Department for Environment Food & Rural Affairs

Llywodraeth Cymru Welsh Government

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Environment Agency

# delivering benefits through evidence


# Cost estimation for channel management – summary of evidence

Report – SC080039/R3

Flood and Coastal Erosion Risk Management Research and Development Programme

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Miranda Kavanagh

**Director of Evidence**

# Executive summary

This summary of evidence provides indicative costs and guidance on a number of channel management and maintenance aspects for natural and engineered channels/banks.

| **Channel management** | | |
|---|---|---|
| Key cost components | Operation and maintenance costs can make up a large proportion of total revenue spend for organisations with responsibility to maintain channels. The most important cost components are therefore operational (inspection) and maintenance costs (de-silting, bank repairs, obstruction removal and so on).<br><br>Management of environmental features within channels can be a significant issue, resulting in additional costs.<br><br>Capital costs of new channels may be significant – the availability of unit costs for new channels is limited and will be highly variable. | |
| Key asset types | • Natural channels and banks<br>• Engineered channels and banks | |
| Data reviewed in specific guidance | Key reports and data sources include:<br>• Environment Agency Unit Cost Database (capital costs)<br>• Environment Agency Maintenance Standards (maintenance costs)<br>• limited information on unit costs for narrow new channels in the Environment Agency Unit Cost Database Estimating Guide<br>• IDB unit costs provided by the Shire Group of IDBs<br>• indicative costs and case studies associated with dredging<br>• SEPA indicative costs associated with hard and soft bank protection measures | |
| Other relevant data | Local or proxy records such as data from Environment Agency SAMPs and local authority information | |
| Relative cost importance | Enabling costs | Not applicable unless new channels are constructed. |
| | Capital costs | Not applicable unless new channel are constructed. |
| | Maintenance costs | Variable operation and maintenance costs are critical for channels relative to other cost elements. |
| | Other cost considerations | Variable costs. May need to consider dredging, bank restoration/reinforcement/repair costs. |

| | | |
|---|---|---|
| Cost estimation methodology | Initial concept/ national appraisal | Approximate O&M range of rates available |
| | Strategic, regional, or conceptual design | Approximate O&M range of rates available |
| | Preliminary feasibility/design | Costs built up using guidance to allow appraisers to define type and frequency of works. |
| Design life information | Not applicable unless hard engineering works are used to create a channel, in which case the design life of the materials/structures is relevant. | |
| Quality of data | Approximate unit rates for the maintenance aspects are available along with a number of historical data and reference projects.<br><br>Available data for unit costs are provided, although cost curve information is not available. Unit rates and examples from a number of sources are available. | |
| Additional guidance | Checklist of factors likely to influence maintenance costs and key factors to consider for detailed costs estimation<br><br>List of R&D and general design guidance | |

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# Contents

# 1 Flood mitigation measure – channel management

Channel management and maintenance works are performed on rural channels with natural banks and engineered channels by a range of organisations and for a range of flood risk and environmental aspects providing multiple benefits. The purpose of channel management and maintenance works is to:

- retain flow capacity and conveyance
- sustain riparian rights to the ordinary use of water flowing past their land
- manage water levels to sustain land functions
- retain and protect flora and fauna dependent or resident within the watercourse

Further general guidance on design and maintenance aspects are provided in the Environment Agency's Fluvial Design Guide. Additional links to research and more specific guidance are provided at the end of this evidence summary.

## 1.1 Data requirements

A number of standard cost parameters are required for channel management. These include the following aspects:

- capital costs of new channels (if applicable)
- operational costs (inspection)
- maintenance costs (de-silting, bank repairs, obstruction removal and so on)

Capital expenditure may be required where new channels are constructed such as part of a river realignment scheme, an existing channel is re-graded, bank slope stability is an issue or river restoration measures are necessary. While river restoration measures are covered elsewhere in the guidance, the capital costs associated with the construction of new channels are provided in this evidence summary.

There is also a link between riverbank protection and the use of bioengineering solutions that can provide alternative sustainable solutions for riverbank protection, bankside stabilisation and marginal vegetation habitats. The costs associated with these sorts of measures are provided in this evidence summary for completeness.

