the Environment: Good Practice Guides](#)
- [Sediment Matters Handbook](#)
- [Manual of River Restoration Techniques](#)
- [Drainage Channel Biodiversity Manual](#)
- [Woodland for Water: Woodland Measures for Meeting Water Framework Directive Objectives](#)
- [Working with Natural Processes to Manage Flood and Coastal Erosion Risk \(PDF, 6.24 MB\)](#)

Local Environmental Stewardship Schemes must be considered as they may influence channel management option selection due to resultant impacts on land use.

As every channel is unique, the intervention options suggested in the matrix may not always be the best option for your channel. The final decision will depend on site-related issues such as access and other constraints as well as the costs and affordability of each option, which are situation and organisation specific.

3.6.7 Appraising a shortlist of appropriate options and choosing the preferred solution

Although the processes described above may enable you to identify a preferred option, in some cases they may only get you a shortlist of options requiring further appraisal to determine the preferred solution.

A number of tools are available to support the process of moving through an option screening process to a shortlist or a preferred option. These include:

- benefit–cost analyses: for costs and benefits that can be valued monetarily
- appraisal summary tables: to help illustrate the impact of each option on a set of defined criteria (for example, the channel's functional objectives)

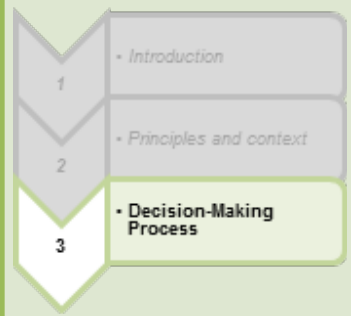
3.6.8 Option appraisal

Benefit–cost analysis involves assessing the costs and benefits of a management plan or intervention over an appropriate appraisal period. The benefits in this case being the reduction in damage or loss, or positive improvements created by the management intervention. Similarly, the cost covers the cost of implementing the solution over the appropriate appraisal period. The measure that is compared across all the options is the total benefits divided by the total costs.

Where intangible benefits that are not easily measurable are significant, the scale of the benefits can be appraised and compared with the difference between the quantified benefits to see if it is large enough to change the option choice. Ideally this should be done with the involvement of appropriate experts on the different functions and impacts. Where the uncertainty remains, other approaches such as eco-systems valuation methods can be used. It is important to stress the need for proportionality in economic assessment, with more complex analyses only carried out where the scale of impacts and the impact of the uncertainties on the choice of options justify them.

Appraisal summary tables are tables that capture impacts of each option across a range of categories. These categories can be the important functions and requirements or the functional objectives. They are used to record:

- whether any impacts are expected under each category for each option and whether these impacts are considered significant (or not)



The diagram illustrates a three-step process for appraisal. It consists of three numbered steps, each with a corresponding box: 1. Introduction, 2. Principles and context, and 3. Decision-Making Process. The steps are arranged in a descending staircase format, with step 3 being the final and highlighted step.

Further information

Further information and more detailed guidance on appraisal, including benefit–cost analyses, appraisal summary tables and ecosystem services can be found in the [Flood and Coastal Erosion Risk Management Appraisal Guidance](#) (FCERM_AG) and its associated [supporting documents](#):

- Supporting Document for the Appraisal Summary Table
- Guidance on Applying the Scoring and Weighting Methodology
- Economic Evaluation of Environmental Effects

- who or what is affected by the impacts
- a description of differences in impacts (qualitative, quantitative and monetary, as appropriate) across the options being appraised
- any crucial assumptions or uncertainties associated with the description of the impacts

The tables can be helpful in drawing out the scales of the impacts and the differences between the impacts for each functional objective. They allow those options with unacceptable consequences and which cannot be improved to be screened out. They also provide information for the appropriate group of experts or stakeholders to decide on the preferred option. The information from this process can also be used for a scoring and weighting multi-criteria approach if that level of analysis is required.

The reality of funding availability means that costs and affordability play a part in this process. However, it is important this is not used to compromise appropriate solutions. It may be possible to obtain partnership funding or in-kind delivery of aspects of the solution. It may also be possible to make the case for improved funding.

As with all appraisals, the Do Nothing option remains valid at this stage and its impact should be reviewed alongside the other options. Where the outcome of this process, either at the channel-reach scale or broader asset system scale, suggests that there is no economic case for carrying out channel management, then the protocol for management of flood and coastal risk management (FCRM) assets, described in [Section 3.5](#), can be considered for Environment Agency assets.

The outcome of this stage is the confirmation of a preferred option. It is essential that this option is agreed with all relevant partners, functional experts and stakeholders.

Once you have selected the most suitable management options, proceed to [Stage 5: Develop/review channel management plan and specifications](#).

3.7 Stage 5: Develop/review channel management plan and specifications

3.7.1 Designing management interventions

Having identified the preferred management intervention option to deliver the channel's functional objectives, the next step is to develop the details in the most effective and appropriate way. This could relate to a detailed plan for managing the channel over time or the detailed design for a particular management intervention.

It is important at this stage to maintain the broad engagement as the input and continued buy-in of some stakeholders such as landowners on whose land you may be carrying out or accessing works will be crucial as the details of the plan or works emerge. It is not unusual at this stage to identify new challenges in terms of actual fit of proposed options to the details and constraints of the site, from the physical activities to the timings of works and access for longer term maintenance or realisation of the plan.

Guiding principles of channel management

Design of management interventions must be in proportion to the risk of not managing the issue. Appropriate selection of the intervention depends on understanding the problem and working within the environmental context of the issue.

Act in proportion to the risk

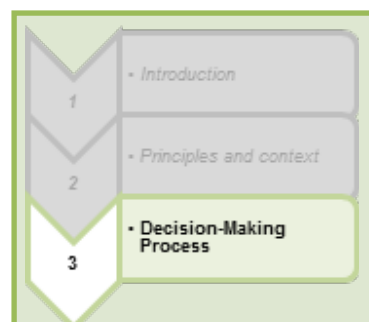
- The level of management intervention or maintenance performed should be proportionate to the level of risk that is being managed.
- The level of detail required to characterise the channel context and make an informed management decision should also be dependent on the level of risk.

Deal with the cause, NOT the symptom

- Appreciate that management issues may not be manifested at the source of the problem and the most effective solutions may be undertaking action in the upstream or downstream channel or elsewhere in the wider catchment.
- Weigh the long-term costs of managing the symptoms against that of addressing the root cause.

Aim to work with natural processes and deliver multiple objectives

- It is important to work with natural processes rather than against them.
- Recognise that working with natural processes can deliver real management benefits as well as environmental improvements.
- Aim to balance the requirements of multiple objectives to deliver a consensus benefit.
- Use best practice to minimise disruption to the environment.



Further information

The development of an appropriate design is vital for the success of a channel management intervention. Best practice guidance from the Environment Agency, the Scottish Environment Protection Agency (SEPA) and other UK bodies provides detailed information on approaches used to realise different types of channel management interventions. This guidance includes:

- [Culvert Design and Operation Guide](#)
- [River Weirs – Good Practice Guide](#)
- [Fluvial Design Guide](#)
- [Trash and Security Screen Guide](#)
- [SEPA Engineering in the Environment: Good Practice Guides](#)
- [RESTORE Healthy Catchments – managing for flood risk and WFD](#)
- [Manual of River Restoration Techniques](#)

What is a successful plan?

A successful channel management plan or intervention needs to:

- achieve the required functional objectives in an efficient and cost-effective way
- minimise adverse impacts on any other functional objectives
- ensure the plan or intervention can be implemented safely both in terms of operational access and work, and the public
- work to design out safety issues and mitigate any remaining risks through design and operational processes
- avoid creating unnecessarily onerous maintenance requirements
- where possible, work with rather than against natural geomorphological and hydrological processes
- be appropriate for the type of channel to which it will be applied
- ensure that all relevant legislation is complied with, for example, by ensuring that there is no deterioration in water body status, impediment to fish passage, or impacts upon protected species
- ensure that there is no unacceptable increase in flood risk or reduction in land drainage
- where possible within operational and budgetary constraints, seek to achieve environmental enhancements (for example, additional mitigation measures identified in the RBMP)

Where a channel management plan already exists, this stage will detail the required changes in terms of the outcomes of the option appraisal stage. This may relate to the form, timing or frequency of intervention. It is important that the updated plan is agreed with all relevant stakeholders and communicated appropriately.

Local [Environmental Stewardship Schemes](#) must also be considered as they may influence channel management option selection due to the resulting impacts on land use.

A number of legislative requirements such as flood defence consent, WFD compliance assessment, Environmental Impacts Assessment (EIA) or Habitats Regulations Assessment (HRA) could be required depending on the nature of the works. It is important that effective engagement is carried out with the relevant statutory regulators to understand likely requirements so that the scheme development can incorporate these as early as possible. Further information about these are provided in [Stage 6](#) and [Technical Support Document D](#).

At the end of this stage, it is important to record details of the works and any associated agreements and consents. This information will support implementation, monitoring and future reviews.

Once you have developed or reviewed a channel management plan and specifications, proceed to [Stage 6: Carry out channel management activities](#).

Ensure that the channel management plan and specifications are recorded using the guidance given in [Stage 8: Record](#).

Case study 7: Warrington Brooks

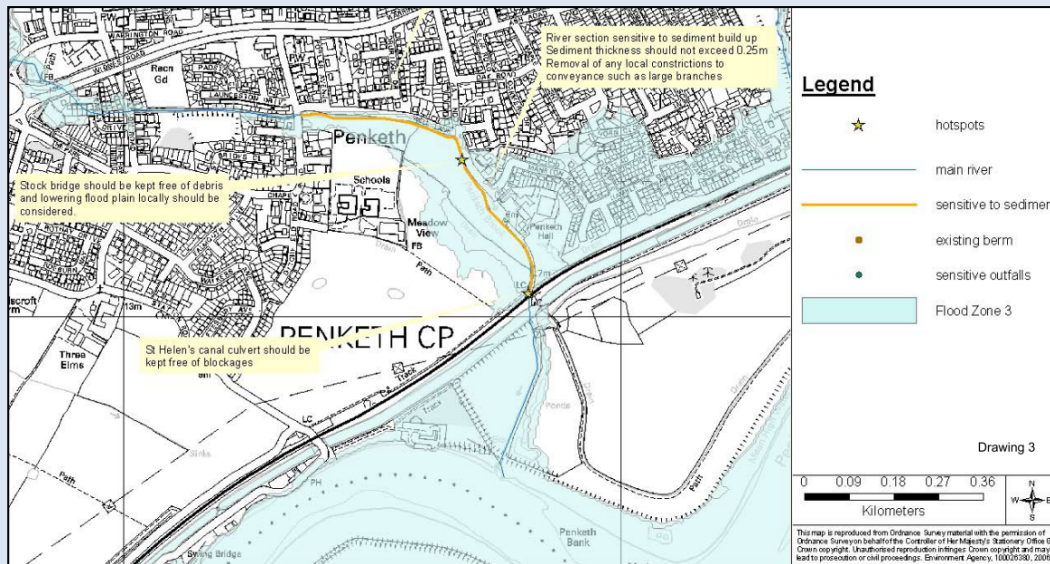
This case study highlights an example where testing and monitoring led to the implementation of an effective management plan. It demonstrates how [Stage 4](#) of the ACMF process can feed successfully into [Stage 5](#).

Case study 7: Warrington Brooks

Case study details

The town of Warrington in Cheshire is located in a low-lying area on the banks of the River Mersey. The area is drained by four brooks, which were originally maintained as trapezoidal canalised channels. To prevent flooding, the channels were regularly de-silted and in-channel vegetation was removed. These highly invasive management practices have been discontinued and replaced with a less onerous annual maintenance programme. Debris and blockages are removed, grass is cut on both banks, and weed growth within the channel is controlled. In addition, targeted de-silting is carried out where sediment raises water levels and limits channel capacity.

Flooding is becoming an increasing issue along the brooks. However, the relationship between the current maintenance regime and flood risk is not well understood. It was therefore necessary to review the maintenance programme and develop an evidence base for intermittent maintenance. An agreed programme of maintenance would make input from all functions of the Environment Agency easier before actions were implemented on the ground. It would also provide readily available evidence that could be used to explain the rationale behind maintenance activities to the local authority, residents and conservation groups. The modelling results formed an evidence base that can be used to target maintenance activities in the areas where it provides the greatest benefits from a flood risk and conveyance perspective. The evidence base also helped to justify less regular maintenance at less sensitive parts of each brook, delivering ecological benefits and cost savings.



Extract of drawing summarising maintenance requirements, based on the scenario modelling.
©Environment Agency

Title: Determining an appropriate maintenance regime for the Warrington Brooks

Location: Warrington, Cheshire

Technique: ISIS modelling to inform management strategy

'Typical' channel management issue: sedimentation and vegetation growth affecting water levels and flood risk

Management technique(s): develop management strategy, undertake sensitive vegetation management

How it was delivered: Environment Agency (lead partner)

More information: [Conveyance Manual \(PDF, 4.5 MB\)](#)

Stage 5: Develop/review channel management plan and specifications (or Do Nothing)

The Environment Agency's existing ISIS models of the four brooks were used to test the impact of siltation and vegetation growth on water levels and flood risk in order to develop a management strategy. The following scenarios were tested.

- The impact of siltation was tested by increasing the channel bed levels by 0.25, 0.50 and 0.75 m for a series of return periods between 1 in 1 and 1 in 1,000 years.
- The impact of vegetation growth was tested by increasing the roughness value used in the model. Three different vegetation growth or channel maintenance scenarios were tested: no vegetation growth/complete removal of vegetation; biannual vegetation removal; and uncontrolled vegetation growth.

The impact of siltation and vegetation growth under each scenario was assessed through changes to water levels at each cross-section in the model. This allowed the management team to identify which stretches of the brooks were most sensitive.

3.8 Stage 6: Carry out channel management activities

When planning management interventions for a channel (including routine maintenance and one-off interventions), it may be necessary to apply for relevant consents and licences from the statutory regulators. These are commonly the Environment Agency in the case of Main Rivers, Natural England in the case of protected sites consent and protected species licences, and either LLFAs or IDBs in the case of Ordinary Watercourses. The most commonly required permission is a **Flood Defence Consent**. As part of this you may be required to undertake a **Water Framework Directive Compliance Assessment**.

The consenting process is extremely important. It may not be possible to implement management interventions if the required consents are not in place. Early consultation with the relevant regulators is recommended to avoid potential delays.

3.8.1 Flood defence consent

Flood defence consent is required for any works in, on, under or near channels and flood defences. Using an online form, the applicant must provide:

- details of the location of the proposed works
- detailed drawings of the proposals
- accompanying method statements

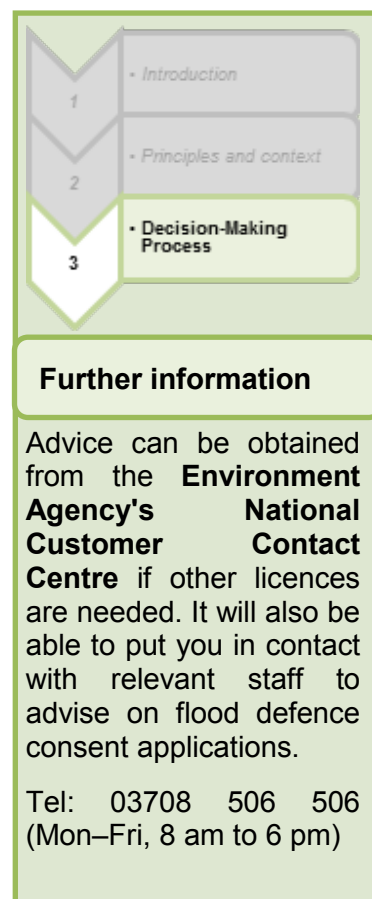
Further information on flood defence consents is provided in [Technical Support Document D7 Flood risk management and flood defence consents](#).

3.8.2 WFD compliance assessment

A WFD compliance assessment may be needed for activities that could potentially compromise the delivery of water body objectives. The compliance assessment must demonstrate the activity does not compromise the achievement of WFD objectives. It may include a demonstration that:

- The activity does not risk status deterioration
- The activity does not compromise the effectiveness of planned improvement measures and the achievement of future status objectives
- Where appropriate, the activity contributes directly to the delivery of improvement measures

Physical works that occur in and around channels could potentially conflict with these legal requirements and cause harm to the water environment. The Environment Agency, Natural Resources Wales and other operating authorities must secure compliance with the requirements of the Water Framework Directive and meet their other environmental duties when carrying out physical works in watercourses or issuing permits/licences for others to do so.



An applicant applying for a permit or licence to perform physical works in or around a channel may be required to provide the Environment Agency or Natural Resources Wales with information to demonstrate the proposed works meet the requirements of WFD.

To ensure physical works in channels protect and, where possible, improve the water environment, channel managers should be confident that:

- works will not lead to **deterioration** in the quality of a water body
- works will not prevent the **future improvement** of a water body

More information on whether or not your activity requires a WFD compliance assessment can be found in [Technical Guidance Document D4](#).

3.8.3 The Environment Agency is due to publish further guidance in 2015 Natural England protected species licence

A licence is required by anyone who wishes to carry out an activity prohibited under wildlife legislation, for example, to disturb or damage the habitat of certain strictly protected species. The type of licence required (general, class or individual) depends on the activity proposed and its likelihood of impacting on protected species.

3.8.4 Environmental Impact Assessment

An Environmental Impact Assessment (EIA) is a document that is often required to accompany planning application submissions or is required to be developed when capital works are planned. It details the potential impacts on the environment (including on human receptors such as noise, air quality and historic environment) for the construction, operation and decommissioning phases of a scheme and suggests mitigation to minimise these impacts. In some cases, an EIA may be required for significant channel works. A screening opinion should be sought from the local authority to determine if an EIA is required. Further information on EIAs can be found in [Technical Guidance Document D5](#).

3.8.5 Biosecurity



When carrying out management activities within watercourses, a good biosecurity routine is essential to reduce and minimise the risk of spreading invasive, non-native plant species and other harmful organisms/diseases such as Crayfish plague.

The most cost-effective method of managing non-native invasive species is to prevent their spread. Many forms of management result in disturbance and fragmentation, which may result in the spread of the plant. This may result in an offence under Section 14 of the Wildlife and Countryside Act 1981

It is vital that anyone carrying out channel management activities follows the 'check-clean-dry' campaign. This includes the following.

- Inspect and clean clothing and equipment thoroughly before and after its use.

- Avoid areas containing non-native invasive species that are not intended for management (to reduce contamination).
- Dry equipment thoroughly for at least 48 hours before re-use.

For advice visit the [Non-Native Species Secretariat \(NNSS\) website](http://www.nonnativespecies.org/checkcleandry/) (<http://www.nonnativespecies.org/checkcleandry/>).

3.8.6 Waste disposal

Legal waste management is essential for effective pollution prevention.

While it is usually cost-effective and usually makes good sense in terms of the environment and carbon footprint to re-use material generated from channel management activity within the works or locality, removed material is likely to be classed as waste and as such is governed by legislation which controls how it can be re-used or disposed.

Under the Duty of Care you have a legal duty to make sure any waste you produce during channel works does not escape from your control. Waste must be transferred to an authorised registered or exempt waste carrier or waste manager. It must be accompanied by a full description of the waste and a waste transfer note and be disposed of lawfully. This can be effectively dealt with by producing a site waste management plan (see [Pollution Prevention Guidelines 5: Works and maintenance in or near water](#)).

Any material excavated and requiring disposal off-site will need to be characterised and disposed of in accordance with the Landfill Regulations 2002 (as amended) and the Hazardous Waste Regulations 2005, where applicable. Any material classified as hazardous waste will require pre-treatment prior to disposal to either reduce the volume of hazardous waste requiring disposal or to reduce the hazardous nature of the material. Wastes will also require some form of pre-treatment prior to disposal.

Any soils imported to the site will need to be tested and verified to ensure that they do not pose a risk to human health or controlled waters. They will also need to be accompanied by all relevant Duty of Care documentation. Further information on waste management can be found in [Technical Guidance Document D6](#).

Case studies: Knettishall and River Nene

Both these case studies highlight where channel management activities have been carried out after gaining a comprehensive understanding of the issues affecting the channel.