## 1.2 Channel and bank operation and maintenance

Channel maintenance costs as a percentage of total expenditure represented an average of 35% for all Internal Drainage Boards (IDBs) in the 2009-2010 financial year.[1] Some 46% of the estimated frequent maintenance activities identified for all Environment Agency System Asset Management Plans (SAMPs) for the 2010-2011

[1] Based on IDB1 returns for 2009-2010.

financial year related to maintaining channel conveyance. For medium and low consequence systems, this proportion increased to 52% and 61% respectively[2].

Channel and bank operation and maintenance (O&M) activities will include a number of inspection and maintenance activities. Maintenance activities will include both frequent and annual management aspects to maintain conveyance, as well as less intermittent activities such as dredging/de-silting.

Channel operation and maintenance costs vary according to the type of channel (open or engineered), the responsible authority (Environment Agency, local authority or IDB) and the target grade (including frequency of inspection/maintenance).

Channel inspection activities may include the following depending on the channel type and the flood risk associated with the watercourse:

- operational inspections (includes debris/blockage clearance where required)
- pre storm inspections to ensure watercourse is fully clear of debris or post flood inspections to check the need for urgent repair works (critical channels only)
- visual asset condition assessments (typically risk-based inspection frequency as a trigger for more detailed inspection)
- hydromorphological evaluations

Channel maintenance activities may include the following:

- weed control (by hand or mechanical means)
- obstruction removal
- bank clearance (including removal of small trees and shrubs)
- intermittent works such as bank protection, dredging and repairs

Previous national assessments (Environment Agency 2010a) estimated that:

- inspection costs were approximately £2 per metre
- engineered channel maintenance was £5 per metre
- natural channel maintenance was £2 per metre

It is not clear how these estimates were derived other than by engineering judgement. Newman (2007) noted that British Waterways carried out hydromorphological evaluations every six years on rivers at an estimated cost of £300–500 per km.

These values may be appropriate for very broad level analysis, although more recent studies (discussed in the following sections) provide additional detail that may be more suitable.

### 1.2.1 Environment Agency O&M costs

The annual O&M costs given in Tables 1.1 and 1.2 for natural and engineered watercourses respectively are based on Environment Agency Maintenance Standards (Environment Agency 2010b). Costs are provided for three target condition grades based on the Environment Agency Condition Assessment Manual (CAM) (Environment

[2] Based on SAMP-IT output provided by Linsay Hensman, December 2010.

Agency 2006). Costs for condition grade 1 (Very Good) are not provided as these are not standard asset management targets for the Environment Agency. These costs are derived from experience, contract rates and estimated rates for a range of activities. They represent indicative costs and provide a broad range of costs per year per watercourse length depending on the method of vegetation clearance. These costs in particular have very wide range, and careful estimation and determination of the appropriate costs for any given watercourse is required. The Environment Agency's recommended approach is discussed further below.

**Table 1.1 Open channel maintenance unit costs (£/km/year)**

| Target grade | Manual clearance | Mechanical clearance |
|---|---|---|
| Grade 2 | 2,830–25,345 | 830–8,445 |
| Grade 3 | 1,025–20,770 | 260–5,235 |
| Grade 4 | 710–5,035 | 120–1,210 |

Notes: Natural channels are those with natural banks, typically found in rural and suburban reaches.
Maintenance activities include grass control, weed control, tree work, operational inspections, reactive obstruction removal and de-silting.
Target grades vary from 1 (Very Good) to 5 (Very Poor).
Source: Environment Agency (2010b)

**Table 1.2 Engineered channel maintenance unit costs (£/km/year)**

| Target grade | Manual clearance | |
|---|---|---|
| Grade 2 | 985–6,040 | 830–5,330 |
| Grade 3 | 580–2,730 | 500–2375 |
| Grade 4 | 165–995 | 165–815 |

Notes: Engineered channels are those with an engineered bank made from materials such as concrete, brick, steel or timber. This type of channel is most likely to be present in urban reaches.
Maintenance activities include vegetation clearance and channel repair works, operational inspections, reactive obstruction removal and de-silting.
Source: Environment Agency (2010b)

As the range of costs for watercourse maintenance is very wide, the Environment Agency Maintenance Standards document recommends use of a weighting and scoring methodology to work out an appropriate point within the range based on the factors listed in Table 1.3 that influence O&M costs. These factors are based on judgement and expert opinion. Ongoing data reviews and cost capture of maintenance activities will help to inform this procedure in the future.