Case study 8: Knettishall Heath river restoration

Case study details

The Little Ouse has been subject to continuous management for the past century. This has included installation of a series of stop-board weir water level management structures throughout the length of the reach at Knettishall Heath, resulting in extensive impoundment and lack of in-channel habitat diversity.

The in-channel structures have a considerable impact on the river and prevent it reaching good ecological status under the Water Framework Directive. Removal of in-channel structures was not a viable option at the site due to funding constraints, but restoration options involving bed and bank reprofiling aimed at improving the local hydromorphology by increasing the range and quality of in-channel habitats were implemented.

In addition to improvements to local hydromorphology, the amenity value of the river landscape was also considered in the project design, given the visibility of the site located within Knettishall Heath Country Park, which is popular with the public.



It is possible to deliver significant hydromorphological and ecological improvements in a heavily impounded river without the need to remove structures. This represents a significant cost saving.

Benefits

- All works and alterations were achieved without importing any materials onto the site. Similarly no disposal of spoil was necessary during implementation of the scheme.
- The introduction of numerous in-channel features resulted in significant improvements to the quality and range of in-channel habitats.
- Improvements to local hydrology and morphology contributed towards re-naturalisation of flow and sediment regimes, and achievement of good ecological status for the Little Ouse water body.

Title: Knettishall Heath River Restoration

Location: Little Ouse, Knettishall Heath, Suffolk

'Typical' channel management issue: restoration of geomorphological issues

Management technique(s): creation of new gravel features

How it was delivered: Environment Agency with its partner, Suffolk Wildlife Trust

Stage 6: Carry out channel management activities

The implementation of the Knettishall Heath River Restoration Plan was achieved by:

- creating pools and runs from the existing flat river bed through reprofiling of the existing material
- creating a two-stage channel by installing dense reed stands to prevent the complete 'closure' of the channel and avoid ponding of water upstream
- narrowing of sections of the channel by pushing in the banks
- installing single (pushing flow toward a particular bank) and double deflector shoulders (that focus flow into the centre of the channel) created from local large woody debris, encouraging hydromorphological diversity and zones of erosion and deposition

Restored section after
project completion
©Environment Agency



Case study 9: Best practice dredging in the River Nene

Case study details

The River Nene in Northampton is the primary route for flood water to pass through the town. During a period of flooding in 1998, parts of the town were severely affected. As a result, a substantial programme of flood defence works was implemented. However, the effectiveness of the flood defences depends on the free flow of water through the main river channel. Parts of the river adjacent to the Grand Union Canal and around a large sluice are subject to considerable siltation and consequently require regular dredging to maintain the performance objectives of the channel from a flood risk management perspective.

The main challenge that faced channel managers was to carry out the dredging and channel bank maintenance necessary to maintain the required flood defence standards for Northampton in a manner that minimised costs and environmental impacts while gaining the support of stakeholders such as the internal waterways team, the local authority and a white water adventure centre.

The project achieved its primary aim of dredging the river in an environmentally sensitive manner, achieving the required performance objectives for flood risk management. The scheme also improved existing defences downstream.

The scheme also provided a suite of wider benefits for other functions including biodiversity improvements along the river corridor and improvements for navigation and recreational boating.



Land-based excavator
removing material
©Environment Agency

Title: Best practice dredging in the River Nene

Location: River Nene, Northampton

'Typical' channel management issue: Siltation reducing channel capacity and affecting water levels and flood risk

Management technique(s): Dredging

How it was delivered: Environment Agency

Stage 6: Carry out channel management activities

Sediment was removed from the river using a barge-mounted excavator and skip barges pushed by tugs. This removed the need for 500 lorry movements through the town. The arisings were incorporated into a flood storage area downstream of the dredging site, replacing existing clay deposits which were then used to make the defences more robust.

The Environment Agency worked closely with the local authority, which carried out tree and maintenance work alongside the river channel. This increased the positive benefits of the dredging work on the river environment.

The Environment Agency also worked closely with the internal waterways team and a local whitewater adventure centre to improve the condition of the parts of the river used for navigation and by canoes and rowing boats.



The barge-mounted
excavator and skip
barge
©Environment Agency

3.8.7 Summary of management considerations

In summary are many management aspects that you have to consider before you carry out any channel management activities. Table 3.2 presents a summary check list of important factors to consider during the management process and the subsequent actions required if your system meets any of these highlighted aspects management considerations (adapted from [Aquatic and Riparian Plant Management Guide](#)). [Appendix D](#) presents a full discussion of all relevant legislation.

Consideration	Action required
Is the watercourse designated or does it flow into, through or out of a statutory designated nature conservation site?	If YES – contact Natural England or Natural Resources Wales. You may require consent.
Is the watercourse located adjacent to or within? a Scheduled Monument?	If YES – contact English Heritage or Cadw. You may require consent.
Does the watercourse support protected species?	If YES – seek advice from Biodiversity staff and implement appropriate mitigation measures and working practices when conducting management. Consider modifying management, including timing, to avoid adverse impacts. If adverse impacts cannot be avoided, contact Natural England or Natural Resources Wales for further advice and obtain a licence if required. You may need to employ a suitably licensed and experienced ecologist to advise you.
Does the watercourse support priority species or habitats, or notable and/or rare species?	If YES – implement appropriate working practices when conducting management. Consider modifying management to avoid adverse impacts. Seek advice from Biodiversity staff. Contact Natural England or Natural Resources Wales for further advice if required.
Are spawning fish present?	If YES – implement appropriate working practices when conducting management. If possible, time works to avoid spawning season. Contact the Environment Agency for further advice if required.
Do the proposed management works require a WFD Compliance Assessment?	If YES – assess the ecological and hydromorphological impacts of the proposed management works. Consult with the Environment Agency/ Natural Resources Wales /IDB/LLFA for further advice.
Do the proposed management works fall under the EIA Regulations?	If YES – assess the environmental impacts of the proposed management works and determine whether an Environmental Statement is required. You will need to advertise and consult on the outcome of the assessment.
Have you identified all health and safety implications?	Ensure that: <ul style="list-style-type: none"> • all necessary risk assessments are made • risks have been avoided or reduced as far as practicable • safe systems of work are in place for residual risks • operatives are properly trained, instructed and provided with appropriate personal protective equipment (PPE)

Consideration	Action required
Have you considered biosecurity?	Assess the level of risk posed by the management works and put in place appropriate biosecurity measures.
Will the proposed management works create waste which requires disposal?	If YES – register waste exemptions or apply for permits where necessary. If waste has to be removed from site, ensure it is taken by a licensed waste carrier to a suitably authorised landfill site.
Do the proposed management works require Flood Defence/Land Drainage consent?	If YES – apply to the appropriate authority for consent. Holding preliminary discussions with the appropriate authority before submitting any application is advised.
Do the proposed management works require the use of herbicide in or near water?	If YES – apply to the Environment Agency/Natural Resources Wales for agreement. Further guidance on the use of herbicides in or near water is provided in Technical Support Document C .
Have you explored the possibility of partnership working?	Identify and consult with any other interested parties and consider setting up a partnership/working group to undertake management.
Have you considered management in the context of the wider catchment?	Ensure upstream and downstream watercourse function(s) and management requirements are identified and integrated within a catchment-scale approach.

Table 3.2 Management considerations

3.9 Stage 7: Monitor and review

Even when channel management decisions have been made following detailed analysis and design, many assumptions and uncertainties will remain about the actual performance into the future. Post-intervention monitoring is an important component of the Adaptive Channel Management Framework and should be part of all management regimes. Monitoring requirements are often overlooked when management interventions are planned, but it is vital these are considered at all stages.

Monitoring provides the input for an assessment of the impact of an intervention, helps gain an understanding of the performance of a management intervention, and allows a clear judgement on whether the functional objectives are being achieved. The resulting data and information need to be stored and managed carefully. They need to capture not only the spatial but also the temporal factors, as it is essential to understand how management and other developments influence the channel over time.

Post-intervention monitoring should be carried out regularly to ensure:

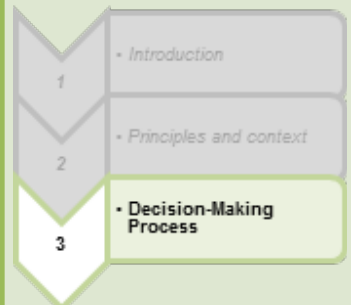
- the effectiveness of management interventions in achieving the performance objectives can be evaluated
- changes in the channel can be identified, including responses to management and natural variation
- there is an appropriate dataset on which to base ad hoc or periodic review of the management decision
- management decisions can be changed and/or management interventions amended to provide continued effectiveness as part of a programme of adaptive management

3.9.1 What needs to be monitored?

Monitoring requirements need to be closely related to the characteristics of the channel being managed. They need to focus on the performance indicators associated with the functional objectives set for the channel and the type of management interventions implemented.

Monitoring of the following important factors will allow the effectiveness and impacts of a management option to be assessed:

- hydraulic parameters such as water levels, flow velocities, discharge and roughness
- physical parameters such as bank profile, bed levels, sediment supply, erosion, deposition and sediment transport



Further information

Guides to monitoring, providing low-cost options to full monitoring strategies at varying scales, include:

- [Practical River Restoration Appraisal Guidance for Monitoring Options \(PRAGMO\)](#)
- [Geomorphological Monitoring Guidelines for River Restoration Schemes \(PDF, 992 KB\)](#)
- [Aquatic and Riparian Plant Management Guide](#)
- 'Mitigation Measures Monitoring Trials', Environment Agency, 2011

See [Technical Support Document E](#) for more on the techniques available to monitor your channel.

- ecological parameters such as vegetation type and extent, fish populations and invertebrate populations
- condition and performance of structures (discussed in more detail in [Section 3.4](#)).

It is essential to set up monitoring programmes for new management plans and interventions.

It is also important to update existing monitoring plans where a review and appraisal process leads to a change to the plan. Subsequent monitoring should be designed to:

- determine the impact of the change in management
- provide the information to assess whether the change has achieved the expected impact and to provide further knowledge on which to base any further adaptations of the system

As part of setting up a monitoring plan, it is necessary to identify trigger points which indicate when a review or some operational activity or action is required to enable continued achievement of performance objectives. The review process is discussed below.

3.9.2 The importance of reviewing decisions

The Adaptive Channel Management Framework guides the user to make decisions on whether channel management interventions are required and, if they are, to identify and implement the most suitable option for that channel. However, it is important to recognise that:

- channels are dynamic systems that are subject to natural change
- the management requirements of a channel could be subject to change in response to natural variations and/or shifting of functional objectives

There are two main types of review:

- **periodic reviews** that are conducted at pre-defined time intervals, for example, as part of the pre-planned asset management planning process
- **ad hoc reviews** that are conducted in response to specific events (such as a trigger level being reached), unplanned changes in channel condition or policy drivers

It is vital that reviews are based on the best available evidence, and as such, they should be informed by the results of monitoring carried out on a channel. The effort should be kept proportionate to the risks and impacts. The reviews should also take on board performance-related information from other sources such as the local community.

The review should consider all the stages of the original decision-making process from setting objectives ([Stage 1](#)) through to delivering management activities ([Stage 6](#)). This can be a very quick process where the impacts indicate no change is required or could involve detailed analysis if major changes or impacts are identified.

Guiding principles of channel management

The monitoring and review of the channel management decision needs to be in proportion to the risk. Selecting an appropriate monitoring scheme should follow the guiding principles of channel management. The monitoring and review must feed into the lessons learnt which will influence the next phase of implementation of the management action:

Act in proportion to the risk

- The level of management intervention or maintenance performed should be proportionate to the level of risk that is being managed.
- The level of detail required to characterise the channel context and make an informed management decision should also be dependent on the level of risk.

Learn and adapt

- Ensure that the results of channel management are properly monitored and recorded.
- Use evidence and the results of monitoring to review and, if necessary, amend key decisions.
- Ensure that lessons learned are clearly recorded and used to inform future decisions.

Case studies: Castledyke and Rothes

These case studies illustrate how effective monitoring can establish the results of management options implemented and shape further management.

Ensure that the results of monitoring and review are recorded using the guidance provided in [Stage 8: Record](#).

It is important that the outcomes of this stage are used in [Stage 1: Set/review functional objectives](#) as part of an ad hoc or periodic review process.

Case study 10: Castledyke Drain weed control programme

Case study details

The south Lincolnshire Fens contain some of the country's most productive Grade 1 agricultural land relying on land drainage. In realising this land drainage function, the IDB has added objectives to enable navigation and minimise environmental habitats. Most fields have perforated plastic pipes or clay land tiles that drain into riparian (private watercourses) before entering IDB managed systems to convey water to pumping stations for discharge to sea.

Vital to the conveyance of flow is the cyclical management of vegetation growth within the channel. The 9.6 km long Castledyke Drain has a problem with the filamentous algal weed 'spirogyra', known locally as 'cott'. The weed chokes the channel and, when it dies, adds to sediment build-up. The weed also restricts navigation and chokes other weed growth. A recent inspection showed that cut weed growth was seriously raising upstream water levels and restricting conveyance.

Options were assessed including herbicides (previously used but no longer allowed for use in water) and mechanical removal options. The use of a cut rake was preferred as it allows silt and aquatic organisms to fall back into the drain through the rake. The management plan and specifications have been reviewed to ensure that management options (that is, mechanical removal and herbicide treatment) are recorded and reviewed. It was such a review that identified that available herbicides were no longer acceptable.

Title: Castledyke Drain weed control programme

Location: Lincolnshire Fens, England

'Typical' channel management issue: vegetation issues affecting channel conveyance

Management technique(s): mechanical weed removal

Contact Witham Fourth District IDB for more information

Stage 7: Monitor and review

The watercourse is monitored on a regular basis by the IDB's experienced operational staff. Removal is scheduled before weed growth reaches a point where it has a serious impact on conveyance; this is identified by the extent of elevated water levels at the upstream end of the watercourse. Land owners are served notice of entry giving six months' warning of commencement of operations. The notice also advises them of the width of land required for the works to take place (typically 6 m), allowing them to plan crops accordingly.



Excavator with 'cott rake'
©Witham Fourth District IDB



Excavated cott drying out
©Witham Fourth District IDB

Case study 11: Rothes flood alleviation scheme

Case study details

The Rothes flood alleviation scheme is required to protect over 400 properties in the town of Rothes from the Back Burn, Burn of Rothes and Black Burn to a 1 in 100 year standard of protection. The design needs to account for the high sediment transport to minimise the blockage risk at structures and bridges during high flows, minimise whole life maintenance costs, and improve the river habitat and visual appearance.

Understanding the catchment context and designing to work with this was a very crucial stage in this scheme. The three Burns are very steep and morphologically active, with significant transportation and deposition of sediments through to the lower sections of the burns, including through the town of Rothes. Bank stabilisation to reduce erosion at the upstream reaches was not regarded as fundable from the flood risk budgets. Large amounts of sediments have been known to be carried out in single large flow events, causing significant blockage to the channel and structures through Rothes and leading to flooding of properties. It was important that the reaches downstream of Rothes were not starved of sediments to prevent instability. Geomorphological studies, ecological studies and sediment modelling were used to support the system understanding and options development.

The channel has been widened historically and very frequent sediment removal occurs following high flows to restore conveyance through the channel and structures. A scheme to reduce the flood risk is definitely needed, but would need to work with the system to provide flood risk and environmental benefits as well as ensuring the system is resilient to high sediment transport and deposition during high flows. Options were developed to work with the channel processes and engagement with the local community. The preferred solution included multi-stage channels that kept the low flow channel narrow with berms and shallow slopes at higher levels to achieve flood conveyance. The channel cross sections enabled sediment deposition at appropriate locations where they caused no risk and can be removed easily. The channel cross sections immediately upstream of or at structures or bends through the town discouraged deposition. The engagement with the local community was carried on into the construction phase.

Title: Rothes flood alleviation scheme

Location: Morayshire, Scotland

'Typical' channel management issue: sediment issues affecting channel conveyance

Management technique(s): adaptive management, working with natural processes

Stage 7: Monitor and review

Gauge boards, rain gauges, level and flow monitoring were installed as part of the channel improvement works to enable future monitoring and adaptive management. Monitoring and surveys were carried out before, during and immediately after construction to provide a baseline of information to base future changes on. An O&M manual was developed providing the details of the required maintenance, record keeping and monitoring. The manual requires periodic reviews of the monitoring information at set intervals as well as after every major high flow event or when any of the set thresholds are reached. These reviews would be to assess whether changes to the maintenance regime or the Scheme configuration are required to continue to meet the channel management objectives.



Rothes Flood Alleviation Scheme
©Royal HaskoningDHV

3.10 Stage 8: Recording the outcomes

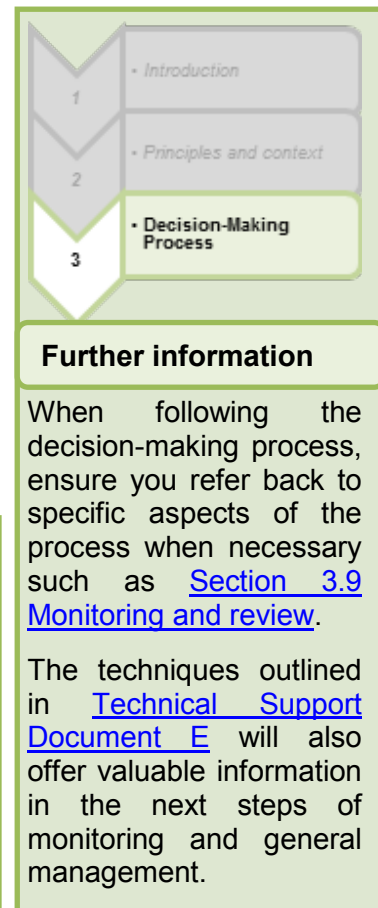
Whatever the outcome of the decision-making process, it is crucial that you record your decision. The channel manager should record the outcome (either to carry out a particular type of intervention or to delay or not carry out an intervention), and the reasons for this selection. This will help with setting up appropriate monitoring processes to assess the impact of the intervention (or lack of it) to support future adaptive management and performance evaluation.

Guiding principles of channel management

This stage of the Adaptive Channel Management Framework encapsulates the guiding principle that addresses reviewing decisions and learning lessons so that the management option can adjust in future.

Learn and adapt

- Ensure that the results of channel management are properly monitored and recorded.
- Use evidence and the results of monitoring to review and, if necessary, amend key decisions.
- Ensure that lessons learned are clearly recorded and used to inform future decisions.

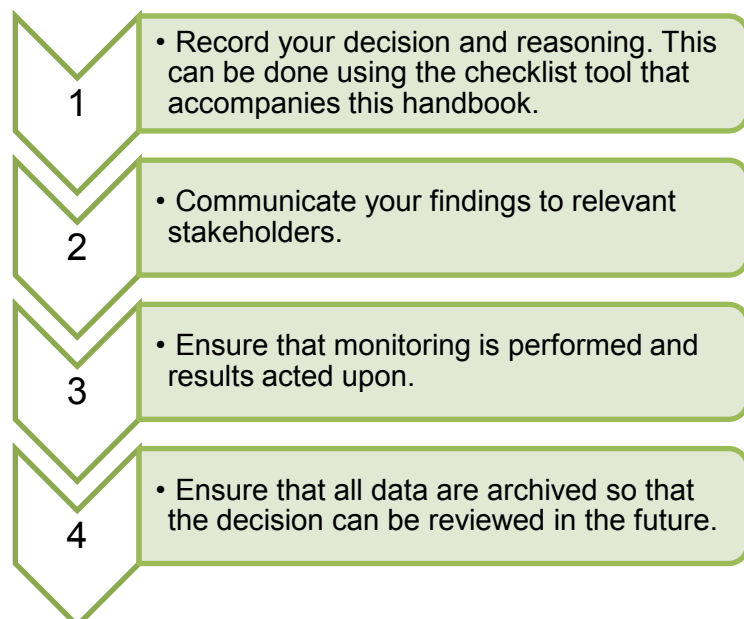


The findings of post-implementation monitoring must be acted on to ensure that the intervention is working properly and is not causing any unwanted effects. In some cases, it might be necessary to amend the intervention so that it performs as required. It is also important that all data used to inform the decision-making process are stored and managed carefully so that they are available for use when the decision is next reviewed. The review process and associated data management should form a central part of the management cycle.

The experts consulted as part of the decision-making process set out in the Adaptive Channel Management Framework, along with other stakeholders, should be informed of the outcomes of your decision.

The next steps are summarised in Figure 3.2.

Figure 3.2: Next steps



Technical Support Document A: Channel typologies

The channel typology used in this handbook is based on the typology developed as part of the [Aquatic and Riparian Plant Management Guide](#). This in turn built on previous geomorphological classifications by Montgomery and Buffington. The typology covers the types of channel found naturally in the UK. It also considers the degree of modification that affects natural channels.

The main river channel types are intended to represent natural or near-natural conditions, where anthropogenic modifications are absent (likely to be a rare occurrence in most UK watercourses), spatially very limited, or have a minimal impact on channel form and function. However, the majority of channels are likely to have been affected in some way by anthropogenic interventions, either through direct changes to the channel morphology or as a result of changes to the flow and sediment regime (for example, as a result of floodplain cultivation, the installation of floodplain drainage ditches and water abstraction).

Modifications to a channel can mean that there is a need to manage it in a different way to a natural or near-natural channel. Unless the modifications are sufficiently significant to remove all residual natural functionality from the system, the management of modified natural channels still needs to take into account the main flow, and the sedimentary and morphological characteristics of the overall channel type.

Completely artificial channels can be managed differently to modified natural channels since they do not necessarily have a natural flow and sediment regime that controls how they function.

More information is provided in the channel typology table (Table A1) and the degree of channel modification table (Table A2).



Identifying your channel type



The different types of channel outlined in Table A1 can be easily distinguished based on important physical characteristics such as:




- substrate type and composition
- type and extent of depositional features
- degree of bank modification and reinforcement
- flow characteristics



The characteristics given in Table A1 may not be accurate for all channel types. The most important geomorphological features of each respective channel type is presented, however note that this is a generalisation.




Table A1: Geomorphologically based channel typology



Channel type		Example	Key geomorphological features	UKTAG river types	JNCC river types
Natural or modified natural channels	Step pool channel		<ul style="list-style-type: none"> Occurs in steep valleys where lateral movement is restricted. Contains distinct steps across the channel, made up of boulders or bedrock outcrops. Areas between steps are dominated by pools which span the entire width of the channel and are between 1 and 4 channel widths in length. Sediment load is generally coarse, although there is usually some fine sediment. 	2, 3, 10, 11, 13, 16, 18	CVIII, DIX, DX
	Bedrock channel		<ul style="list-style-type: none"> Occurs in steep valleys where lateral movement is restricted. Dominated by bedrock outcrops, with bed sediment restricted to scour holes or behind obstructions. Sediment load dominated by very coarse material (cobbles and boulders). 	10, 11, 18	CVIII, DIX, DX

Channel type		Example	Key geomorphological features	UKTAG river types	JNCC river types
Natural or modified natural channels	Plane bed channel		<ul style="list-style-type: none"> Occurs in moderate to steep gradients. Contains a planar bed with very little morphological diversity and few depositional features. Flows are typically uniform and shallow. Pools may develop as a result of obstructions (including woody debris). Sediment load dominated by coarse material (gravel and cobbles). Bed armouring frequently develops, with material only moving during large floods. 	1, 2, 4, 6, 7, 13, 14, 15, 16, 17	CVII, DIX
	Wandering channel		<ul style="list-style-type: none"> Occurs on moderately steep slopes where lateral movement is unconfined. Typically has a wide valley floor. Contains a gravel bed and a diverse range of large gravel features, including lateral and medial bars. In-channel features are frequently re-worked during flood events. The channel can avulse (change position) within the wider active watercourse corridor. Sediment load is dominated by coarse material (sands, gravels and cobbles). 	1, 2, 10, 11, 12, 13, 15, 16	BV, BVI, CVII

Channel type		Example	Key geomorphological features	UKTAG river types	JNCC river types
Natural or modified natural channels	Active meandering channel		<ul style="list-style-type: none"> Occurs in moderate to low gradients. Meandering planform with some gravel features. These are frequently limited in size due to lack of sediment supply. Considerably less lateral adjustment than wandering channels. Sediment load dominated by sand and gravel. 	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 13, 14, 15, 16, 17	AIII, AIV, BV, BVI, CVII, CVIII, DIX
	Pool riffle channel		<ul style="list-style-type: none"> Occurs in low gradients. Pools consist of topographic depressions caused by increased energy and bed scour on meander bends, with a spacing of between 5 and 7 channel widths. Pools can also develop in response to obstructions such as woody debris. Riffles consist of slightly elevated areas of channel in areas of lower energy flow between pools. Sediment load dominated by sand and gravel. 	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17	BV, BVI, CVII, CVIII, DIX
	Inactive single thread channel		<ul style="list-style-type: none"> Occurs in low gradients. Highly sinuous meandering planform, with steep, high banks. Dominated by cohesive (typically clay) substrates which are resistant to bed and bank erosion. Low energy environment with low level of morphological adjustment and limited geomorphological and flow diversity. Low sediment load due to cohesive substrates; 	6, 7, 9, 14, 15, 17	AI, AII, AIII, AIV

Channel type		Example	Key geomorphological features	UKTAG river types	JNCC river types
			generally dominated by fine material (silts).		
Natural or modified natural channels	Tide locked channel		<ul style="list-style-type: none"> Occurs in low gradients adjacent to the coast or an estuary. Flow regime dominated by tidal influence. Low energy impounded conditions during high tide. Higher energy freshwater system during low tide. 	1, 2, 3, 4, 5, 6, 7, 8, 9	AI, AII, AIII, AIV, BV, BVI
	Small unreinforced drainage channel		<ul style="list-style-type: none"> Artificial channel. Typically occurs in low gradients. Bed and banks not generally reinforced, but have a uniform profile. Frequently straight planform. Typically narrow and deep. Low energy, with low velocity flows. 	N/A	N/A

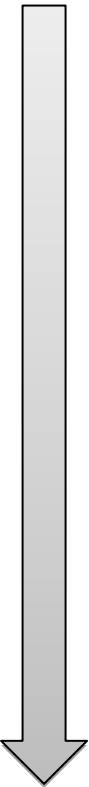
Channel type		Example	Key geomorphological features	UKTAG river types	JNCC river types
Artificial or extensively modified channels	Large unreinforced drainage channel		<ul style="list-style-type: none"> • Artificial channel. • Typically occurs in low gradients. • Bed and banks not generally reinforced, but have a uniform profile. • Frequently straight planform. • Sediment dominated by fine material (silts and clays). • Low energy, with low velocity flows. 	N/A	N/A
	Reinforced drainage channel		<ul style="list-style-type: none"> • Artificial channel. • Bed and banks are frequently reinforced. • Generally straight planform. • Low energy, with very low velocity flows. 	N/A	N/A
	Canal		<ul style="list-style-type: none"> • Artificial channel. • Bed and banks are frequently reinforced. • Generally straight planform. • Low energy, with very low velocity flows. 	N/A	N/A

Channel type		Example	Key geomorphological features	UKTAG river types	JNCC river types
Artificial or extensively modified channels	Natural channel (high modification)		<ul style="list-style-type: none"> • Natural channel that has major modifications to flow and sediment regime, bed, banks and floodplain. • Widespread modifications, dominant in some reaches. • Retains characteristics of natural channel type. • Bed and/or banks frequently reinforced or reprofiled. • Channel capacity frequently increased. 	All	All
	Natural channel (significant modification)		<ul style="list-style-type: none"> • Natural channel that has significant modifications to flow and sediment regime, bed, banks and floodplain. • Majority of channel modified. • Retains characteristics of natural channel type. • Bed and/or banks generally reinforced or reprofiled. • Channel capacity generally increased. 	All	All

Notes: Adapted from [Aquatic and Riparian Plant Management Guide](#)

JNCC = Joint Nature Conservation Committee; UKTAG = Water Framework Directive UK Technical Advisory Group

Table A2: Degree of channel modification

Degree of modification		Key channel characteristics	Implications for management
	Natural or near-natural	<ul style="list-style-type: none"> Natural or near-natural channel with limited modifications Natural flow and sediment regimes Natural bed, banks and floodplain 	Manage according to natural river type
	Low	<ul style="list-style-type: none"> Near-natural channel with limited modifications Minor modifications to flow and sediment regime Minor modifications to bed, banks and floodplain Modifications have a limited spatial extent in isolated reaches 	Manage according to natural river type
	Moderate	<ul style="list-style-type: none"> Moderate levels of modification to natural channel Changes to flow and sediment regime Changes to bed, banks and floodplain Widespread modifications 	Manage according to natural river type
	High	<ul style="list-style-type: none"> Extensive modifications to natural channel Major changes to flow and sediment regime Major changes to bed, banks and floodplain Widespread modifications, dominant in some reaches 	Manage according to natural river type
	Significant	<ul style="list-style-type: none"> Extensive modifications to natural channel Significant changes to flow and sediment regime Significant changes to bed, banks and floodplain All reaches modified 	Manage according to natural river type
	Artificial	<ul style="list-style-type: none"> Artificial channel with no natural origins Artificial flow and sediment regime Artificial bed and banks, floodplain may be absent 	Manage as artificial channel

Technical Support Document B: Management Intervention Selection Matrix

The [Management Intervention Selection Matrix](#) uses the channel typology outlined in Technical Support Document A as a basis for determining which management interventions are appropriate for use to achieve different functional objectives.

The matrix provides information for the following functions:

- flood risk management
- land drainage
- water resources
- fisheries
- nature conservation
- navigation
- recreation

For each function, the matrix provides guidance on the suitability of different techniques that can be used to implement the following management interventions:

- **No intervention**
- **Sediment management**
 - manage upstream erosion of sediments
 - manage in-channel erosion and deposition
 - restore channels
- **Vegetation management**
 - manage recruitment of debris
 - maintain conveyance
 - reduce chance of surface erosion
- **Debris management**
 - planned management of debris recruitment and transport
 - reactive debris removal

See [Technical Support Document C](#) for more details on each of these management intervention techniques.

Case studies

The matrix provides references to case studies relevant to specific management intervention options. These are given in Chapter 3 of the Channel Management Handbook.

How to use the matrix

Suitable management interventions can be selected using the following process:

- 1 • Use Columns A-C in the matrix to identify the correct channel type based on the geomorphologically based channel typology outlined in **Technical Support Document A**, Table A1.
- 2 • In Column D, identify the function(s) you need to manage the channel for.
- 3 • In the remaining columns, look up the management interventions you need to use. Each of the four main groups of interventions is divided into different types of intervention, which are themselves divided into different techniques.
- 4 • The matrix provides guidance on the applicability of each technique for each objective in each channel type. Each box is shaded according to a four-point scale (see key below).

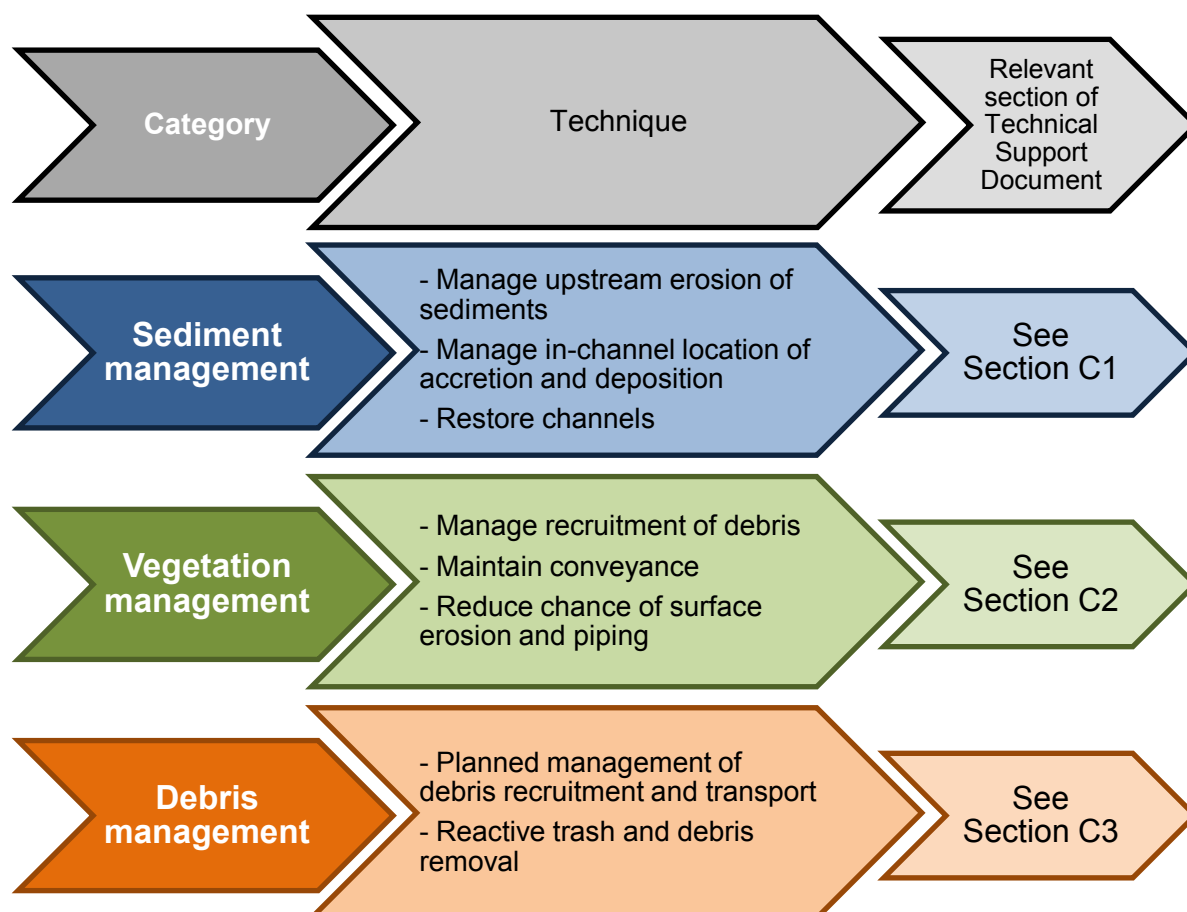
✓✓	Suitable for options consideration
✓	Requires investigation and discussion before considering as potential option
✗	Unlikely to be suitable for options consideration
-	Not applicable for channel type

The matrix provides a series of recommendations based on existing guidance and expert judgement for the type of interventions typically suitable for options to support different functions within each type of channel. These recommendations do not give a definite management option and should not be used as such. Instead the matrix provides a tool to encourage further investigation and discussion with relevant experts on a site-specific basis.

[Download the Management Intervention Selection Matrix](#)

Technical Support Document C: Management intervention options

This Technical Support Document describes a number of typically used techniques.



A short summary of each management category is provided within each section. This outlines when the need for the management type may be required and the aims of the overall management strategy.

An indication of potential costs is also given for each technique. Cost bandings are as follows:

- £ – low cost
- ££ – medium cost
- £££ – high cost

The respective techniques are sub-divided into measures to further detail the various potential management technique approaches available.

The information on each specific management technique is for reference only. Further information should be sought if the management technique is selected for implementation.

C1 Sediment management

Sediments are a natural part of aquatic systems. They are essential for the hydrological, geomorphological and ecological functioning of those systems. Sediment forms a variety of habitats, which directly and indirectly support a broad range of flora and fauna. Sediment may need to be managed for a number of reasons, including:

- sediment removal or deposition for flood defence purposes
- sediment removal and reinstatement for fisheries interest
- aggregate extraction
- land drainage

The **aims** of sediment management might be to:

- ensure environmentally acceptable methods for the disposal of dredged sediments, ensuring use for enhancement where appropriate
- manage sediment supply at source by putting in place agricultural best practice techniques
- reinstate sediment to:
 - increase the quantity and/or quality of spawning habitat for targeted species
 - reduce fine sediment deposition in spawning and/or rearing habitats
- prevent or control the distribution of contaminated sediments
- coordinate, monitor and manage activities which may affect sediment supply, removal and transport at a catchment scale through implementation of a dredging strategy

A sediment removal strategy will normally seek to:

- safeguard the geomorphology and biological diversity of surface water
- prevent unnecessary sediment removal
- ensure sediment removal deemed essential for navigation, flood risk management, water supply purposes, infrastructure protection and so on is performed in a coordinated and sustainable manner with minimal impact on biological diversity and natural channel processes

Section C1 covers the following overarching techniques:

- **C1.1 Manage the upstream erosion of sediments:** The over-supply of sediment from upstream sources (both rural and urban) can present a significant management issue in some channels. By managing sediment supply at source, sediment volumes in downstream channels can be reduced.
- **C1.2 Manage in-channel erosion and disposition:** It may be possible to actively manage in-channel sediments in cases where sediment removal is necessary to maintain a flood risk or land drainage function or would be of demonstrable benefit to ecology and geomorphology, and where sediment supply cannot be controlled. Management intervention should ensure appropriate approaches are taken to limit the impact of further sediment removal on hydromorphology and biology. It should also be carried out at an appropriate time to minimise impacts on channel ecology.
- **C1.3 Restore channels:** Restoring modified and enlarged channel systems following the ending of historical dredging activities (for example, for flood risk management and land drainage) forms an important component of modern approaches to channel management.

C1.1 Manage upstream erosion of sediments

Summary

Upstream erosion of sediments may be managed by the following measures.

- Develop management strategy.
- Implement best practice agricultural management techniques.
- Change the way land drains are managed.
- Install sediment traps.

Cost: £



Develop management strategy

This measure is concerned with ensuring that appropriate approaches are taken to limit the impact of further sediment removal on hydromorphology and biology in situations where sediment removal is deemed necessary.

In most cases it is recommended that sediment is retained in the channel because it is an intrinsic part of the functioning of the river system, contributes to diverse channel morphology, and provides vital habitats for aquatic organisms. Policy statements by the Environment Agency and SEPA state that, in general, there is a presumption against sediment management. However, individual situations and site-specific conditions may necessitate sediment manipulation. In cases where sediment removal is necessary to maintain channel function or would be of demonstrable benefit to ecology and geomorphology, and where sediment supply cannot be controlled, it may be possible to actively manage in-channel sediments.

This measure is relevant to all channels, including both the gravel bedded ones and those with mixed bed substrates.

The approaches described in relation to sediment removal are relevant to rivers where sediment removal is deemed necessary. Since sediment removal is not a sustainable practice in the long term, the justification for sediment removal should be reviewed and examined in detail before proceeding. Before removing sediment, consideration should be given to whether the sediment present in the channel is having a significant impact on the conveyance or preventing achievement of the channel's functional objective(s). To minimise or avoid the need for sediment removal, it is recommended that investigations are made into upstream sediment sources that may be the source or contributing to the problem.

Good practice management of in-channel sediments can help by:

- allowing the development of sediment-related features that occur naturally in alluvial channels – such features help to provide a range of flow velocities, flow depths and substrates and hence a diversity of habitats within a channel
- limiting sediment removal and reinstating sediments where they have previously been removed – can assist recovery of more natural channel morphology and provide more diverse bed conditions and habitats on which macrophytes, invertebrates and fish depend
- ensuring that, where sediment removal is deemed necessary, use of approaches that are more sensitive to the need to work with channel systems can be used to reduce the degree to which natural processes are disturbed and the time that the system takes to recover
- improving water quality status, for example, through the oxygenation of water over riffles and reducing the re-suspension of fine sediment that can cause turbidity and spread of sediment-bound contaminants downstream

Good practice management of in-channel sediments can also bring about a number of other benefits. For example, limitation of sediment removal may result in significant cost savings when carrying out channel maintenance and disposal of sediments removed.

References and further reading

- [Fluvial Design Guide](#)
- [Dredging Pilot Studies](#)
- [Rivers, Sediment and Habitats](#)
- [Sediment Matters: A Practical Guide to Sediment and its Impacts in UK Rivers](#)
- [Rural Sustainable Drainage Systems](#)
- [Evidence: Impacts of Dredging \(PDF, 321 KB\)](#)
- [RESTORE Healthy Catchments – managing for flood risk and WFD](#)

Implement best practice agricultural management techniques

If it is difficult or impossible to control the source of the sediment, the pathways of run-off and erosion can still be managed. Methods for this include:

- grassed areas in corners of fields to slow down overland flow or collect run-off
- low embankments to create bunds to trap water
- blocking gullies or grips

Planting and using hedges can be very effective in slowing flows and can be used to pond water, creating a small storage area. The hedges act along the pathway of the flow. Ideally they should be perpendicular to the flow where the flow can be effectively 'checked' and stored in small amounts. Sediment run-off is checked and dropped out behind the hedge

Benefits for agricultural landowners include:

- financial incentives for farmers through Entry Level Stewardship (ELS) for environmentally friendly land management that supports healthy soil and water
- release of wildlife potential in farms within less productive areas
- helps to restore characteristic communities of flora
- improved feeding habitats for birds

Change the way land drains are managed

It is possible to amend or enhance structures used for drainage purposes, or operational processes, to limit flow that may cause erosion or sediment issues.