**Table 1.3 Weighting and scoring approach to work out appropriate cost within range**

| Factor influencing maintenance costs | Weight |
|---|---|
| **Natural watercourses** | |
| Difficult access (distance to work site, protected sites/species, overhead power cables) | 2 |
| Location known for excessive fly-tipping | 2 |
| Urban location with a greater requirement for reactive obstruction removal | 1 |
| Invasive weeds | 1 |
| Protected species which may require a more sensitive environmental option | 1 |
| **Engineered watercourses** | |
| Difficult access (distance to work-site, protected sites/species, overhead power cables) | 2 |
| Invasive weeds | 1 |
| Protected species which may require a more sensitive environmental option | 1 |

Notes: A score between 0 and 2 is given to each factor. Scores are multiplied by the weight to give a score between 0 and 14. A value of 0 corresponds to the lower end of the cost range and a value of 10 corresponds to the higher end of the unit cost range.
Source: Environment Agency (2010b)

### 1.2.2 IDB maintenance costs

Maintenance costs for IDBs account for approximately 30–45% of total expenditure (JBA 2006). The IDB Review project carried out in 2006 reviewed the average maintenance costs per km of watercourse for IDB maintained assets. The average costs per km were £660 for all IDB regions, but varied between £602 and £1,364 per km as shown in Table 1.4. Unfortunately no information on how these costs vary with condition of channel was available to investigate this relationship further.

This analysis was repeated four years' later using more up-to-date information provided by IDBs via the IDB1 forms submitted to Defra.[3] Average costs had increased over the period to £804 per km (Table 1.4). The maximum costs for any one IDB are in the region of £3,700 per km, although this may represent costs for dealing with one-off influences such as dealing with flood events or higher intermittent costs for certain years for example.

[3] Personal communication from Defra Flood Management Division.

**Table 1.4 Average maintenance costs per km**

| Category | 2004-2005 season | 2009-2010 season |
|---|---|---|
| All IDBs | £660 | £800 |
| Grouped IDBs | £600 | £780 |
| Standalone IDBs (income >£100,000) | £840 | £1,130 |
| Standalone IDBs (income <£100,000) | £460 | £380 |
| Environment Agency administered IDBs | £1,360 | £1,106 |

As part of this study, JBA Consulting reviewed data provided for 39 catchments managed for the Shire Group of IDBs. Annual watercourse maintenance expenditure for each of these catchments was assessed for the 2007-2010 period. Two types of catchments were chosen – those where the maintenance is carried out in-house and those where external contractors were used. Costs included all watercourse maintenance activities such as flailing and de-weeding. The cost of channel maintenance was found to vary significantly, with direct labour costs much higher than those of external contractors as shown in Table 1.5 and Figure 1.1.

**Table 1.5 IDB watercourse maintenance cost per km by method**

| | External contractors | IDB direct labour |
|---|---|---|
| Maximum | £1,595 | £2,071 |
| Minimum | £331 | £458 |
| Average | £542 | £1,836 |