Install sediment traps

As an alternative to the direct removal of fine sediments from the channel bed, it may be possible to install sediment traps to collect fine sediments for subsequent removal. This technique avoids the need to dredge long lengths of channel and thus has a considerably reduced impact on channel morphology and ecology. There are a wide variety of different traps that can be installed depending on the amount of sediment that needs to be controlled and the size of the watercourse.

Silt traps, which consist of an area of lowered bed within the channel in which sediment accumulates preferentially, are recommended for use on drainage channels of all sizes. An existing pool or slack water area can be enlarged to reduce flow velocities and encourage fine sediments to accumulate. Material can then be physically removed from this area, reducing the sediment load of the watercourse while minimising the size of the dredging footprint. Sediment needs to be removed regularly to prevent the material being resuspended and this technique is unlikely to be suitable for application in channels with rapid flows.

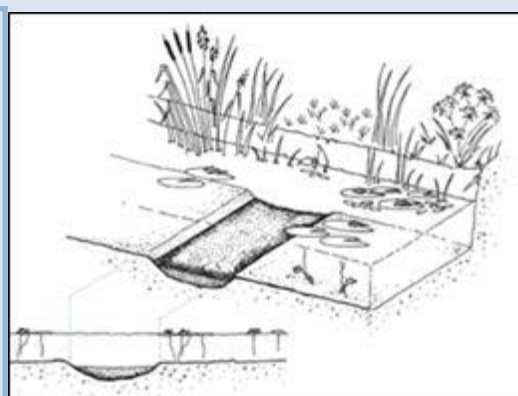
Alternative options

Wooden sediment traps:

- Impound flows and encourage sediment deposition
- Wide range of potential designs
- Generally only suitable for application in small watercourses

Straw bales:

- Cheap to install
- Can be used to trap both fine and coarse sediments
- Can be removed alongside sediments once they are full
- Generally only considered suitable for short-term use



A silt trap in the bed of a drainage channel
©Association of Drainage Authorities and Natural England

References and further reading

- [The Drainage Channel Biodiversity Manual: Integrating Wildlife and Good Risk Management](#), Association of Drainage Authorities and Natural England, 2008
- [Waterways and Wetlands: A Practical Manual](#), British Trust for Conservation Volunteers, 2003
- [Best Practice Erosion and Sediment Control](#), International Erosion Control Association Australasia, 2007

C1.2 Manage in-channel location of accretion and deposition

Summary

In-channel accretion and deposition may be managed by the following measures:

- Appropriate management of bed and scour
- Direct removal of sediment
- Install sediment traps
- Install detention basins
- Conduct sediment management at an appropriate time

Cost: £££



(©Healthy Catchments guidance)

Appropriate management of bed and scour

A wide range of soft engineering techniques have been successfully applied for bank stabilisation.

Soft engineering techniques can be applied to three different types of design categories:

- **Bioengineered:** Designs that rely wholly on plants to provide stability and protection from erosion. Examples include coir pallets, coir rolls and facines.
- **Biotechnical:** Designs that use hard techniques to provide structural support for plants or live bioengineered products. Examples include rock rolls to support coir rolls and reinforced vegetated geotextiles. They can also be referred to as composite or hybrid designs.
- **Biostructural:** Those designs that have a hard structure with a soft face such as vegetated gabions.



Pre-planted coir rolls used in an urban river enhancement project.
(©Royal HaskoningDHV)

Useful design guidance on soft bank face protection techniques is given in:

- [Good Practice Guide for Bank Protection: Rivers and Lochs \(SEPA Good Practice Guide WAT-SG-23\)](#)
- Waterway Bank Protection: A Guide to Erosion Assessment and Management (Environment Agency, 1999)
- [Environmentally Sensitive Channel and Bank Protection Measures](#), US Transportation Board National Cooperative Highway Research Program (NCHRP) Report 544
- [Estuary Edges: Ecological Design Guidance](#)

Practical examples of the application of these techniques can be found in the River Restoration Centre's [Manual of River Restoration Techniques](#).

Direct removal of sediment

The critical question here is whether sediment removal is appropriate.

The River Sediments and Habitat's R&D developed three overarching founding policy-related premises in relation to assessing whether sediment removal is appropriate:

- a. There is a general presumption against the removal of sediment for a watercourse.
- b. The justification to move or remove sediment should be based on evidence and understanding.
- c. When removal of sediment is found to be justified, best practice must be used to carry out the necessary work to minimise adverse effects on the environment.

The SEPA (2006) *Position Statement to support the implementation of the Water Environment (Controlled Activities) (Scotland) Regulations 2005 – Sediment Management* also provides a useful framework for assessing when the removal and active management of in-channel sediments is likely to be justified:

- **Bridge or culvert maintenance:** Strong justification for removal where the function or integrity of the structure could be compromised. A more sustainable solution should be sought if recurring works are likely to be necessary:
- **Removal behind impounding structures:** Potential justification for removal if sediment accumulation disrupts the efficient operation of the impoundment. The potential impacts of reducing sediment supply in this manner should be considered.
- **Flood management:** Potential justification for removal if there is a demonstrable link between in-channel sedimentation and flood risk. A more sustainable solution should be sought if accumulation is a long-term problem. Potential for scour during floods should be considered before removal is undertaken.
- **Habitat works and fisheries improvements:** Potential justification if an underlying sediment issue is identified (for example, at the reach scale) and is addressed as part of a wider catchment remediation strategy, or where wider improvements to the channel and the ecology it supports can be demonstrated. Works targeted at a single reach are unlikely to be justified, as are actions where an underlying sediment issue has not been demonstrated.
- **Aggregate extraction:** Potential justification for small-scale removal where resources are abundant and habitats are insensitive to sediment removal. The effects of sediment removal on the sediment budget of the channel and the use of

alternative sources that are not directly linked to the channel should be considered.

- **Land drainage:** Unlikely to be justified in natural watercourses. May be justifiable in minor watercourses that have been routinely managed for drainage purposes in the past. Alternatives such as control of sediment sources or channel restoration to restore natural sediment conveyance should be considered on larger watercourses.
- **Removal of gravel for use as bank protection:** Unlikely to be justified, since it can cause considerable disturbance to the channel. Alternative options which do not disturb the substrate should be considered.

Sediment management should not be carried out unless there is clear evidence suggesting it is needed. The reasoning behind the decision must be clear and justified. This requires the decision to be objective and evidence based.

A standard approach to aid decision-makers to come to reasoned and sound justification has been proposed and articulated in a set of 'Guiding Principles'. This set of Guiding Principles has been generated by the River Sediments and Habitats R&D project. This is a systemic approach to the assessment of the needs, methods and feedback from sediment-related activities and provides a step by step guide to ensure maintenance activities are sustainable:

Six guiding principles for sediment management in watercourses

1. Identify why you are considering action.
2. Understand the sediment-related issues and identify their causes.
3. Identify and prioritise the watercourse's function(s).
4. Identify and appraise possible management options based on risk.
5. Balance the multiple goals of watercourse management.
6. Inspect and appraise the performance of management options with respect to prioritised functions.

Install sediment traps

See [Section C.1.1](#).

Install detention basins

A detention basin is an enlarged area of channel characterised by low velocity flows and sediment accumulation. The technique uses the same principles as the sediment trap, but is typically much larger and used on a natural channel with greater flow variability. Detention basins generally incorporate a flow control structure such as a small weir, slot or gates, which creates a pool upstream. The pool is frequently excavated to create a larger detention basin. These structures can be used to control both fine and coarse sediments, and are periodically emptied to maintain their effectiveness.

Installation of sediment detention basins is only recommended once detailed investigations have been made into:

- alternative sediment control measures
- impacts on channel morphology and sediment regime

- potential mitigation to offset the potential effects of sediment starvation on the channel and in-channel habitats downstream of the structure

References and further reading

- [Stream Habitat Restoration Guidelines \(PDF, 23.3 MB\)](#) (Technique 13), Washington State Aquatic Habitat Guidelines Program, 2004

Conduct sediment management at an appropriate time

Sediment does not accumulate in a channel at a steady rate. The transport of sediment depends in a highly non-linear way on the flow velocity. This means that significantly more sediment is transported in floods than during low flow periods. Since the need for removing sediment from a given reach may not occur at regular intervals, removal therefore must depend upon the observed condition of the channel rather than on a fixed temporal programme of maintenance activities.

C1.3 Restore channels

Summary

Channel restoration can be managed by the following measures:

- Gravel augmentation
- Creation of new gravel features
- Bed raising
- Gravel cleaning
- Encourage natural recovery

Cost: £££



Gravel augmentation

Gravel augmentation, also known as gravel seeding, injection or replenishment, seeks to replenish a proportion of a regulated channel's sediment budget deficit with imported sediment. This is typically achieved by pumping clean spawning gravels into the channel at locations upstream of degraded spawning habitat reaches (for example, just downstream of a weir or dam). It is assumed that augmented gravels will be entrained during high flows with the competence to transport them downstream.

Important considerations and constraints are summarised in Table C1.

Table C1: Important factors when considering gravel augmentation

Key considerations	Key constraints
<ul style="list-style-type: none"> Type, shape and grain size distribution of the gravel material to be used and its potential mobility If possible, gravels added to the channel should be as close to the natural sediment characteristics as possible to preserve or reinstate the geomorphological functionality of the watercourse and provide the same range of habitats. It may be possible to use sediments from dredged material where this has been deposited along the channel bank. More frequently, however, it is likely that additional material will need to be imported and carefully selected on the basis of its size and angularity. 	<ul style="list-style-type: none"> It does not replace natural sediment supply and is therefore unlikely to be sustainable over the long term. An adaptive management approach is therefore recommended to ensure that the correct activities are targeted at the appropriate locations to deliver maximum benefits for the channel and the habitats it supports.

Designs are rarely necessary for gravel augmentation, but a sediment budget and a monitoring programme to enable adaptive management are appropriate.

If the mobility of the gravel is to be limited to prevent rapid downstream transport, it can be slightly oversized to discourage downstream transport. However, this needs to be carefully considered in terms of the geomorphological functioning of the channel and the potential impacts on sensitive habitats such as spawning gravels.



References and further reading

- [Gravel Mitigation and Augmentation below Hydroelectric Dams: A Geomorphological Perspective \(PDF, 2.56 MB\)](#) US Department of Agriculture, Forest Service, 2004

Several case studies demonstrate the implementation of gravel augmentation including along the River Chess ([Manual of Restoration Techniques, Project 3.9 \(PDF, 1.82 MB\)](#)), River Restoration Centre, 2012) and the River Glaven ([Chalkstream Habitat Manual, Gravel rehabilitation/restoration \(PDF, 3.67 MB\)](#), Wild Trout Trust, 2008), where gravel augmentation was combined with the use of large woody debris.

Creation of new gravel features

Creation of new gravel features through the placement of gravel differs from gravel augmentation in that the augmented gravels are placed as specific bed features (typically riffles or bars), potentially providing immediate spawning habitat. Placed gravels are intended to reduce local depth and to increase velocity to better match observed spawning preferences. Although bed enhancement may quickly provide usable spawning habitat, limited project lifespans may result without adequate consideration of geomorphic processes.



Bed raising

In channels that have been extensively dredged, resulting in over-deepening of the channel, it is possible to reinstate a proportion of the removed sediment to raise the bed and reduce the size of the channel. This has been successfully achieved in the Lymington River catchment in the New Forest, where a mixture of gravels and finer sediments originally derived from the channel was used to raise the bed of 1.56km of river channel (New Forest Life Partnership, 2006).

References and further reading

- [Sustainable Wetland Restoration in the New Forest: Final Technical Report \(PDF, 510 KB\)](#), New Forest Life Partnership, 2006

Gravel cleaning

Gravel cleaning involves the removal of fine sediment from within existing gravel bed features. The Wild Trout Trust's [Chalkstream Habitat Manual](#) describes a number of methods of carrying out gravel cleaning including mechanical cleaning, gravel washing and use of a 'mud' engine.

Although these methods can help to clean gravels in the short term, they do not address the cause of siltation over the gravels, which is likely to reoccur. It is more appropriate to tackle fine sediment issues at source.

Encourage natural recovery

Where gravel sourcing and transport downstream is still naturally occurring within the wider catchment, it may be possible to encourage natural recovery within mixed and gravel bedded channels through stopping sediment removal. The potential for this may be limited by several factors including upstream sediment supply, stream power, transportability of bed and bank materials, and existing channel modification. However, the ideal situation is that the system becomes self-regulatory once again, avoiding the need for further intervention.

C2 Vegetation management

Vegetation is a natural part of channel ecosystems providing shade and cover; promoting bank stability; enhancing physical in-channel features; providing an input of woody debris; filtering sediment and serving as a source of nutrients to support fauna and flora. Management of vegetation in and alongside watercourses is currently undertaken for a range of purposes including agriculture, recreation and flood risk management. Where management is required to maintain the use of the channel, good practice vegetation management measures promote activities which support diversity of vegetation, allow natural regeneration and prevent the spread of non-native, invasive species.

Section C2 covers the following overarching techniques:

- **C2.1 Manage recruitment of debris:** Vegetation growth on the banks of a channel can be a significant source of debris including fallen leaves, dead stems and fallen branches. Once entrained in the channel, this can accumulate and cause a blockage.
- **C2.2 Maintain conveyance:** Dense growth of vegetation in a channel can reduce conveyance, reduce flow energy and promote sedimentation. It may therefore be necessary to control growth so that functional objectives can be achieved.
- **C2.3 Reduce chance of surface erosion:** Vegetation plays an important role in stabilising channels and reducing the erosion of the channel banks. It also helps to reduce sediment input from catchment sources by intercepting surface run-off. Vegetation must therefore be managed carefully to avoid changes to the sediment regime as a result of over-management.

References and further reading

- [Aquatic and Riparian Plant Management Guide](#)
- [The Drainage Channel Biodiversity Manual: Integrating Wildlife and Good Risk Management](#), Association of Drainage Authorities and Natural England, 2008
- [HSE Chemicals Regulations Directorate's guidance on pesticides](#) (www.pesticides.gov.uk/guidance/industries/pesticides)
- [Code of Practice for Using Plant Protection Products \(PDF, 3.05 MB\)](#), Defra and others, 2006
- [Environment Agency's Protocol for the maintenance of flood and coastal risk management assets \(England only\)](#) Environment Agency, 2013
- [Government guidance on Japanese knotweed, giant hogweed and invasive plants](#) (www.gov.uk/japanese-knotweed-giant-hogweed-and-other-invasive-plants)
- [Using herbicides](#) (<http://naturalresourceswales.gov.uk/apply-and-buy/water-licences-discharges/using-herbicides/?lang=en>)
- [Riparian Vegetation Management \(SEPA Good Practice Guide WAT-SG-44\)](#)
- [The Herbicide Handbook: Guidance on the Use of Herbicides on Nature Conservation Sites](#), English Nature, 2003
- [Woodland for Water: Woodland Measures for meeting Water Framework Directive Objectives](#), Forest Research, 2011

C2.1 Manage recruitment of debris

Summary

The recruitment of debris can be managed by the following measures:

- Good practice approaches to cutting and clearance
- Use of herbicides
- Tree management

Cost: £



Good practice approaches to cutting and clearance

Cutting emergent vegetation involves removal of marginal vegetation that grows above the water line but it may have its roots in the water. The emergent or marginal vegetation usually grows on the edges or margins of the channel and on the banks.

Cutting is carried out during the late summer/autumn months to increase the conveyance of water in the channel by:

- removing some of the blockage that vegetation can cause
- reducing the channel roughness



It is usually possible to leave some or all of the emergent vegetation without compromising the required conveyance capacity of the channel.

The cutting or management of emergent vegetation must also consider the impacts of the activity upon ecology and hydromorphology. The application of sensitive cutting techniques can reduce or avoid adverse impacts on the environment and can capitalise on opportunities to benefit wildlife through habitat enhancement. As good practice management techniques are based on an understanding of channel processes and work towards maintaining or returning a channel to a more natural condition, the need for future engineering works will be reduced along with the associated costs.

The [Aquatic and Riparian Plant Management Guide](#) and the [Drainage Channel Biodiversity Manual](#) include a range of guidance sheets for the maintenance of emergent vegetation. Extensive guidance is provided on the selective removal of aquatic plants to permit re-colonisation of desirable species.

Recommendations and considerations

It is important to choose the timing and extent of vegetation cutting to benefit flood risk, birds and fish due to potential regrowth from roots and rhizomes, but also because of the potential impact to breeding birds and aquatic invertebrates.

Autumn cutting is recommended over summer mowing as it:

- avoids the breeding bird season
- maintains abundance and diversity of species
- provides invertebrates with food and shelter

This option may involve a number of techniques including machines that work from the bank with weed cutting buckets, hand cutting and herbicides.

Before using machinery around watercourses, it is important to consider:

- the timing of works
- the type of machinery used
- the operating skills required for the task

Machines working from the bank tend to be more selective than those working from the channel. However, they need access along the bank which can be a major limitation in more natural or urban areas. Machines working from the channel have less of an issue with access and the operator is in a better position to locate nests and avoid destroying them. However, their use is seasonal and they are not suitable for any other tasks.

Use of herbicides

Herbicides should not be used without first contacting the appropriate regulatory authority. Their use is restricted and should be considered carefully in consultation with the authority. Spot treatment or preventing a vegetation problem by correct management and early remedial action is preferable to widespread herbicide use to control a problem.

Further advice on the use of herbicides is given in:

- [Aquatic and Riparian Plant Management Guide](#)
- 'The New Rivers and Wildlife Handbook', RSPB, 2001
- [Riparian Vegetation Management \(SEPA Good Practice Guide WAT-SG-44\)](#)

Guidance is also provided in the following documents:

- [The Herbicide Handbook: Guidance on the Use of Herbicides on Nature Conservation Sites](#), English Nature, 2003
- [Agreement to Use Herbicides in or near Water. Guidance Notes \(PDF, 326 KB\)](#), Environment Agency, 2010

Tree management

Trees should be retained where possible as they provide structural support to the channel sides. Where management is required, coppicing or pollarding (cutting to encourage regrowth from the stump) should be considered before complete removal which is always a last resort option. These methods reduce excessive shading without removing the stabilising effect of the stump and roots.

Coppicing and pollarding need to be performed as part of a regular maintenance regime to maintain growth.

Selective tree thinning should be carried out as part of the management strategy for a watercourse.

All tree works should be carried out by trained staff during the winter months to avoid adversely affecting nesting birds.

Guidance on tree management options is provided in:

- [Riparian Vegetation Management \(SEPA Good Practice Guide WAT-SG-44\)](#), pp. 31-36
- 'The New Rivers and Wildlife Handbook', RSPB, 2001, pp. 274-281

The advice covers coppicing, pollarding and thinning.

C2.2 Maintain conveyance

Summary:

Conveyance maintenance may be managed by the following measures:

- Selective management of in-channel, marginal and emergent vegetation
- Use of herbicides

Cost: ££



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Selective management of in-channel, marginal and emergent vegetation

Good practice management of in-channel vegetation refers to works or maintenance practices (for example, macrophyte cutting) carried out in a manner that considers the impacts of the activity on ecology and hydromorphology.

The application of sensitive techniques can reduce or avoid adverse impacts on the environment. It can also capitalise on opportunities to benefit wildlife through habitat enhancement.

As good practice management techniques are based



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on an understanding of channel processes and work towards maintaining or returning a channel to a more natural condition, the need for future engineering works will be reduced along with the associated costs.

Diverse and well-structured aquatic vegetation provides excellent habitat for invertebrates and other wildlife. However, if one species becomes dominant, it can block waterways and suppress the growth of other species. In such cases, management is desirable but there are many factors to consider before carrying out works such as when and how to carry out control, and how much vegetation to remove.

Other factors that should be considered include:

- the threat to nesting birds and fish spawning
- shading of open waters
- disposal of cuttings
- the need for repeated cutting throughout the growing season
- the risk of flooding to people and property under various management scenarios

Further considerations

- Broader ecosystem considerations should be built into any plan at the design stage, as species that rely on the water environment can be vulnerable at different times of the year. For example, autumn removal of vegetation can reduce overwintering habitat for invertebrates while summer weed cutting can reduce fish habitat. An integrated approach to management of the wider system over the longer term is likely to provide the maximum potential both for biodiversity as well as for the management aims.
- Timing of cutting is important due to potential regrowth from roots and rhizomes, but also because of the potential impact to breeding birds and aquatic invertebrates. As a general rule, submerged plants should be cut in summer and emergents cut in autumn.
- Cutting should be accompanied by collection and removal to avoid blockages of downstream structures such as culverts and deoxygenation of water.
- Large quantities of cut vegetation should not be left on the bank as bankside plant communities can be smothered and die.
- When silt accumulates around aquatic vegetation, de-silting (using a mechanical excavator) restores channel capacity more efficiently than cutting. As with cutting, alternate lengths can be de-silted and left untouched, allowing rapid recolonisation of aquatic plants and invertebrates.
- Before using machinery around watercourses, it is important to consider the timing of works, the type of machinery used and the operating skills required for the task. Machines working from the bank tend to be more selective than those working from the channel, but they need access along the bank which can be a major limitation in more natural or urban areas. Machines working from the channel have less of an issue with access and the operator is in a better position to locate nests and avoid destroying them. However, their use is seasonal and they are not suitable for any other tasks.

Use of herbicides

See [Section C.2.1.](#)

C2.3 Reduce chance of surface erosion

Summary:

In-channel accretion and deposition may be managed by the following measures:

- Introduction of buffer strips
- Selective management of riparian vegetation
- Controlled grazing regime

Cost: £



Introduction of buffer strips

Buffer strips refer to the vegetated riparian zone between a watercourse and adjacent land. They may consist of trees, wetland, scrub or grassland. Buffer strips protect water quality by trapping sediments and breaking down pollutants before they reach the watercourse. They can easily be created through the establishment of fencing to separate them from adjacent land use, particularly grazing livestock.



Section 3.3 of the [Riparian Vegetation Management \(SEPA Good Practice Guide WAT-SG-44\)](#) provides a detailed methodology for the design of buffer strips including minimum widths.

Selective management of riparian vegetation

Good practice management of riparian vegetation involves sensitively managing existing riparian vegetation to achieve management aims such as bank protection or flood control. When carried out sensitively, the ecological value of the riparian zone can be greatly enhanced.

Riparian vegetation occurs on the top or face of the channel bank and marginal vegetation refers to emergent aquatic macrophytes.



Within watercourses there are many different types of marginal and riparian vegetation which can be managed in a wide range of ways for a range of different reasons. The purpose for management should be clearly defined so that unnecessary action to remove or

reduce vegetation is avoided. If some intervention is needed then the benefits of the activity should be clearly identified in objectives of undertaking the work. A management plan may be of use.

Good practice management of riparian vegetation can help by:

- preventing dominant species out-competing other species, thereby increasing plant diversity and habitat diversity
- encouraging the development of native plant assemblage which provides more suitable habitat for native invertebrates
- improving water quality by increasing the buffer between land and channel, allowing sensitive species of macrophyte and invertebrate to survive
- providing fish with shelter and spawning habitat through the creation of diverse and well-structured marginal vegetation
- reducing bank erosion through the stabilising effect of the root structure and protecting the channel from the direct force of flow by plant biomass

Marginal vegetation can encourage the deposition of sediments and the formation of side bars, which can help to restore the natural functioning of the channel (provided excessive sedimentation is not an issue). Such processes increase channel and flow diversity, giving rise to greater habitat and species diversity.

Good practice management of riparian vegetation provides a number of other benefits. Some examples are given below.

- Well-managed bankside vegetation provides cover and foraging habitat for water voles, otters (a European protected species), terrestrial invertebrates and waterbirds.
- The riparian zone tends to be continuous and so can provide a valuable wildlife corridor linking fragmented or isolated habitats.
- Vegetation management is also likely to result in an improvement in visual amenity and public enjoyment of watercourses.
- Banks protected by well-structured vegetation are likely to require less maintenance and repair.
- The presence of well-established native vegetation helps to reduce the opportunities for undesirable invasive species to become dominant.
- The increased hydraulic roughness provided by bankside vegetation can help to slow flood flows thereby reducing flood risk downstream.

Before starting on a particular maintenance regime, it is important to consider whether riparian vegetation management is necessary. Excessive vegetation growth may be seasonal or temporary, and given time, 'normal' vegetation may naturally re-establish. Watercourses that have little or no open water in mid-summer due to aquatic vegetation growth do not necessarily need any management. The water margins and vegetated shallows are a far more valuable habitat than is open water. Where management is deemed necessary, complete removal of a particular species or clearance of a certain area is rarely possible and often harmful. In nearly all cases, rotational management of different areas

over a period of years is more effective than total clearance in creating a balanced environment.

Guidance on vegetation management methods is given in:

- [Aquatic and Riparian Plant Management Guide](#)
- Chapter 14 of the [Waterways and Wetlands: A Practical Manual](#)
- 'The New Rivers and Wildlife Handbook', RSPB, 2001
- [Riparian Vegetation Management \(SEPA Good Practice Guide WAT-SG-44\)](#)

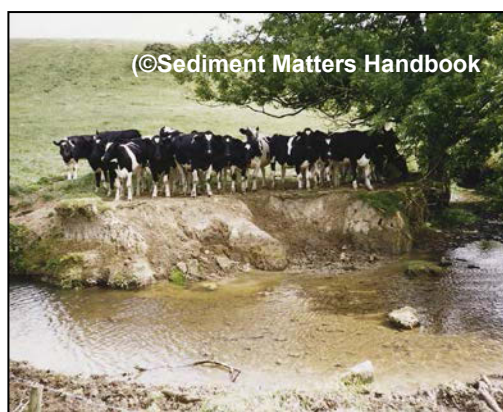
The method employed to control bankside vegetation is important and depends on the management aims and the required outcome. Grazing, mowing and herbicides are common methods used for this purpose, but their impact on wildlife can be very different.

More information on slope stability and engineering good practice for vegetation management can be found in '[Vegetation Management for Slopes](#)' from the Canal and River Trust.

Controlled grazing regime

Grazing is an environmentally sensitive approach to vegetation control. It is a widespread and valuable tool that benefits wildlife as well as flood defence. Low intensity grazing on grassland with no additional inputs can benefit wildlife and can be cheaper than cutting by machinery or by hand, especially on wet sites.

Timing and intensity of grazing is critical, as is the choice of livestock. If a site requires summer grazing, cattle should be used. Stocking before July is undesirable, especially in sites good for ground nesting birds. Livestock densities must be managed to ensure that overgrazing does not occur.



The aims of grazing should be to:

- graze at a level that allows banks to be inspected
- reduce the dominance of grasses
- encourage plant richness and habitat structure for invertebrates and birds

Overstocking will adversely affect the quality and structure of the sward, thereby reducing wildlife interest.

More advice on judicious grazing management is provided in:

- 'The New Rivers and Wildlife Handbook', RSPB, 2001, (pp. 256-257)
- Section 4.1 of the [Riparian Vegetation Management \(SEPA Good Practice Guide WAT-SG-44\)](#), pp. 25-26

C3 Debris management

Activities carried out to manage debris aim to change the way in which channel blockages operate to reduce the impacts these have on:

- flow patterns
- the way sediment is transported and deposited
- the upstream and downstream movement of fish and other aquatic organisms



Section C3 covers the following overarching techniques:

- **C3.1 Planned management of debris recruitment and transport:** Strategic management can help to prevent blockages impacting on the functional objectives of a channel. A number of management techniques can be used to minimise the risks of impacts occurring as a result of blockages. These can be performed in a strategic and planned way.
- **C3.2 Reactive trash and debris removal:** In addition to planned debris management, unplanned management is often necessary in response to unexpected of debris in a channel (for example, due to tree falls or fly-tipping). Removal methods will depend on the access and type of debris and trash. Its components as well as the associated health and safety issues will dictate the method of removal. Typical methods vary from use of hand and mechanical equipment like shovels, weed rakes, mechanical grabs and winches to automatic weed-screen cleaners.

Summary:

Debris can be managed by the following measures:

- Increase the size of in-channel structures
- Install trash screens
- Install boundary protection measures
- Adopt wider catchment management techniques
- Use sensitive management techniques
- Retain some debris in channel

Cost: £–£££



C3.1 Planned management of debris recruitment and transport

Increase size of in-channel structures

In many instances, culvert removal may not be practicable (for example, where a culvert flows beneath existing infrastructure) and modification of the culvert may be the only form of possible mitigation. Changes to the conveyance and risk of flooding will determine the extent to which measures can be implemented within a culvert.

It is important to ensure that the treatment of inlet and outlet structures does not block flow from entering or exiting the culvert, or have the potential to do so. As with other obstructions, a simple solution is to install a weir downstream of the outlet. This can be used to mitigate perching and to improve the water depth in the culvert. Any such structure should be located far enough downstream of the outlet so as not to encourage sediment or debris deposition within or close to the culvert. Low weirs can be constructed of stone or other materials. They should have head drops of not more than 0.3 m (ideally 0.1–0.2 m for coarse fish passage) and be not less than 6 m apart if possible. Where necessary, notches should be provided to ensure a sufficient width and depth in which fish can traverse the weir. Depth below the traverse should be at least twice the head drop. The most downstream structure should be flush with the channel bed to help prevent erosion. A series of such weirs can be installed

over a length of the downstream channel depending on the overall head difference that is to be overcome.

CIRIA's [Culvert Design and Operation Guide](#) covers the design and operation of culverts from conception to decommissioning, encompassing the whole life cycle of an infrastructure asset.

Install trash screens

A properly designed screen can reduce or even eliminate the possibility of debris blockage or unauthorised access. However, screens themselves can cause severe problems, most notably local flooding upstream due to blockage of the screen. It is therefore essential that all practical alternatives are investigated and eliminated before making the decision to provide a screen. There should be a presumption that all screens will block eventually, some often. Unless they can be reactively cleared in a timely manner they should be avoided as they will increase flood risk in these locations.



Where screens are installed within channels with a high chance of blockage by debris, it is good practice to provide measures further upstream of the screen to trap and remove larger debris before reaching the screen.

Approval is unlikely to be given unless the promoter of the screen can demonstrate that all other options have been explored and rejected as impracticable. Any application for approval therefore needs to be supported by evidence that a credible investigation of alternatives has been carried out. Justification may take the form of a benefit–cost assessment in which all the costs and benefits are evaluated over the whole life of the screen. In the case of a security screen, the emphasis may shift away from a simple economic analysis but, even so, it is essential that the justification is clear and the economics investigated so that the initial investment and long-term costs are understood and accepted.

Screen construction and gap size

Screens should be constructed from square, oblong, or wedge wire section materials. Round section materials, which more easily lead to gilled and trapped fish, should not be used.

Where security is an issue, the guidelines recommended free gap in the screens is ≥ 75 mm to ≤ 150 mm. The gap should be a minimum of 75 mm because of the increased risk of blockage with smaller gaps. Generally a gap of 150 mm is regarded as sufficient to exclude children, although in areas of very high risk, it might be considered appropriate to reduce this. Where occasional horizontal bars are used on vertical screens, they should be spaced at least 400 mm apart.

Where security is not an issue and it is simply a case of protection from waterborne debris, the free gap used for screens should err on the generous size and not be limited to the minimum gap specified above. Thus, the size of free gap employed in the screen should be 250–300 mm.

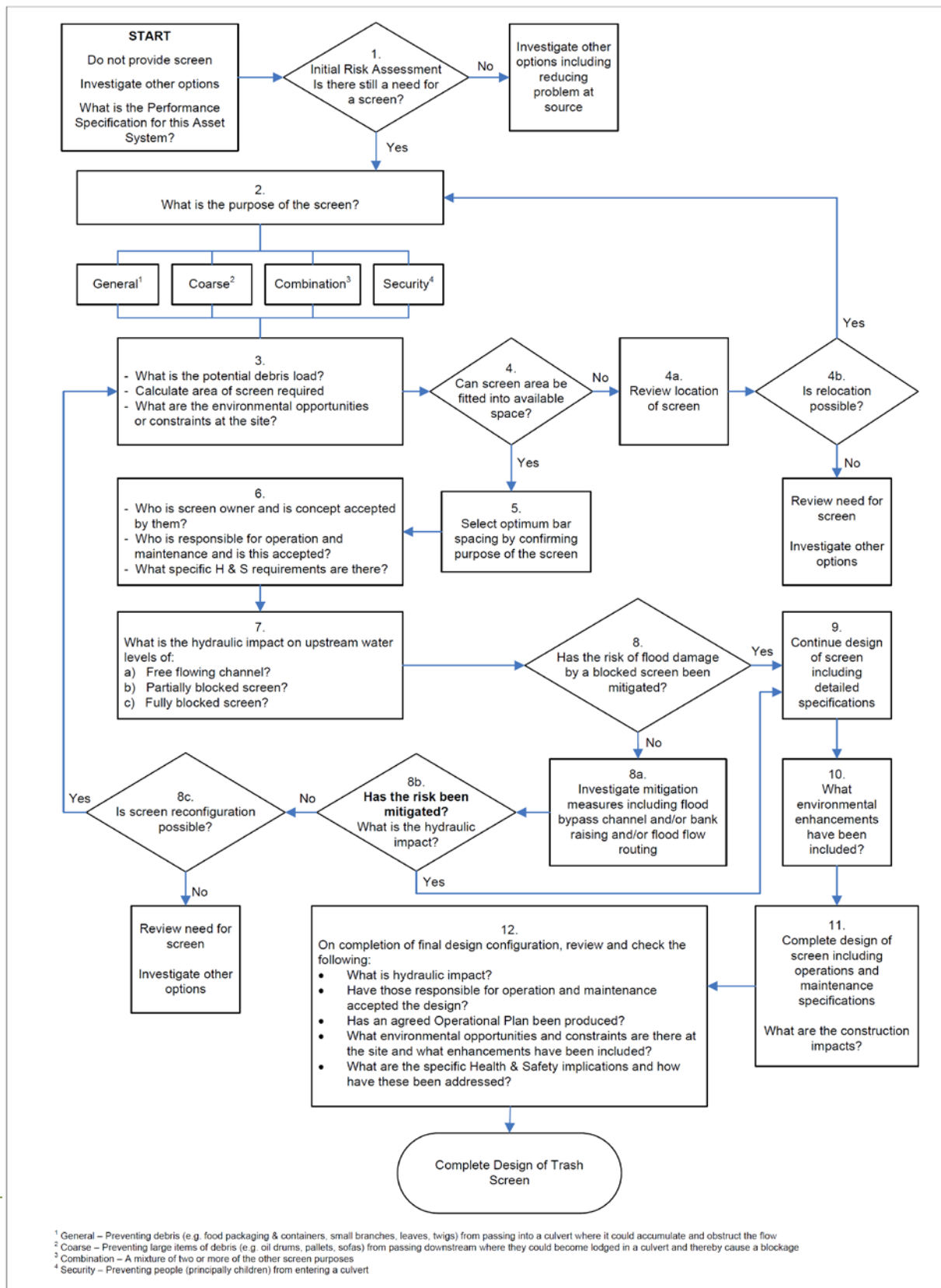
Best practice for the design and installation of screens is detailed in the [Trash and Security Screen Guide](#) (Environment Agency, 2010).

Figure C1 illustrates:

- the step-by-step approach required to assess the need for a screen
- the stages at which various levels of justification are required
- the processes to be completed in the subsequent design

Figure C1: Flow chart to consider requirements for a new trash or security screen

Source: [Trash and Security Screen Guide](#) (Environment Agency, 2010, p. 12)



Install boundary protection measures

Fencing can be used effectively where the sediment or debris is likely to enter the watercourse. The fencing is used to prevent or control livestock from poaching the bank. Poaching of a channel bank by grazing animals can create significant erosion and decrease bank stability.

The fencing should be as far away from the bank as possible. Locating the fence parallel to the water flow reduces:

- the obstruction to flood water
- debris collection

One or two stock access points can be provided to allow access for stock to the water – see the River Restoration Centre's [Manual of River Restoration Techniques](#).

Fencing can also help to prevent fly-tipping.



Adopt wider catchment management techniques

Adopting wider catchment management techniques helps to minimise debris recruitment and blockage formation. This could include:

- co-ordinated management of riparian vegetation to minimise the input of natural vegetative debris – see [Section C2.3](#) for more information on the selective management of riparian vegetation
- sequenced operation of in-channel structures to allow debris to pass downstream
- anti fly-tipping campaigns to minimise recruitment of urban debris, for example, education of the local community and riverside residents through informational flyers and community days such as those provided by the waterway charity, Thames21.

Use sensitive management techniques

See 'Selective management of in-channel, marginal and emergent vegetation' in [Section C2.2](#).

Retain some debris in channel

Entire trees, branches and roots that have fallen into watercourses are commonly referred to as 'large woody debris' (LWD). LWD helps to create a healthy functioning freshwater ecosystem and should be retained as far as possible. The wood can span the width of the channel to accumulate into debris dams. LWD can change the physical nature of, and flow in, the watercourse.

There are a number of different ways of managing LWD.

- Leave the LWD in place if there is no risk to flooding.



- Monitor the LWD to check it's not becoming a risk.
- Remove some of the wood to scale down the impact on water levels but retain the benefits of improved habitat – see below.
- Secure or reposition the LWD to make sure it doesn't drift downstream and block culverts or bridges.
- Remove all or most of the LWD if the impact on water levels creates a flood risk.

The benefits of this approach include:

- stabilises channel banks and beds
- reduces upstream velocities
- provides habitat for fish
- creates niche habitats
- increases floodwater storages upstream
- traps sediment upstream
- provides cover, space and food
- supports invertebrate communities

C3.2 Reactive trash and debris removal

Summary

Blockages can be managed by the following measures:

- Remote identification of blockages
- Mechanical removal techniques
- Manual removal techniques
- Retaining some debris in channel

Cost: ££



Remote identification of blockages

The recommended method for detecting screen blockages is to position water level monitors upstream and downstream of a screen with the data transmitted, normally by telemetry, to an operational centre.

- Under normal conditions, that is, when a screen is relatively free flowing with little debris build-up, the difference in the two water levels will be small.



- When the screen is blocked, there will be a greater difference in level between the upstream and downstream sensors. If the blockage remains, this difference will increase as the flow increases.

Alarms can be triggered by the increasing difference between the two water levels. Alarms can also be triggered by high upstream water levels alone.

Physical removal techniques (manual and mechanical)

It is essential that blockages are removed in a sensitive way to minimise unnecessary disturbance to the bed and banks of the channel.

Some blockages can be removed by hand. These techniques are most suitable for the removal of small blockages (typically woody debris or trash) from a channel or upstream of an in-channel structure such as a weir, sluice or trash screen, where there is safe access to do so. Manual techniques may require in-channel working and may therefore not be suitable for all channels.

Larger blockages may need to be removed using heavier equipment such as excavators or large vehicle-mounted winches. Care should be taken to ensure that:

- only the blockage itself is removed
- the in situ bed and bank sediment is retained in place

Although it may be necessary to completely remove trash from the channel, it may be possible to retain a proportion of sediment and woody debris while still reducing the risk of blockages occurring. For example, there should be a general presumption against removing all woody debris and coarse sediment from a channel, as these can frequently provide important wildlife habitats.

Retaining some debris in channel

See 'Retain some debris in channel' in [Section C3.1](#).

Technical Support Document D: Management considerations and governing legislation

This Technical Support Document details a number of important management considerations for when planning your channel management activities. Careful consideration needs to be given to a range of management factors such as:

- Is the watercourse is protected by a statutory designation, or are there priority habitats present?
- What fisheries interests or protected and priority species are supported by the watercourse?
- Does the management option require a WFD compliance assessment?

A full checklist of these management considerations is presented in Table D1. The table lists important factors to consider during the management process and the subsequent actions required if your system meets any of these highlighted aspects.

Work on watercourses has to be carried out within a framework of environmental and regulatory legislation which aims to prevent harm to both people and the environment. A good understanding of the legislation relevant to channel management is an essential prerequisite before you start to plan any channel management activity. You may have colleagues who can advise you, such as Biodiversity staff.