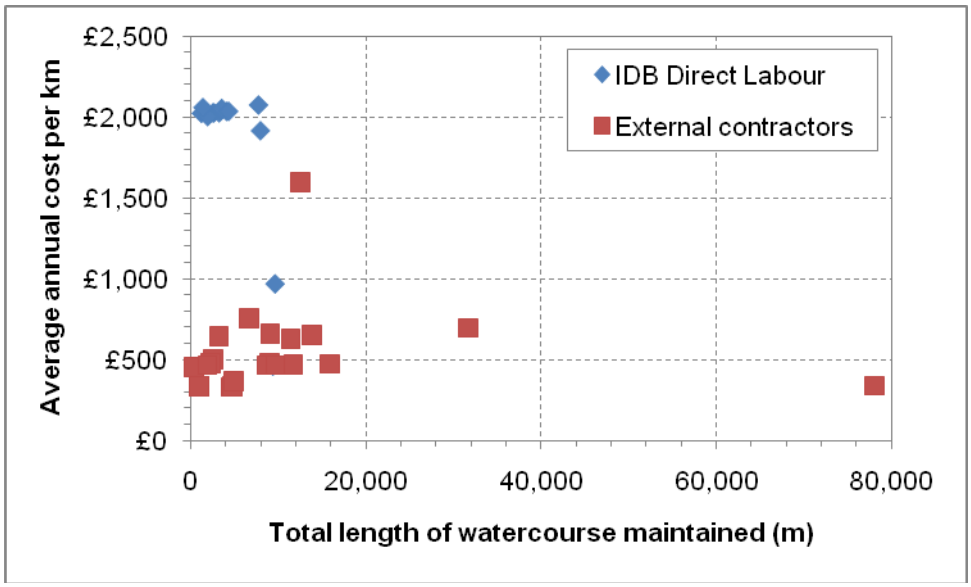



**Figure 1.1 Average annual costs per km by length of watercourse maintained**

The lower costs for maintenance work that is contracted out reflect the greater efficiency and better cost control by this method. An advantage of direct labour is easier availability. In addition, the employment of direct labour is not limited to just maintenance work on that particular District's watercourses and pumping stations; for

example, direct labour can be hired out to complete additional maintenance works for other IDBs and organisations.

### 1.2.3 Detailed O&M costs and guidance

O&M costs depend on:

- level of inspection and annual maintenance required
- type of watercourse

#### *Operational inspection frequencies*

Operational inspections are an essential component for setting maintenance targets. However, they can constitute a large long-term cost because of the requirement for trained inspectors to assess sites regularly to ensure that channels remain in good condition.

Channels and defence structures for which the Environment Agency is responsible for are assigned an inspection frequency for each river reach. Inspection frequencies vary from six to 24 months.

The determination of inspection frequency takes account of risk which considers both the consequence of failure and the probability of failure.

The consequence of failure is based on factors such as land use, population, environmental designations, topography and development proposals.

The probability of failure is influenced by the integrity of the defence (present condition, age, material, gaps, breaches and low spots) and likely deterioration rate (maintenance regime, residual life, vermin, channel conveyance and susceptibility to erosion).

#### *Annual maintenance costs*

Annual maintenance costs will depend principally on the type of activity undertaken as well as cutting frequencies, treatment with herbicides and the presence of invasive species.

Typical annual maintenance activities may include a number of generic aspects including:

- grass control
- weed control
- operational inspections and access to control structures, bridges and other locations where debris can accumulate
- removal of reactive obstruction

Typical channel maintenance activity frequency, as defined by the Environment Agency, is provided in its Maintenance Standards (Environment Agency 2010b) and summarised in Table 1.6.

**Table 1.6 Suggested annual maintenance activities and frequencies**

| Maintenance activities | Frequency |
|---|---|
| Grass control | 12 monthly to 3 yearly |
| Weed control | 6 monthly to 2 yearly |
| Reactive obstruction removal | 6 monthly to 5 yearly |

Source: Environment Agency (2010b)

### *Intermittent maintenance activities*

Intermittent activities cover a range of works that are not required every year, but are required intermittently to ensure conveyance and an appropriate watercourse condition relative to the risk associated with a particular watercourse.

Types of intermittent maintenance activities include:

- de-silting
- tree works
- bank slips and erosion control
- channel repairs
- structural or revetment repairs
- vermin control
- scour protection
- disposal of materials

Typical channel intermittent maintenance activity frequencies as defined by the Environment Agency are summarised in Table 1.7. No specific costs are available for these activities, although information provided by the SAMPs database may provide some useful information on these aspects.

**Table 1.7 Suggested intermittent maintenance activities and frequencies**

| Maintenance activities | Frequency |
|---|---|
| Tree work | 2 yearly to 5 yearly |
| De-silting/dredging | 12 monthly to 5 yearly or more |
| Minor channel repair works | 6 monthly to 2 yearly or more |

Source: Environment Agency (2010b)

It is recommended that the high level data provided in sections 1.2.1 and 1.2.2 are used except in situations where detailed costs are required to be built up from known inspection rates and standard or assumed workforce charge out rates. Some examples are provided below.

### *Tree works example*

Assumptions:

Two operatives @ £54 per hour

500 m per day

Rate = £54 × 8 x× 2 per km

Rate = £864 per km

### *Grass cutting example*

Assume the following:

One operative carries out mowing by tractor/flail @ £27 per hour plus £18 per hour for plant rate.

Rate of 0.5 km per hour

An additional 0.5 hour per km for travel between/within sites

Rate = £(27+18)/0.5 + (27+18)/2

Rate = £112.5 per km

Assume cutting is required twice per year.