This Technical Support Document provides an overview of some of the critical management considerations, with links to relevant organisations and legislation you may need to consult. The information given draws heavily from a more extensive range of management considerations examined in the Technical Guide of the [Aquatic and Riparian Plant Management Guide](#).

Table D1: Management checklist

Consideration	Action required
Is the watercourse designated or does it flow into, through or out of a statutory designated nature conservation site?	If YES – contact Natural England or Natural Resources Wales. You may require consent.
Is the watercourse located adjacent to or within? a Scheduled Monument?	If YES – contact English Heritage or Cadw. You may require consent.
Does the watercourse support protected species?	If YES – seek advice from Biodiversity staff and implement appropriate mitigation measures and working practices when conducting management. Consider modifying management, including timing, to avoid adverse impacts. If adverse impacts cannot be avoided, contact Natural England or Natural Resources Wales for further advice and obtain a licence if required. You may need to employ a suitably licensed and experienced ecologist to advise you.
Does the watercourse support	If YES – implement appropriate working practices when

Consideration	Action required
priority species or habitats, or notable and/or rare species?	conducting management. Consider modifying management to avoid adverse impacts. Seek advice from Biodiversity staff. Contact Natural England or Natural Resources Wales for further advice if required.
Are spawning fish present?	If YES – implement appropriate working practices when conducting management. If possible, time works to avoid spawning season. Contact the Environment Agency for further advice if required.
Do the proposed management works require a WFD Compliance Assessment?	If YES – assess the ecological and hydromorphological impacts of the proposed management works. Consult with the Environment Agency/ Natural Resources Wales /IDB/LLFA for further advice.
Do the proposed management works fall under the EIA Regulations?	If YES – assess the environmental impacts of the proposed management works and determine whether an Environmental Statement is required. You will need to advertise and consult on the outcome of the assessment.
Have you identified all health and safety implications?	Ensure that: <ul style="list-style-type: none"> • all necessary risk assessments are made • risks have been avoided or reduced as far as practicable • safe systems of work are in place for residual risks • operatives are properly trained, instructed and provided with appropriate personal protective equipment (PPE)
Have you considered biosecurity?	Assess the level of risk posed by the management works and put in place appropriate biosecurity measures.
Will the proposed management works create waste which requires disposal?	If YES – register waste exemptions or apply for permits where necessary. If waste has to be removed from site, ensure it is taken by a licensed waste carrier to a suitably authorised landfill site.
Do the proposed management works require Flood Defence/Land Drainage consent?	If YES – apply to the appropriate authority for consent. Holding preliminary discussions with the appropriate authority before submitting any application is advised.
Do the proposed management works require the use of herbicide in or near water?	If YES – apply to the Environment Agency/Natural Resources Wales for agreement. Further guidance on the use of herbicides in or near water is provided in Technical Support Document C .
Have you explored the possibility of partnership working?	Identify and consult with any other interested parties and consider setting up a partnership/working group to undertake management.
Have you considered management in the context of the wider catchment?	Ensure upstream and downstream watercourse function(s) and management requirements are identified and integrated within a catchment-scale approach.

Source: [Aquatic and Riparian Plant Management Guide](#), Technical Guide, Table 4.1

D1 Designated sites

Watercourses may have a specific designation such as:

- Special Area of Conservation (SAC)
- Special Protection Area (SPA)
- Ramsar site
- Site of Special Scientific Interest (SSSI)

Such sites are designated under statute because they contain habitat types and species of nature conservation value described as ‘special interest features’. Statutory designated sites have conservation objectives which define the desired state for each of these features. Such features are said to be in ‘favourable condition’ when they are being managed in a way which maintains their nature conservation value.

Channel management activity may be required to maintain or achieve a favourable condition. The management of any watercourse within a statutory designated site must be agreed in writing with Natural England or Natural Resources Wales. You may need to tailor your specific management action so as not to compromise any conservation objective. If any consents are required then the regulator will be required to consult with Natural England or NRW prior to giving permission.

The presence of designated heritage sites such as Scheduled Monuments within, or immediately next to a watercourse could also constrain channel management activities. Consent may be required from English Heritage (in England) or Cadw (in Wales) to deposit any dredged or plant material removed from a watercourse on land in, on or under which there is such a monument.

Key points

If your channel of interest is statutorily designated for nature conservation, you need to contact Natural England or Natural Resources Wales to agree any management.

If your channel of interest is adjacent to a designated heritage site and you are considering options involving dredged and/or vegetative material, you need to contact English Heritage or Cadw.

Further information on designated nature conservation sites

- [Multi Agency Geographic Information for the Countryside \(MAGIC\)](http://www.magic.gov.uk)
(www.magic.gov.uk)
- [Natural England guidance on SSSIs and historical monuments](https://www.gov.uk/sites-of-special-scientific-interest-and-historical-monuments)
(https://www.gov.uk/sites-of-special-scientific-interest-and-historical-monuments)
- [Conservation, biodiversity and wildlife: work of Natural Resources Wales](http://naturalresourceswales.gov.uk/conservation-biodiversity-and-wildlife/?lang=en)
(http://naturalresourceswales.gov.uk/conservation-biodiversity-and-wildlife/?lang=en)

Further information on Scheduled Monuments

- [English Heritage guidance on Scheduled Monument consent](http://www.english-heritage.org.uk/professional/advice/our-planning-role/consent/smc/)
(www.english-heritage.org.uk/professional/advice/our-planning-role/consent/smc/)
- [Cadw guidance on Scheduled Monument consent](http://cadw.wales.gov.uk/historicenvironment/help-advice-and-grants/makingchanges/schedmonconsent/?lang=en)
(http://cadw.wales.gov.uk/historicenvironment/help-advice-and-grants/makingchanges/schedmonconsent/?lang=en)

D2 Protected species

There are a number of species associated with watercourses that receive special protection under various European and UK laws.

A number of watercourses are designated due to the presence of protected species. For some of these sites, management of aquatic and riparian plants is required to maintain the site's nature conservation interest.

Channel management has the potential to adversely impact on protected species found within the watercourse and also those that may be located on the banks or within adjacent habitats. Such species include nesting birds, water vole *Arvicola amphibious*, otter *Lutra lutra* and white-clawed crayfish *Austropotamobius pallipes*. Protected wild animals and plants are detailed in Schedules 5 and 8 respectively of the Wildlife and Countryside Act 1981.

When planning the management of aquatic and riparian plants within watercourses it is important to know if protected species are present. Species and habitats listed under Sections 41 and 42 of the natural Environment and Rural Communities Act (known as "priority species and habitats") should also be screened for. Although not protected to the same extent, all public bodies have duties toward priority species and habitats.

Operating authorities that carry out management of watercourses on a regular basis are likely to have built up a database of protected species records. Where no records exist, information may be available from desk-based sources such as the National Biodiversity Network (NBN) Gateway, local wildlife groups and/or Local Environmental Records Centres.

Additionally, surveys for protected species may be required. You may require a licence from Natural England or Natural Resources Wales to survey for protected species. Biodiversity staff or a suitably experienced ecologist will be able to advise.

Key point

You need to determine whether or not your watercourse supports protected species before starting works. If your works impact protected species then you may need a licence. You will need to plan for how your works will avoid, mitigate and compensate for any impacts.

Likely sources for records relating to the presence of protected species

- [National Biodiversity Network \(NBN\) Gateway](https://data.nbn.org.uk) (<https://data.nbn.org.uk>)
- [Local Environmental Records Centres](http://www.alerc.org.uk) (www.alerc.org.uk)

Relevant legislation

- [Wildlife and Countryside Act 1981 \(as amended\)](http://jncc.defra.gov.uk/page-1377) (<http://jncc.defra.gov.uk/page-1377>)

D3 Fisheries

Watercourses in the UK support internationally important freshwater fisheries particularly European eel and salmon. Consideration should be given to any potential impacts of channel management activities on spawning areas, the shelter available for fry and/or impacts on the invertebrates on which these fisheries may be dependent.

Under the Salmon and Freshwater Fisheries Act 1975 it is an offence to wilfully disturb any spawn or spawning fish, or any bed, bank or shallow on which any spawn or spawning fish may be.

The Eels (England and Wales) Regulations 2009 afford new powers to the Environment Agency to implement measures for the recovery of European eel stocks.

The presence of fish should always be a consideration when planning channel management activities. Impacts on fisheries can be greatly reduced through considering the timing of activities e.g. avoiding spawning periods.

Key points

It is important to establish whether your watercourse supports important fisheries populations. You must plan for your works to avoid impact to these populations.

Relevant legislation

- [Salmon & Freshwater Fisheries Act 1975](http://www.legislation.gov.uk/ukpga/1975/51) (www.legislation.gov.uk/ukpga/1975/51)
- [The Eels \(England and Wales\) Regulations 2009](http://www.legislation.gov.uk/ukxi/2009/3344/made) (www.legislation.gov.uk/ukxi/2009/3344/made)

D4 Water Framework Directive

The Water Framework Directive aims to protect and improve the water environment. It requires European Union (EU) Member States to divide up the water environment into management units called water bodies. These include parts of rivers, streams, lakes, reservoirs, estuaries, coastal waters, canals and groundwaters.

The general objective of the WFD is for each water body to achieve 'good status' and to protect water bodies by preventing deterioration in status. WFD status is made up of ecological and chemical components. Environmental objectives are set for each water body to help protect and improve its quality.

Some water bodies are designated as 'artificial' or 'heavily modified' water bodies under the WFD. These are water bodies that have been substantially altered to provide benefits for human society. For example, flood embankments may have been built to provide flood protection for a town, a channel may have been deepened to enable navigation or a river may have been impounded and a reservoir constructed to supply drinking water. Where certain criteria are met, these physically altered water bodies can be designated as 'artificial' or 'heavily modified'. Artificial and heavily modified water bodies have an objective to meet good ecological potential rather than good ecological status. They must still meet good chemical status. Good ecological potential is when every effort has been taken to allow the water body to support the best ecology it can, given its specified use(s).

Physical works that occur in and around channels could potentially conflict with these legal requirements and/or cause harm to the water environment.

Although the Environment Agency is the overall authority charged with meeting the objectives of WFD in England and Natural Resource Wales in Wales, it is the individual operating authorities who are responsible for ensuring that they have regard to WFD when carrying out their activities such as issuing permits or licences for physical works in channels, or carrying out those works themselves.

An applicant applying for a consent or licence to undertake physical works in or around a channel that is designated as main river may be required to provide the Environment Agency

or Natural Resource Wales (the relevant operating authority in that situation) with information to demonstrate the proposed works meet the requirements of the WFD. If the works are in ordinary watercourses then the applicant will need to satisfy the lead local flood authority.

To demonstrate that physical works in channels protect and, where appropriate, improve the water environment, channel managers should be able to show via an assessment that:

- works will not lead to deterioration in the quality of a water body
- works will not prevent the future improvement of a water body

If, following assessment, it is concluded by the relevant operating authority that physical works pose a risk of causing deterioration or preventing the achievement of good status, channel managers will only remain compliant with the WFD if they can demonstrate that the works meet the criteria of Article 4.7 of the WFD.

Article 4.7 is a defence against a breach of WFD objectives. When certain strict criteria are met, a scheme or physical works that pose a risk of deterioration or a failure to achieve good status or potential objectives can remain compliant with the WFD.

D4.1 How can channel management lead to deterioration in WFD status?

Channel management can:

- modify the size and shape of a channel
- reduce or increase the flow of water
- introduce artificial materials
- remove sediment and/or vegetation from the channel

Such physical modification or changes to flow can affect physical habitat. Physical habitat is essential for fish, macrophytes and invertebrates to live and thrive.

There is a risk of deterioration in WFD status from physical works due to direct or indirect impacts on:

- physical habitat
- water quality
- fish
- macrophytes
- invertebrates

Physical works can directly alter or remove physical habitat and could impact on fish, macrophyte and invertebrate populations. This may lead to deterioration in ecological status and a breach of WFD requirements.

Physical works can indirectly impact fish, macrophytes and/or invertebrates by changing how physical habitat is created and maintained (the geomorphology of the channel), or by changing water quality. These changes often occur over longer timescales. For example, work to remove sediment from a channel, will interrupt the transfer of sediment downstream and stop it forming habitats.

D4.2 How do physical works prevent future improvement of the water body?

When a water body is not at good status, restoration actions or mitigation measures may be planned or underway. Physical works in or around the channel could conflict with these planned improvements.

For example, a new impoundment structure is proposed in part of a catchment that has a weir removal programme planned or underway with the purpose of allowing migratory fish to reach the upper reaches of the river and hence achieve good status. Building a new weir would be in direct conflict with this programme and, as a result, could prevent the achievement of good status in the water body. It could only be justified if the strict criteria of Article 4.7 would be met.

Does a river basin management plan take account of the proposed activity?

Some ongoing maintenance activities in artificial and heavily modified water bodies are already taken account of in the most recent set of RBMPs. Ongoing maintenance activities in such water bodies should not lead to their deterioration where they:

- are related to the reason for the water body's designation
- incorporate mitigation measures identified in the RBMP
- do not change the geographical location, extent, technique or frequency from that given in the original designation

Note that this applies only to ongoing maintenance works in artificial and heavily modified water bodies.

D4.3 Does the proposed scheme already require an EIA?

If works require an EIA under the Environmental Impact Assessment Directive 2011/92/EU, the EIA should be used to collect the information required to demonstrate the works meet the legal requirements to protect and improve the water environment under the WFD.

Where a European designated site is impacted, this will require a separate Habitats Regulations Assessment (HRA).

Where a WFD assessment, EIA and/or HRA are required, it is recommended that these assessments are, wherever possible, carried out together.

D4.4 How the Environment Agency assess WFD compliance

It is up to each operating authority to satisfy themselves that physical works are not contrary to WFD objectives. Below is a high level description of how the Environment Agency approaches this.

The flow chart shown in Figure D2 summarises the Environment Agency's approach to assessing compliance with the WFD.

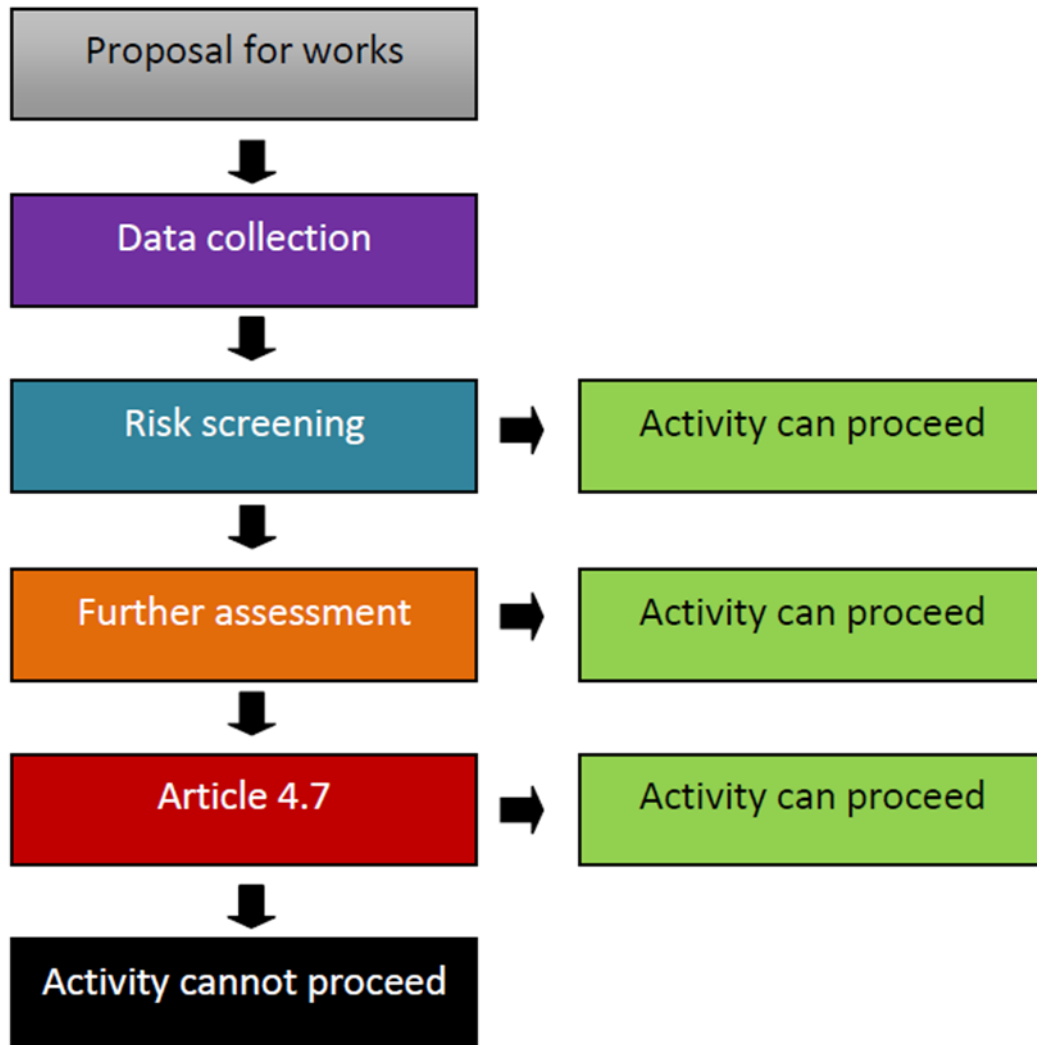


Figure D2: Flow chart for an Environment Agency WFD compliance assessment

Data collection

Basic data is collected about the proposed physical works and WFD water body(ies), and the nature conservation, heritage, landscape or fisheries features.

Risk screening

(a) Screening for high status

The aim is to identify if proposed physical works are in or near water bodies at WFD high status or with high status morphology.

'High status' water bodies are those with limited human alteration and which display close to undisturbed conditions. Any physical works occurring in a high status water body therefore pose a heightened risk of causing deterioration and are scrutinised closely. Only activities which demonstrate, with a high degree of certainty, that they will not cause deterioration of any element in a high status water body are allowed.

Operational and regulatory teams from the Environment Agency check whether the proposed works occur in or near a high status water body. If this is the case, Environment Agency Area experts advise operational teams (for Environment Agency's own works) or applicants (for works submitted for consent/licence) on the assessment requirements. To ensure proper scrutiny, proposals in or near high status water bodies are sent to the Area's fisheries, biodiversity, geomorphology and water quality experts for further consideration.

(b) Screening for risk of WFD deterioration and risk to water body status/ potential objectives

The aim is to identify if there is any risk of the channel management works causing WFD deterioration or conflicting with any planned water body improvement measures or actions.

The proposed physical works are screened against a table of WFD risk screening thresholds. The thresholds that are relevant to channel management are set out in Table D2. These thresholds indicate if the activity poses a risk to the delivery of WFD objectives and indicate whether further assessment is needed beyond the risk screening stage.

Table D2: Risk screening thresholds

Type of activity or modification	Length	Further WFD assessment required?
Sediment management	Any length or extent	Yes
Channel widening, deepening, straightening or realigning	Any length or extent	Yes
Riparian vegetation management	Undertaken over >20 m of channel length	Yes
	Undertaken over ≤20 m of channel length	No
In stream vegetation management	Undertaken over >20 m of channel length	Yes
	Undertaken over ≤20 m of channel length	No
Woody debris management	Undertaken over >20 m of channel length	Yes
	Undertaken over ≤20 m of channel	No

Type of activity or modification	Length	Further WFD assessment required?
	length	
Removal of urban trash	Any length	No

Further assessment

Where the thresholds shown in Table D2 are exceeded ecology and geomorphology experts at the Environment Agency discuss the specific requirements for further assessment with the applicant. Depending on the site-based risk and the exact nature of their proposal, either no further assessment is needed at this point or more detailed survey work is required.

Key points

Understanding which elements (for example, ecological and physiochemical) of your watercourse need to be improved (if necessary) to meet WFD standards will enable you to select the most appropriate management techniques to meet these requirements.

Using the Environment Agency's approach to WFD compliance assessment will help to ensure that your channel management activities are compliant.

Further information on the Water Framework Directive

- [European Commission's introduction to the Water Framework Directive](http://ec.europa.eu/environment/water/water-framework/index_en.html)
(http://ec.europa.eu/environment/water/water-framework/index_en.html)
- [Policy: Improving water quality](http://www.gov.uk/government/policies/improving-water-quality)
(www.gov.uk/government/policies/improving-water-quality)

Details of RBMPs

- [River basin management plans in England](http://www.gov.uk/government/collections/river-basin-management-plans)
(www.gov.uk/government/collections/river-basin-management-plans)

Further information about WFD implementation and mitigation measures

- [Healthy Catchments – managing for flood risk and the Water Framework Directive](http://www.ecrr.org/RiverRestoration/Floodriskmanagement/HealthyCatchmentsmanagingforfloodriskWFD/tabid/3098/Default.aspx)
(<http://www.ecrr.org/RiverRestoration/Floodriskmanagement/HealthyCatchmentsmanagingforfloodriskWFD/tabid/3098/Default.aspx>)

D5 Environmental assessment

It is possible that your planned channel management activity will require a formal EIA. An EIA will certainly be required, for example, you are planning any modification to the channel (widening, narrowing, deepening) or the installation of structures to alter flow characteristics. More routine management activities such as grass cutting or management of aquatic plants are unlikely to require an EIA.

Under the Environmental Impact Assessment (Land Drainage Improvement Works) Regulations 1999 (as amended), drainage bodies (the Environment Agency, Natural

Resources Wales, IDBs and LLFAs/local authorities) are required to determine whether 'improvement works' will have a significant impact on the environment.

Land drainage improvement works performed by drainage bodies are 'permitted development' under the Town and Country Planning (General Permitted Development) Order 1995 and are exempt from planning permission.

For European designated sites (SACs and SPAs), provisions in the Town and Country Planning (General Permitted Development) Order 1995 and the Conservation of Habitats and Species Regulations 2010 (as amended) are designed to ensure that permitted developments likely to have a significant effect on a European site cannot go ahead unless the local planning authority has determined, after consultation with Natural England or Natural Resources Wales, that the development would not affect the site's integrity.

Key points

If the planned channel management work is likely to have an impact on the environment, you need to undertake an EIA.

Guidance on the EIA Land Drainage Improvement Works) Regulations

- [The Environmental Impact Assessment \(Land Drainage Improvement\) Regulations 1999: Notes for Guidance \(PDF, 46 KB\)](#)
- [The Environmental Impact Assessment \(Land Drainage Improvement Works\) \(Amended\) Regulations 2005: Notes for Guidance \(PDF, 44 KB\)](#)

D6 Waste management

The management of aquatic and riparian plants, particularly by physical techniques, may create waste which requires disposal.

Under the Environmental Permitting Regulations (England and Wales) 2010 (as amended), you must either [register for an exemption or apply for a permit](#) (www.gov.uk/get-an-environmental-permit) to carry out waste operations. Registration for an exemption is free. For a list of exemptions, see Table 4.2 of the Technical Guide in the [Aquatic and Riparian Plant Management Guide](#) series.

Key points

It is essential to consider the full lifecycle of your management intervention, including the disposal of any waste.

Further information about waste exemptions

- [Registering as exempt](#)
(www.gov.uk/environmental-permit-how-to-apply/register-as-exempt)
- [Waste exemptions: using waste](#)
(www.gov.uk/government/collections/waste-exemptions-using-waste)
- [Waste exemptions: treating waste](#)
(www.gov.uk/government/collections/waste-exemptions-treating-waste)
- [Waste exemptions: disposing of waste](#)
(www.gov.uk/government/collections/waste-exemptions-disposing-of-waste)
- [Water discharge and groundwater activity exemptions](#)
(www.gov.uk/water-discharge-exemptions)

D7 Flood risk management and flood defence consents

Flood risk management is primarily regulated by the Water Resources Act 1991 and the Flood and Water Management Act 2010. These acts describe the roles and responsibilities of the operating authorities and form the basis for their operational, supervisory, regulatory and executive powers to do work in the fluvial environment. With respect to flood risk management, the operating authorities are:

- Environment Agency for all main rivers
- Internal Drainage Boards for their respective internal drainage districts
- Lead Local Flood Authorities for ordinary watercourses (that is, not a main river)

The Environment Agency carries out work on main rivers using the permissive powers granted it under the Water Resources Act 1991. Work on main rivers by others requires flood defence consent under Environment Agency regional flood defence byelaws which operate under sections 210–211 and Schedule 25 of the Water Resources Act 1991. The [Environment Agency's Regulatory Position Statement on De-silting \(PDF, 508 KB\)](#) is being trialled in pilot locations up to 14 March 2015. It allows landowners to help manage flood risk by carrying out de-silting work in main rivers without having to obtain flood defence consents. The aim is to make it easier to carry out certain low risk de-silting activities while not compromising the environment.

In some areas, local land drainage byelaws may require you to obtain consent for activities on an ordinary watercourse. Specific byelaws may be in place made by the Lead Local Flood Authority or, where applicable, the Internal Drainage Board.

Key points

Responsibilities for flood risk management are split between:

- Environment Agency or Natural Resources Wales – main rivers
- Lead Local Flood Authorities (LLFAs) – ordinary watercourses
- Internal Drainage Boards (IDBs) – watercourses in their drainage districts

If you are a landowner adjacent to a watercourse it's likely you'll need consent to carry out work or comply with the Environment Agency's Regulatory Position Statement.

Further information on flood defence consents

- [Apply for a flood defence consent](http://www.gov.uk/flood-defence-consent-england-wales) (www.gov.uk/flood-defence-consent-england-wales)
- [River maintenance and drainage charges: farmers and landowners](http://www.gov.uk/river-maintenance-and-drainage-charges-farmers-and-landowners) (www.gov.uk/river-maintenance-and-drainage-charges-farmers-and-landowners)

Details for IDBs and LLFAs

- [Association of Drainage Authorities](http://www.ada.org.uk) (www.ada.org.uk)
- [Local Government Association's flood risk portal](http://www.local.gov.uk/floodportal) (www.local.gov.uk/floodportal)

Technical Support Document E: Techniques for assessment

This Technical Support Document contains information on techniques to help you find out more about your channel. The techniques are listed in Table E1.

Table E1: Assessment techniques for channels

Technique number	Technique
1	Anecdotal evidence
2	Catchment surveillance
3	Aerial survey
4	Repeat fixed point photography
5	Channel cross-section survey
6	Bed-sediment analysis (grab samples)
7	Bed-sediment analysis (re-suspension)
8	River Habitat Survey (RHS) and geomorphological RHS (GeoRHS)
9	River Corridor Survey
10	Electrofishing
11	Flow estimation
12	Turbidity and flow monitoring
13	Bank erosion
14	Rapid geomorphological assessment
15	Fluvial audit
16	Predictive models
17	Hydraulic modelling
18	Sediment modelling

Each technique is described below along with an indication of who can carry out the technique and potential costs.

Cost bandings are as follows:

£ – low cost

££ – medium cost

£££ – high cost

Abbreviations used for Environment Agency teams are:

FCRM Flood and Coastal Risk Management

CSF Catchment Sensitive Farming

FRB Fisheries, Recreation and Biodiversity

1. Anecdotal evidence

Observations by people living and working in the catchment can provide important evidence on factors such as historic channel form, sediment sources and flow variation. The Environment Agency's Area public relations officer or similar Natural Resources Wales staff is recommended as the first person to contact for additional local information. The following may also be able to provide valuable information:

- long-serving members of staff
- local residents
- parish groups
- recreational users of the river
- river trusts
- conservation groups

The evidence obtained tends to be qualitative and can vary in detail, but can be useful for developing a broad, initial understanding of the catchment and channel issues. Where possible, information should be verified through follow-up work.

Use this technique as a first step when you need to improve your understanding of the channel's wider context to help target monitoring.

Who can carry out technique?

Environment Agency staff such as
Environment Officers, CSF or FRB staff

Potential cost

£ – staff time, vehicle or phone costs

2. Catchment surveillance

A reconnaissance survey in the catchment is usually performed by driving or walking and, where access is possible, making observations of sediment-related features. The survey is best done during or following wet weather. It can help to confirm features and observations from desk studies. Take a camera to record evidence, noting the location of any pictures. Some of the things to look out for include:

- land use
- water levels
- flow types
- channel conveyance
- bank stability
- evidence of erosion in fields
- river uses
- evidence of deposition of sediment in the river
- ecology
- pathways that link the surrounding land to the river
- land management that restricts/enhances linkage between the field and the river

A catchment surveillance run is useful for developing a general understanding of the wider context and principles that may affect your channel. The survey can help to confirm understanding gained from desk studies. It may also identify the root cause of specific issues and help to target further detailed investigations. This is a complementary method to the desk study.

Who can carry out technique?

Environment Agency staff such as
Environment Officers and FRB staff

Potential cost

£ – staff time, vehicle costs

3. Aerial survey

Aerial images such as photographs allow identification of factors that may lead to issues such as sediment erosion, transport and deposition. Photographs are useful for visual identification of potential sources, pathways and depositional features, particularly in areas that are not easily accessible from the ground.

Photographs are useful for gaining a conceptual and broad understanding of the catchment and an overall view of potential linkages. Aerial images can help to confirm features and observations made from desk studies. Use when you need to improve your overall, qualitative understanding of sediment sources, pathways and stores in the catchment and to help target detailed monitoring.

Images may be available from Environment Agency FCRM teams or online sources such as Google Earth. Alternatively, bespoke flights can be made. Rivers trusts may have river corridor images. The cost of obtaining high resolution images may not be justified by the greater information that can be derived.

Ultimately, the approach gives a limited understanding of processes operating in the catchment but can help to identify specific areas for surveillance.

Who can carry out technique?

Anyone with an understanding of channel dynamics – possibly with Environment Agency FCRM teams

Potential cost

£–£££ – acquiring some images is low cost or free (for example, Google Earth), but new, high resolution images may be expensive

4. Repeat fixed point photography

This technique involves taking images of specific features from the same point at different times. Locations can be geo-referenced using a global positioning system (GPS).

The images can be specifically commissioned current images or historic images, which also give an indication of catchment changes. They may be simple photographs or more complex technologies such as LiDAR (radar images), although cost may restrict repeat imagery.

Comparing images taken at different times will allow you to see how the landscape has evolved, in particular with regard to erosional or depositional features. The technique provides good evidence of landscape change but does not reflect processes that are operating well enough.

Images can be analysed qualitatively to identify important changes in features or can be digitally overlain and analysed quantitatively.

Use this technique when you wish to improve your understanding of changes in channel and catchment features over time.

The [Guidebook of Applied Fluvial Geomorphology](#) provides more information.

Who can carry out technique?

Environment Agency staff such as Environment Officers and FRB staff

Potential cost

£ – cost of photography

5. Channel cross-section survey

A repeat topographic survey of representative channel cross-sections enables changes in the profile of channel bed and banks to be assessed.

Surveys should be geo-referenced and taken from a fixed point. Photographic evidence to accompany the survey data is recommended.

The results can indicate factors such as where bank erosion is occurring and where sediment is being deposited.

Cross-section survey data can be compared to show the rate and location of channel change over time. Data can be presented as a spreadsheet or as a cross-section diagram.

Use this technique when issues related to bank erosion and/or deposition on the river bed have been identified.

Who can carry out technique?

Environment Agency staff, consultant or contractor

Potential cost

£

6. Bed-sediment analysis (grab samples)

This method provides specific point data on fine sediment content within the bed of the river channel.

A sample of the bed of the river is made by taking a 'bite' of bed material using a device called a grab. The sediment collected in the grab is removed from the river for analysis.

This technique can give you a simple estimate of how habitats can change through the deposition of sediment. Analysis of the particle size of sediment can help to understand the link between sediment and deposition of contaminants.

Grab samples of bed material provide an indication of the sediment composition at that specific location at that specific sample time.

Use this technique when issues related to sediment regarding deposition on the river bed have been identified.

The technique is best suited to deep channels with sandy/silty beds and sampling off bridges when the river bed is not accessible.

Who can carry out technique?

Environment Agency staff, consultant or contractor

Potential cost

£ – although requires maintenance

7. Bed-sediment analysis (re-suspension cylinder)

Samples of fine sediment deposited in the river bed can be collected using a cylinder placed on the bed of the river to confine an area of the bed. The bed is stirred up to release the stored fine sediment and a sample of the stirred-up sediment is collected. The concentration of fine sediment in the sample can be used to estimate the volume of sediment deposited.

Automated re-suspension cylinders apply a known velocity shear stress to an isolated section of the river bed so as to determine the re-suspension potential of particular sediment grades.

The technique is useful if you need to know how much fine sediment is deposited, for example, to understand impacts on salmon spawning habitats. The technique works particularly well for gravel bed rivers.

This technique is also part of the methodology for a Riffle Sedimentation Survey (RSS), a technique developed by the Environment Agency in conjunction with the Game and Wildlife Conservation Trust. An RSS looks at overall riffle characteristics and sediment deposition to assess habitat quality.

Who can carry out technique?

Environment Agency staff such as
Environment Officers and FRB staff

Potential cost

£

8. River Habitat Survey (RHS) and geomorphological RHS (GeoRHS)

The survey is designed to characterise and assess in broad terms the physical structure and vegetation of freshwater streams and rivers. For example, for sediment monitoring it identifies geomorphological features such as substrate, depositions, bars, berms, pools, eroding banks and land use (potential sediment sources).

A survey is carried out by walking 500-metre reaches of the river bank/channel. Observations (including physical attributes, banktop structure, land use and channel vegetation) are made at 10 equally spaced spot checks along the channel and a 'sweep up' assessment made to cover the whole 500 metres. Information on valley form and land use in the river corridor provides additional context.

The survey can also be used to assess how modified a reach is and how this compares with other rivers. The Urban RHS can be used in urban areas. The GeoRHS includes additional consideration of the linkage of the channel to the floodplain.

The [River Habitat Survey Guidance Manual: 2003 version](#) and the [GeoRHS Guidance Manual](#) describe the survey method. Further information is available from the Environment Agency's National Environmental Monitoring Service team who can advise on accredited surveyors, costs and contracts.

Use this technique to link factors within your channel (for example, sediment to ecology). It can be used to assess habitat quality by calculating a habitat modification score and a habitat modification class. The role of sediment in habitat quality can be assessed.

Who can carry out technique?

Accredited consultants, Environment Agency
staff trained in the current version of RHS

Potential cost

£–££ – requires staff time for site-based
surveys

9. River Corridor Survey

This survey identifies the ecological and morphological features of a reach.

A survey is carried out by walking 500-metre reaches of the river bank and channel, mapping features on a base map. A record is made of features within 50 metres of the banktop. It includes ecology and morphology, flow features, substrate, bank structure, vegetation types, land use, eroding banks, bars or berms.

Standardised maps of vegetation structure along 500 metres stretches of river are produced, providing a detailed outline of the physical habitat available for aquatic animals, coupled with botanical survey of all vascular plants recorded in each stretch.

The 'River Corridor Surveys Methods and Procedures (Conservation Technical Handbook)' issued by the National Rivers Authority in 1992 provides details of the methodology. Further information is available from Environment Agency FRB and Environmental Monitoring teams.

Who can carry out technique?

Environment Agency FRB teams and consultants

Potential cost

£-££

10. Electrofishing

This technique provides an assessment of the fish population within a given channel area. It can be used at any time, but is not advisable in high temperatures due to stress and low dissolved oxygen, or in winter due to possible fish aggregations.

Results are annotated on maps and geographical information system (GIS) outputs recording the location of reeds. The survey can help to identify areas of gravel bed sufficiently unimpacted by sediment ingress to still be used for spawning.

Surveys of fish populations are carried out by wading, or from a boat and working between two stop nets. Operators move with a hand-held anode and net, and with a trailing cathode passing a current through the water. The current stuns the fish, which are then visible and can be captured.

Further information on methodology is available from Environment Agency Fisheries or Environmental Monitoring teams.

This technique is useful if observations show issues that could be impacting fish populations such as a high level of fine sediment deposition in gravels.

Who can carry out technique?

Environment Agency Sampling and Collection or FRB teams
Accredited consultants

Potential cost

Cost of staff time per day plus equipment

11. Flow estimation

There is an extensive gauging station network in the UK, but not all streams are gauged and not all the existing gauges will be at a suitable location within the catchment.

Flows can be estimated using the methods detailed in the Centre for Ecology & Hydrology's [Flood Estimation Handbook](#), which estimates flow based on catchment characteristics and catchments with similar characteristics in the UK. No fieldwork is undertaken.

This technique will provide you with an estimate of flow where no flow gauging exists for a specified period of time. This can be analysed alongside other data to provide an understanding of the relationship between flow and other variables such as sediment dynamics.

Who can carry out technique?

Environment Agency FCRM staff
Consultant or contractor

Potential cost

£

12. Turbidity and flow monitoring

Automatic monitoring data enable a detailed temporal understanding of various hydraulic factors in the river.

This technique can be useful in gaining a detailed understanding of when sediment is transported and to establish how much sediment is transported. This is done by combining a turbidity-derived sediment concentration record with a record of flow collected at the same point and at the same time, thus allowing an estimate of sediment load to be made.

In this instance, flow is derived from automatic depth readings using stage discharge relationships. Turbidity probes measure suspended solids levels at set intervals. This allows changes in sediment concentration to be measured during individual storm events and the longer term.

High frequency, event-based monitoring is required to capture sediment concentrations before during and after a rainfall event. This allows detailed temporal understanding of suspended sediment in the river. Routinely collected monitoring data are generally limited by the frequency of collection.

In the long term, this technique can help to identify the effectiveness of any sediment reduction measures implemented within the catchment.

Who can carry out technique?

Environment Agency staff such as
Hydrology, Water Resources Management
and FRB staff
Consultant or contractor

Potential cost

££

13. Bank erosion

The rate of bank erosion can be measured using simple markers in the river bank or on top.

Pins or rods can be driven into the bank and the distance from the top of the pin to the bank surface measured on a number of different occasions.

The rate of bank erosion can also be measured by using marker pegs on the top of the bank. The distance to the exposed bank face can be measured on a number of different occasions.

This technique is useful in gaining an understanding of the rate of bank erosion at a specific site and the contribution of bank erosion to the total sediment load of the river channel. Or it can be used to compare the relative importance of different bank erosion sites to target mitigation. Sediment supply from other sources, such as the catchment surface, can be assessed alongside bank erosion to develop a catchment sediment budget.

This technique is most useful when all eroding banks have been identified and the relative importance of individual sources can be assessed. The rate of erosion may be important if a critical piece of infrastructure is threatened. However, more simple repeat photography of measuring the bank edge from a fixed point may be just as effective and much cheaper and easier.

Who can carry out technique?

EA staff such as Environment Officers and FRB staff
Consultant or contractor

Potential cost

£

14. Rapid geomorphological assessment

Rapid geomorphological assessments provide a basic level of information and are generally used to propose potential solutions to small-scale problems. The technique involves a field survey and desk-based study to find a simple explanation of the processes occurring.

The technique provides a high level understanding of processes that may be causing a specific problem; the focus tends to be on the geomorphological nature of the problem.

The [Guidebook of Applied Fluvial Geomorphology](#) provides more information.

Who can carry out technique?

Trained Environment Agency staff and consultants

Potential cost

£–££

15. Fluvial audit

The audit provides a catchment-scale and reach-scale assessment, focusing on sediment sources, transport mechanisms and understanding of the drivers of change in sediment processes. The audit will often identify 'hotspots' for action and provide the basis for a catchment-wide approach to more sustainable channel management.

Detailed mapping of channel sediment features can be carried out according to a set format; see the [Guidebook of Applied Fluvial Geomorphology](#) for guidance.

The technique uses a combination of fieldwork to map features, historical maps and documented sources.

Who can carry out technique?
Consultants/specialist contractors

Potential cost
££ – will depend on the length of reach audited

16. Predictive models

The Environment Agency's Decision Support Tool (DST) can be used to identify land with a high or low risk of delivering sediment based on the type of land use. It can also be used to assess the potential benefits of management options such as introducing buffer strips and other measures to reduce nutrient and sediment delivery to streams. This should only be used as a guide to exploring where to target sediment reduction measures and is best used in conjunction with other source mapping methods.

[SCIMAP](http://www.scimap.org.uk) (www.scimap.org.uk) is a software package, developed by Durham and Lancaster Universities that can model the connectivity of sediments and give an indication of relative risk. The SCIMAP framework can be used to generate maps of diffuse pollution risk within catchments. SCIMAP aims to determine where within a catchment is the most probable source of diffuse pollution.