Rate = £225 per km per year

## 1.3 Channel dredging

Although dredging for the purposes of flood risk management may not be applicable to most watercourses, cost evidence is provided here for completeness.

Watercourses are designated into two main categories – main river and ordinary watercourses – by the Land Drainage Act 1991 (as amended). The Environment Agency has responsibilities under the act to maintain main river and any ordinary watercourses which lie within an IDB or council district. Local authorities or IDBs, where they exist, have powers for ordinary watercourses that are similar to those on main rivers.

Canals are predominantly under the responsibility of British Waterways, but some costs on dredging are available that may be useful for cost estimation purposes. The Broads Authority is also responsible for 200 km of navigable inland waterways.

Although the requirement for dredging and de-silting varies significantly and is in decline, many of these watercourses require dredging at defined intervals – though the driver is dependent on factors such as siltation and navigation rather flood risk. The costs and disposal of the dredged material are seen to be the more technically challenging and expensive task, with disposal problems being magnified by increasing environmental and legislative constraints.

### 1.3.1 Dredging costs

Dredging costs identified in CIRIA's *Inland Dredging: Guidance on Good Practice* (Bates and Hooper 1993) based on information from British Waterways suggested a range of unit costs from £3 per $m^3$ for simple dredging and disposal to £50 per $m^3$ for complicated sites or those involving the treatment of contaminated sediments. Adjusting for inflation, these values range from £5 to £75 per $m^3$.

The costs of dredging will depend on the methodology used. A wide variety of dredging equipment and methodologies are available for use on inland waterways. Some will be more acceptable for particular applications than others. Machines such as hydraulic backhoes, draglines and grabs work from the bank and may travel on tracks. The alternative for larger watercourses is floating equipment that may include hydraulic backhoes and grabs, rope-operated grabs, bucket dredgers, suction dredgers, ploughs and water injection devices.

Costs will also be heavily dependent on the disposal and transport of material. Costs will clearly be lower when the dredged material is used for bankside spreading, spreading on agricultural land or to improve flood embankments, as opposed to the more expensive hauling or pumping to a dedicated waste disposal site.

Dredging costs defined by British Waterways in 2007 (Newman 2007) were £7 per $m^3$ with an upper limit of £20 per $m^3$. Collated unit costs for various dredging projects obtained in studies by the Broads Authority identified average costs of £12–15 per $m^3$ (Broads Authority 2006a,b).

In 2007 the Broads Authority undertook a proactive strategy to prioritise dredging of the Broads watercourses with the aim of balancing the inputs with outputs, while dealing with a backlog of accumulated sediment. The strategy reviewed the costs of dredging over the last 27 years and indicated that the costs of removal and disposal had increased from 60p per $m^3$ to £1 per $m^3$ in the early 1980s to an average of £13.8 per $m^3$ in 2007 (Broads Authority 2007). Maximum costs were found to be up to £30 per $m^3$ in some instances. The use of the 2007 average value may be of use for costing purposes if inflated to current prices as it compares well with the values suggested by the British Waterways and Broads Authority studies.

Additional costs of different dredging methods summarised from specific projects in a report by the Association of Inland Navigation Authorities (AINA) (AINA 2008). Table 1.8 provides indicative costs and examples for specific sites.

**Table 1.8 Indicative costs for channel dredging**

| Site/example | Cost (2007 values) | Comments |
|---|---|---|
| Floating dredger to navigation channel | £20,500–£27,400 per 500 $m^3$ | Based on Royal and Grand Canal. Based on information from Waterways Ireland. |
| Bank dredging | £55,000 per km reach | Disposal and waste analysis costs excluded. Based on information from Waterways Ireland. |
| Low turbidity (suction dredging) | £12 per $m^3$ | Includes costs to construct lagoons to dewater silt. Based on information from Broads Authority. |

Source: AINA (2008)

### 1.3.2 Detailed cost estimate guidance

Since the methods of dredging tend to be site-specific, it is not possible to provide meaningful relative unit costs for a site. Instead it is suggested that the unit cost of dredging can be found by dividing the total hourly cost of the machine by the average hourly production. Total hourly cost can be taken by the hire rate including operator, or for an owned machine, costs will consist of all relevant cost elements including fixed financial charges.