DST produces a graphical output that quantifies sediment delivery for 1 km × 1 km squares while SCIMAP provides the relative risk of sediment delivery at a 5 m × 5 m square resolution. The outputs can be compared to assess sediment delivery under a range of land use scenarios, and spatial and temporal scales.

Who can carry out technique?
Environment Agency National Research,
Risk and Forecasting teams
Specialist contractor

Potential cost
Time for processing
Field data collection if required for verification

17. Hydraulic modelling

Many different methods and models are available for investigating the hydraulics of water courses and their associated floodplains.

Hydraulic modelling can be used to investigate the impact of river management at a range of flows and can inform ecological decisions by providing water level, velocity and shear stress information.

In a capital scheme or where river management is proposed, the requirement for hydraulic modelling is often driven by flood risk management. It is necessary to provide an assessment of the impact on the water levels through a reach and how the flows through a watercourse and across the associated floodplain may be affected. The level of risk will determine the complexity of the modelling required; for example, if the watercourse is through an urban area, the flood modelling required may be more detailed.

Selection of the appropriate approach and the extent of the river model should be related to the level of flood risk, the type of river management being proposed and the likely impact of the management on upstream and downstream reaches. If the impact is seen to be local, a short reach of river can be modelled. If the impact of maintenance may have a wider effect upstream or downstream either in increased water levels or changing the flow hydrograph, the model needs to extend beyond the areas of likely influence.

- **One-dimensional (1D) modelling:** The outputs are flow, water levels and velocities in the one dimension along the channel at fixed cross-section points. They can simulate flow and/or storage of water on the floodplain. Models can be used in a steady or unsteady state depending on the nature of the river and the management options being considered.
- **Two-dimensional (2D) modelling:** These investigate the flow along and across the watercourse and associated floodplains. The watercourse and/or floodplain is represented by a 2D grid along and across the channel rather than using cross-sections at regular intervals as in a 1D model. A combination of 1D and 2D modelling can be used, with the 2D grid being used where a higher level of detail on flow patterns and velocities is required.
- **Three-dimensional (3D) modelling:** These represent flow along and across the watercourse and floodplain, and through the depth of the water column. They add a further level of detail, complexity, time and costs to modelling but give detailed results and are more commonly used to investigate detailed problems such as bridge scour.
- **Conveyance Estimation System (CES):** The CES is a model developed by the Environment Agency to help investigate river management issues on a more local scale. It performs as a 1D, steady state model with good assessment of roughness and a facility to vary roughness through vegetation growth and simulate vegetation cutting. It can be linked to an ISIS or INFOWORKS model to simulate unsteady flows.
[Download the CES software free of charge](http://www.river-conveyance.net) (www.river-conveyance.net)

An assessment of the data requirements, indicative costs, applications and outputs of the different models can be found in the River Restoration Centre's [River Rehabilitation Guidance for Eastern England Rivers \(PDF, 3.82 MB\)](#).

18. Sediment modelling

Mobile bed numerical models can be used to simulate the movement of water and sediment through a reach of a river. If the sediment transport rate varies spatially along the reach, then erosion or sedimentation will take place and the models can predict the amount and rate of such bed level change. By tracking different sediment size classes separately it is also possible to predict changes in bed sediment composition. Such numerical models can be used for both short-term and long-term predictions.

As the models require river discharges and upstream sediment loads to be specified as boundary conditions, predictions are subject to uncertainty due to uncertainties in the boundary conditions.

Numerical models can be used to predict the impact of some maintenance activities. For example, the impact of dredging on future bed levels can be simulated by removing sediment from the river channel. The flow models used can be 1D, 2D or 3D depending on the nature of the flow and the detail required.

Sediment modelling is carried out to make predictions of future morphological change as a result of changes to:

- morphology of the river
- upstream discharge and sediment load
- sediment disposal or removal

The models can also predict changes in bed sediment composition.

Mobile bed models predict both sediment transport rates and changes in bed level. The input data normally include time series data of discharge. Predictions will therefore depend on the nature of the time series used.

It is essential that sediment modelling is only performed if the geomorphology of the fluvial system is understood. It can provide quantitative predictions associated with identified geomorphological processes. The sediment modelling has to be underpinned by a reliable understanding and model of the flow.

Sediment modelling can be used to ensure that the impact of future morphological change is predicted and taken account of in any future maintenance or capital works.

The application of numerical morphological models is normally a specialist activity. Those who are not familiar with this type of modelling are recommended to seek specialist advice before performing such a study.

Model results are dependent on the input data used and so there is always a risk that inappropriate data are used. Model results always require interpretation and so there is a risk that model results could be incorrectly interpreted. These risks can be reduced by ensuring there is a full understanding of the geomorphology of the system and nature of the flow.

List of abbreviations

ACMF	Adaptive Channel Management Framework
AES	Afflux Estimation System
AOD	above Ordnance Datum
CDM	Construction (Design and Management) [Regulations]
CES	Conveyance Estimation System
CFMP	Catchment flood management plan
CG	condition grade
CSF	Catchment Sensistive Farming
EIA	Environmental Impact Assessment
EMP	Eel management plan
FCRM	flood and coastal risk management
FRB	Fisheries, Recreation and Biodiversity [Environment Agency teams]
FRM	Flood Risk Management [Environment Agency teams]
FRMP	Flood risk management plan
HRA	Habitats Regulations Assessment
HSE	Health and Safety Executive
IDB	Internal Drainage Board
LLFA	Leading Local Flood Authority
LWD	large woody debris
R&D	research and development
RBMP	river basin management plan
RHS	River Habitat Survey
RSS	Riffle Sedimentation Survey
SCA	Special Conservation Area
SEPA	Scottish Environment Protection Agency
SPA	Special Protection Area
SSSI	Site of Special Scientific Interest
WFD	Water Framework Directive
WL	water level

Bibliography

[Agreement to Use Herbicides in or near Water. Guidance Notes \(PDF, 326 KB\)](#),

Environment Agency, 2010

www.gov.uk/government/uploads/system/uploads/attachment_data/file/296857/geho0110brzk-e-e.pdf

[Aquatic and Riparian Plant Management Guide](#), Environment Agency, 2014

www.gov.uk/government/publications/aquatic-and-riparian-plant-management-controls-for-vegetation-in-watercourses

[Best Practice Erosion and Sediment Control](#), International Erosion Control Association Australasia, 2007

www.austieca.com.au/publications/best-practice-erosion-and-sediment-control-bpesc-document

[Catchment Based Approach: Improving the quality of our water environment](#), Defra, 2013

www.gov.uk/government/publications/catchment-based-approach-improving-the-quality-of-our-water-environment

[Chalkstream Habitat Manual](#), Wild Trout Trust

www.wildtrout.org/product/chalkstream-habitat-manual-cd

[Code of Practice for Using Plant Protection Products \(PDF, 3.05 MB\)](#), Defra and others, 2006

www.pesticides.gov.uk/Resources/CRD/Migrated-Resources/Documents/C/Code_of_Practice_for_using_Plant_Protection_Products_-_Complete20Code.pdf

[Condition Assessment Manual \(PDF, 7.16 MB\)](#), Environment Agency, 2006

www.ada.org.uk/downloads/other/members_area/ea_cond_ass/eacondassessment.pdf

[Conveyance Manual \(PDF, 4.5 MB\)](#), Defra and Environment Agency, 2004

www.river-conveyance.net/1_CES_UserGuide.pdf

[Culvert Design and Operation Guide](#), CIRIA, 2010

www.ciria.org/ItemDetail?iProductcode=C689&Category=BOOK

[Debris and Blockage Modelling Guide](#), Environment Agency (publication due 2015)

<http://evidence.environment-agency.gov.uk/fcerm/en/Default/FCRM/Project.aspx?ProjectID=2d265aaf-1bfa-441c-8abd-9de589418a30&PageID=3679217f-8f79-4c83-b935-f277aaadbdf1>

[Drainage Channel Biodiversity Manual](#), Association of Drainage Authorities and Natural England, 2008

<http://publications.naturalengland.org.uk/publication/50004>

[Dredging Pilot Studies](#), Environment Agency

<http://webarchive.nationalarchives.gov.uk/20130903121531/http://www.environment-agency.gov.uk/research/policy/31740.aspx>

[Eel and Elver Passes Manual](#), Environment Agency, 2011

www.gov.uk/government/publications/eel-and-elver-passes-design-and-build

[Environmental Good Practice Guide – Guidance to Help you Maintain your Watercourse in River Maintenance Pilot Areas \(PDF, 1.37 MB\)](#), Environment Agency, May 2014

www.gov.uk/government/uploads/system/uploads/attachment_data/file/307608/LIT_8808_N

AL_LIT__EnvGoodPracticeGuide_V3_280413.pdf

[Environmental Options for Flood Defence Maintenance Works \(PDF, 1.07 MB\)](#), Environment Agency, 2003
<http://lfcc.org.uk/downloads/category/17-flood-risk-management-maintenance-programme-201112?download=37:grass-cutting>

[Environmental Options for River Maintenance Works \(PDF, 1.06 MB\)](#), Environment Agency, 2005
<http://lfcc.org.uk/downloads/category/17-flood-risk-management-maintenance-programme-201112?download=39:weed-control>

[Environmentally Sensitive Channel and Bank Protection Measures](#), US Transportation Board National Cooperative Highway Research Program (NCHRP) Report 544
www.nap.edu/catalog/13556/nchrp-report-544-environmentally-sensitive-channel-and-bankprotection-measures

[Estuary Edges: Ecological Design Guidance](#), Thames Estuary Partnership, 2009
www.thamesweb.com/projects-introduction/72-estuary-edges.pdf

[Evidence: Impacts of Dredging \(PDF, 321 KB\)](#), Environment Agency, 2013
www.wildtrout.org/sites/default/files/library/Evidence_-_impacts_of_dredging_-_August_2013.pdf

[Farming and Watercourse Management Handbook \(PDF, 1.34 MB\)](#), WWF Scotland, 2000, revised 2012
www.sepa.org.uk/water/water_regulation/regimes/engineering/habitat_enhancement/idoc.aspx?docid=dd5cb2a7-1489-4b3d-ba8d-32c0b880b694&version=-1

[Fish Pass Manual](#), Environment Agency, 2010
www.gov.uk/government/publications/environment-agency-fish-pass-manual

[Flood and Coastal Erosion Risk Management Appraisal Guidance](#) (FCERM_AG) and its associated [supporting documents](#)
<http://webarchive.nationalarchives.gov.uk/20131108051347/http://www.environment-agency.gov.uk/research/planning/116705.aspx>
<http://webarchive.nationalarchives.gov.uk/20131108051347/http://www.environment-agency.gov.uk/research/planning/116707.aspx>

[Flood Estimation Handbook](#), Centre for Ecology & Hydrology, 1999
www.ceh.ac.uk/products/publications/cehpublications-h-fehorderhere.html

[Fluvial Design Guide](#), Environment Agency, 2009
www.gov.uk/government/publications/fluvial-design-guide

[Geomorphological Monitoring Guidelines for River Restoration Schemes \(PDF, 992 KB\)](#), Environment Agency, 2007
http://therrc.co.uk/MOT/References/EA_Geomorphological_monitoring_guidelines.pdf

[GeoRHS Guidance Manual](#), Environment Agency, 2006
www.gov.uk/government/publications/refined-geomorphological-and-floodplain-component-river-habitat-survey-georhs

[Good Practice Guide for Bank Protection: Rivers and Lochs \(SEPA Good Practice Guide WAT-SG-23\)](#), SEPA, 2008
www.sepa.org.uk/water/water_regulation/guidance/engineering.aspx

[Gravel Mitigation and Augmentation below Hydroelectric Dams: A Geomorphological Perspective \(PDF, 2.56 MB\)](#) US Department of Agriculture, Forest Service, 2004

www.stream.fs.fed.us/publications/PDFs/Gravel%20Augmentation%20Report.pdf

[Guidebook of Applied Fluvial Geomorphology](http://randd.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&Completed=0&ProjectID=10695), Defra and Environment Agency, 2003
<http://randd.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&Completed=0&ProjectID=10695>

[Key Recommendations for Sediment Management: a Synthesis of River Sediments and Habitats](http://www.gov.uk/government/publications/key-recommendations-for-sediment-management-a-synthesis-of-river-sediments-and-habitats), Environment Agency, 2011
www.gov.uk/government/publications/key-recommendations-for-sediment-management-a-synthesis-of-river-sediments-and-habitats

[Land Use Management Effects on Flood Flows and Sediments: Guidance on Prediction](http://www.ciria.org/Resources/Free_publications/Land_use_management.aspx), CIRIA, 2013
www.ciria.org/Resources/Free_publications/Land_use_management.aspx

[Managing Woody Debris in Rivers, Streams & Floodplains \(PDF, 1.03 MB\)](http://therrc.co.uk/MOT/References/WT_Managing_woody_debris.pdf), Wildlife Trusts, 2006
http://therrc.co.uk/MOT/References/WT_Managing_woody_debris.pdf

[Manual of River Restoration Techniques](http://www.therrc.co.uk/rrc_manual.php), River Restoration Centre, 3rd edition, 2013
www.therrc.co.uk/rrc_manual.php

Mitigation Measures Monitoring Trials, Environment Agency, 2011

[Modelling Decision Support Framework 2](http://evidence.environment-agency.gov.uk/FCERM/en/SC050051.aspx), Environment Agency,
<http://evidence.environment-agency.gov.uk/FCERM/en/SC050051.aspx>

[National Flood Risk Assessment](http://www.gov.uk/government/publications/flooding-in-england-national-assessment-of-flood-risk), Environment Agency, 2009
www.gov.uk/government/publications/flooding-in-england-national-assessment-of-flood-risk

[Pollution Prevention Guidelines 5: Works and maintenance in or near water](http://www.gov.uk/government/collections/pollution-prevention-guidance-ppg), Environment Agency, 2014
www.gov.uk/government/collections/pollution-prevention-guidance-ppg

[Practical Channel Hydraulics: Roughness, Conveyance and Afflux](http://www.crcpress.com/product/isbn/9780415549745), CRC Press, 2009
www.crcpress.com/product/isbn/9780415549745

[Practical River Restoration Appraisal Guidance for Monitoring Options \(PRAGMO\)](http://www.therrc.co.uk/rrc_pragmo.php), River Restoration Centre, 2012
www.therrc.co.uk/rrc_pragmo.php

[Riparian Vegetation Management \(SEPA Good Practice Guide WAT-SG-44\)](http://www.sepa.org.uk/water/water_regulation/guidance/engineering.aspx), SEPA, 2nd edition, 2009
www.sepa.org.uk/water/water_regulation/guidance/engineering.aspx

River Corridor Surveys Methods and Procedures (Conservation Technical Handbook), National Rivers Authority, 1992

[River Habitat Survey Guidance Manual: 2003 version](http://www.gov.uk/government/publications/river-habitat-survey-guidance-manual), Environment Agency, 2003
www.gov.uk/government/publications/river-habitat-survey-guidance-manual

[River Rehabilitation Guidance for Eastern England Rivers \(PDF, 3.82 MB\)](http://therrc.co.uk/pdf/reports/Guidelines_River_Rehabilitation_Eastern_England_Rivers.pdf), River Restoration Centre, 2005
http://therrc.co.uk/pdf/reports/Guidelines_River_Rehabilitation_Eastern_England_Rivers.pdf

[River Sediments and Habitats](http://learning.environment-agency.gov.uk/courses/sediment/player.html), Environment Agency online presentation
<http://learning.environment-agency.gov.uk/courses/sediment/player.html>

[River Weirs – Good Practice Guide](http://www.gov.uk/government/publications/river-weirs-good-practice-guide), Environment Agency, 2003
www.gov.uk/government/publications/river-weirs-good-practice-guide

- [Rural Sustainable Drainage Systems](http://www.gov.uk/government/publications/rural-sustainable-drainage-systems), Environment Agency, 2012
www.gov.uk/government/publications/rural-sustainable-drainage-systems
- [Sediment Management \(SEPA Good Practice Guide WAT-SG-26\)](http://www.sepa.org.uk/water/water_regulation/guidance/engineering.aspx), SEPA, 2010
www.sepa.org.uk/water/water_regulation/guidance/engineering.aspx
- [Sediment Matters Handbook](http://www.gov.uk/government/publications/sediment-matters), Environment Agency, 2011
www.gov.uk/government/publications/sediment-matters
- [SEPA Engineering in the Environment: Good Practice Guides](http://www.sepa.org.uk/water/water_regulation/guidance/engineering.aspx)
www.sepa.org.uk/water/water_regulation/guidance/engineering.aspx
- [Stream Habitat Restoration Guidelines \(PDF, 23.3 MB\)](http://wdfw.wa.gov/publications/00043/wdfw00043.pdf) (Technique 13), Washington State Aquatic Habitat Guidelines Program, 2004
http://wdfw.wa.gov/publications/00043/wdfw00043.pdf
- [Sustainable Wetland Restoration in the New Forest: Final Technical Report \(PDF, 510 KB\)](http://www.newforestlife.org.uk/life3/PDFs/PDFs/FinalReport.pdf), New Forest Life Partnership, 2006
http://www.newforestlife.org.uk/life3/PDFs/PDFs/FinalReport.pdf
- [The Drainage Channel Biodiversity Manual: Integrating Wildlife and Good Risk Management](http://publications.naturalengland.org.uk/publication/50004), Association of Drainage Authorities and Natural England, 2008
http://publications.naturalengland.org.uk/publication/50004
- [The Environmental Impact Assessment \(Land Drainage Improvement Works\) \(Amended\) Regulations 2005: Notes for Guidance \(PDF, 44 KB\)](http://archive.defra.gov.uk/environment/flooding/documents/policy/guidance/eia-guidance.pdf), Defra, 2006
http://archive.defra.gov.uk/environment/flooding/documents/policy/guidance/eia-guidance.pdf
- [The Environmental Impact Assessment \(Land Drainage Improvement\) Regulations 1999: Notes for Guidance \(PDF, 46 KB\)](http://archive.defra.gov.uk/environment/flooding/documents/policy/guidance/eiaguide1999.pdf), Defra, 2005
http://archive.defra.gov.uk/environment/flooding/documents/policy/guidance/eiaguide1999.pdf
- [The Herbicide Handbook: Guidance on the Use of Herbicides on Nature Conservation Sites](http://publications.naturalengland.org.uk/publication/68019), English Nature, 2003
http://publications.naturalengland.org.uk/publication/68019
- The New Rivers and Wildlife Handbook*, RSPB, 2001
- [The Protocol for the Maintenance of Flood and Coastal Risk Management Assets](http://www.gov.uk/government/publications/flood-and-coastal-asset-maintenance-the-environment-agencys-approach), Environment Agency, 2013
www.gov.uk/government/publications/flood-and-coastal-asset-maintenance-the-environment-agencys-approach
- [Trash and Security Screen Guide](http://www.gov.uk/government/publications/trash-and-security-screen-guide-2009), Environment Agency, 2009
www.gov.uk/government/publications/trash-and-security-screen-guide-2009
- Waterway Bank Protection: A Guide to Erosion Assessment and Management*, Environment Agency, 1999
- [Waterways and Wetlands: A Practical Manual](http://www.nhbs.com/title/35684/waterways-and-wetlands), British Trust for Conservation Volunteers, 2003
www.nhbs.com/title/35684/waterways-and-wetlands
- [WFD Expert Assessment of Flood Management Impacts](http://sciencesearch.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&Completed=0&ProjectID=15571), Defra and Environment Agency, 2009
http://sciencesearch.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&Completed=0&ProjectID=15571
- [Woodland for Water: Woodland Measures for Meeting Water Framework Directive](#)

[Objectives](#), Forest Research, 2011
www.forestry.gov.uk/fr/woodlandforwater

[Working with Natural Processes to Manage Flood and Coastal Erosion Risk \(PDF, 6.24 MB\)](#),
Environment Agency, 2010
<http://webarchive.nationalarchives.gov.uk/20140328084622/http://cdn.environment-agency.gov.uk/geho0310bsfi-e-e.pdf>

[Working with Wildlife: Guidance for the Construction Industry](#), CIRIA, 2011
www.ciria.org/ItemDetail?iProductCode=C691&Category=BOOK&WebsiteKey=3f18c87a-d62b-4eca-8ef4-9b09309c1c91

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