Hourly production rates and further guidance can be found in CIRIA 169 report (CIRIA 1997). However, final decisions should only be based on production and cost estimates made by suitably experienced staff. Table 1.9 provides guidance on the factors that will influence costs.

**Table 1.9 Key factors affecting channel management costs**

| Factor | Impact on cost estimation |
|---|---|
| Administration | Costs associated with landowner and stakeholder consents and environmental impact studies. |
| Disposal | Simply removing material from beneath water may only be a small part of the overall costs. Treatment and disposal will increase costs. |
| | Transport methods and haul distances will also have an important economic influence. |
| Access | Access restrictions are commonly caused by weak ground, physical obstruction, growing crops or grazing cattle. |
| Debris | Watercourse debris can restrict the range of dredging methods and disposal options. |
| Contamination of material | Material that contains a significant level of contamination must be disposed of in an approved manner at an appropriate licensed disposal site. |
| | Treatment can be expensive, but may remove or reduce contamination to a level which permits an alternative disposal option that may reduce the overall cost of disposal. |
| | Indicative costs associated with decontamination from US data are summarised in an HR Wallingford report (Burt and Fletcher 1999). |
| Mobilisation and travel | Cost will depend on the length of travel. If the route is short and free of constrictions, then costs may be competitive with land-based plant. Slow rates of travel or long distances will result in higher costs. |
| Method of dredging | Floating machines are usually more expensive than tracked or wheeled machines which work from the land. |
| Capacity of the excavating bucket | Influences the average rate of production. |

### 1.3.3 Dredging example

A trial by the Boards Authority on water injection dredging was carried out in 2008 with removal of 6,200 $m^3$ of sediment from the Lower Bure area (Broads Authority 2006a). This technique involves introducing low-pressure water into the surface sediments on the river bed, which fluidises the material in a high density plume. The material, acting under the influences of differential density, gravity and flow will move along the bed into deeper water and eventually be dispersed to sea.

The trial works were estimated to take eight days to complete at a cost £30,000, achieving a unit cost of £4.84 per $m^3$. The authors of this report suggest that this is around a third of the average unit cost for dredging projects in the Broads system – assuming that an appropriate disposal site can be found within 30 minutes' travel of the dredging site.

## 1.4 Capital costs associated with new channels

There may be initial procurement and capital costs that cover the initial stages of the project. Items that may need to be determined include:

- professional fees – initial survey, appraisal, design and environmental appraisal
- consultation including planning, management and agreements
- licences and consents – planning permission, land drainage consent and others

Estimated capital costs associated with new channels are available in the 2007 version of the Environment Agency's *Flood Risk Management Estimating Guide* (Environment Agency 2007). These costs were excluded from the 2010 update.

Indicative costs per metre are available for earth and lined (with concrete/brickwork) channels for a range of channel lengths. The costs are based on out-turn costs from a total of 19 projects to construct new channels and include all associated works such as excavation, formation, turfing/seeding, and disposal of material. The data are restricted in that they do not provide costs that vary with the depth and width of the channel, and this is a key factor.

The examples are associated with average channel widths of 6 m for earth channels and 3 m for hard channels. The costs provided in Tables 1.10 and 1.11 should therefore be used with caution for channels in excess of these widths. It is recommended that these costs are used only for preliminary or high level cost appraisals and that more detailed specific costs are determined for more detailed determination of costs.

**Table 1.10 Unit costs for new channel construction**

| Length | Earth (£/m length) | Hard (£/m length) |
|---|---|---|
| 50 | 7,200 | 4,700 |
| 250 | 1,300 | 1,200 |
| 500 | 600 | 700 |

| Length | Earth (£/m length) | Hard (£/m length) |
|---|---|---|
| 1,000 | 300 | 400 |
| 1,500 | 200 | 300 |
| 2,000 | 200 | 200 |
| 2,500 | 100 | 200 |

Notes: Earth channels represent those that are unlined.
Hard channels represent channels that are lined with concrete, brickwork and so on.
Costs relate to March 2006 prices.
Source: Environment Agency (2007)

*Estimating Costs of Delivering the River Restoration Element of the SSSI PSA Target* (Environment Agency 2008) defined a methodology and tool[4] to determine the costs associated with re-meandering to restore geomorphologically appropriate channel geometry to heavily modified and straightened channels. This provided an estimated cost for the creation of a new meandering channel based on certain assumptions. The estimated cost associated with excavation a theoretical 20 m wide and 1.5 m deep channel was £1,509 per metre. Assuming a third of all material is to be excavated off site and sent to landfill; the most significant aspect of excavation costs is associated with removal of excavated material.

The costs above and the assumptions used in the study represent the costs associated with the excavation costs only. Additional costs such as the additional of suitable gravel bed material, bank protection, site supervision and contractor overheads, and associated studies, design, planning and negotiation will also be required. Using the tool provided and based on the same assumptions, Table 1.11 provides estimated costs for alternative channel widths.

**Table 1.11 Estimated channel excavation costs**

| Channel width | Channel depth | Cost per metre | |
|---|---|---|---|
| | | Assuming 33% disposal off-site | Assuming 0% disposal off-site |
| 20 | 1.5 | £1,510 | £320 |
| 10 | 1.5 | £500 | £110 |
| 5 | 1 | £250 | £50 |

Notes: Based on Environment Agency cost estimation spreadsheet used for the Environment Agency SSSI PSA target report

Table 1.11 provides a useful tool with which to work out the relative variations in the costs associated with new channels. Although it does not provide costs based on real out-turn costs, it may be useful for indicative assessments for river restoration or new channel design estimates at a broad or early stage in a design assessment.

[4] Personal communication from Duncan Huggett, Environment Agency, and Jenny Wheeldon, Natural England.

### 1.4.1 Detailed capital cost guidance

Costs based on the high level analysis can be used to obtain indicative costs in the first instance of a long term cost estimate. More detailed analysis will require costs to be determined from price estimating books, previous experience or from tender returns at the design stage of an analysis.

Costs may include:

- materials (including supply, delivery, unloading, storage)
- contractor costs (labour, plant, site establishment, temporary works)
- supervision and professional fees
- waste disposal
- land purchase/compensation

Table 1.2 shows a typical breakdown of work elements for new channel structures.

**Table 1.12 Typical work items for new channels**

| New earth channels | New channel with brickwork/masonry cladding |
|---|---|
| Mobilisation and demobilisation | Mobilisation and demobilisation |
| Water management, cofferdam and over-pumping requirements | Water management, cofferdam and over-pumping requirements |
| Site clearance | Site clearance |
| Strip and stockpile topsoil | Strip and stockpile topsoil |
| Excavation | Excavation |
| Disposal of excavated material | Disposal of excavated material |
| Formation of channel bed and sloping surfaces | Preparation of formation |
| Timber (or similar) revetment and stone drainage | Membrane |
| Topsoiling to sloping surfaces | Provide and place blinding |
| Topsoiling/lining to channel bed | Vertical formwork to sides of base and wall |
| Turfing to sloping surface | Reinforcing bar (rebar) |
| Seeding sloping surface and working strip | Place reinforced concrete to base and walls |
| | Invert surface finishes |
| | Brickwork/masonry cover to wall |
| | Selected wall backfill |
| | Drainage and flapped outfalls |
| | Coping stones and handrails if required |

Additional items that may need to be considered include:

- welfare facilities, security, signage and fencing (health and safety aspects)
- preliminaries and contingencies
- site agent and supervision
- contractor overheads, profit and insurances

Items that may increase costs or reduce on-site progress should also be considered. Table 1.13 lists the most important factors influencing costs.

**Table 1.13 Key factors affecting new channel capital costs**

| Factor | Impact on cost estimation |
|---|---|
| Access constraints | Urban/rural locations, distance to site, confined working conditions, ease of movement along site, need for temporary access. |
| Geomorphological appraisal | Significant risk of unforeseen channel changes (with potential adverse habitat implications) if geomorphological appraisal is not incorporated. |
| Size and shape of channel | Size (width and depth of channel will impact on costs. |
| | Typical costs from price estimating books may not be applicable for short lengths. |
| | Efficiency savings may apply for longer reaches. |
| Bed materials | Type of bed materials will impact upon costs. |
| Disposal of material | Disposal off-site may double the project estimate. |
| Weather and flood risk/damage | Winter working will influence productivity and on-site works duration. |
| | Flood risk to a site during construction will impact upon costs and insurance. |
| Tidal working conditions | Tidal working conditions will effect on site productivity and affect normal output/progress. |

## 1.5 Bank protection measures

Bank protection measures may be required for watercourses that are currently in poor condition and require additional works to ensure conveyance and reduced long-term maintenance issues. It is anticipated that bank protection measures would be required as part of a whole life cost estimate for:

- new channels (if required)
- channels that are currently in a poor condition and in need of reinstatement works

Ongoing maintenance should maintain channels at a certain standard before any significant bank protection measures are required – unless external pressures on a watercourse have reduced channel and bank conditions to the point that remedial actions are required.

### 1.5.1 Hard bank reinforcement and revetment

Hard bank reinforcement and revetments are used to protect banks and beds of rivers against erosion. The methods that might be used also include gravity walls and piling, which are covered elsewhere and excluded from this evidence summary.

These types of revetment are often termed ‘engineered’, ‘hard’ or ‘grey bank’ as opposed to the soft bank protection measures discussed in the next section.

A good guide to river revetments is given by Escarameia (1998). However, relative or unit costs associated with each type are not available.

Hard bank revetments may be constructed using a number of materials and methods that include:

- rock (riprap, block stone, hand pitched stone, grouted stone)
- gabions (box, mattress, rock rolls)
- block revetments (loose/interlocking and linked)
- timber revetments

Factors to consider include:

- hydraulic (flow and velocity)
- waves
- flow at bends
- tidal aspects
- high turbulence impacts
- environmental, geotechnical, construction and maintenance aspects

Limited costs associated with hard bank reinforcement and revetments are available, although the summary data given in Table 1.14 have been collated from a number of projects and case study examples.

**Table 1.14 Indicative hard bank reinforcement costs**

| Technique | Approximate cost guide | Source and comments |
|---|---|---|
| Stone rip rap | £26 per m | AINA (2008) based on information from British Waterways (2007 data) |
| Rock rolls | £46 per m | AINA (2008) based on information from British Waterways (2007 data) |
| Stone gabions | £250 per m | AINA (2008) based on information from British Waterways (2007 data) |
| General hard reinforcement costs | £1,075 per m | SNIFFER (2005)<br>Generalised costs for concrete, laid stone, gabion baskets and riprap protection. |
| Gabion baskets | £50–65 per $m^3$ | SNIFFER (2007) |
| Gabions | £1,216 per m | Environment Agency (2008) based on an average revetment volume of 16 $m^3$ per m |

| Technique | Approximate cost guide | Source and comments |
|---|---|---|
| | | and a unit cost of £76 per $m^3$. |
| Rock gabions | £50–70 per $m^2$ | SEPA (2008) |
| Timber piling | £160 per m | AINA (2008) based on information from British Waterways (2007 data) |
| Non-live timber revetment | £100–350 per $m^2$ | SEPA (2008) |
| Riprap | £60–150 per $m^2$ | SEPA (2008) |

### 1.5.2 Soft bank reinforcement

A number of bank protection measures are increasingly being applied for intermittent repair works in typically rural, lowland (low energy) environments. Methods employed may improve environmental aspects or minimise environmental impacts via the use of natural and/or biodegradable materials. These options are often referred to as 'green bank' or bioengineering protection methods and may represent more sustainable solutions.

Bioengineering solutions can offer a cost-effective and sustainable alternative to problems that would traditionally have been approached with hard engineering solutions.

Methods include:

- surface protection such as woven branches or brush, brush mattresses, rolls of living or dead brush, coir rolls or matting, revegetation using biodegradable geotextiles
- toe protection – woven branches; rock, logs or other materials resistant to erosive flows placed at the bank toe
- bank modification using soft methods (re-profiling without raising the bank height; filling holes with layers of branches, brush and compacted earth; increasing bank strength using root-wads)
- timber revetments

#### *Unit cost estimates*

Various costs found in the literature suggest variable costs for these sorts of measures of between £50 and £150 per metre depending on type and approach used. These are typically cheaper than hard engineering alternatives. Sources of information include case studies from the River Restoration Manual (RRC 2002), SEPA guidance on bank protection measures (SEPA 2008) and a review of costs carried out for the AINA study (AINA 2008). These costs are summarised in Table 1.15 and provide some examples and specific case studies for these works.

**Table 1.15 Indicative soft bank reinforcement costs**

| Technique | Approximate cost guide | Source and comments |
|---|---|---|
| Re-profiling, willow spilling, hazel faggots and willow mattress revetment | £300–900 per m | AINA (2008) based on information from British Waterways (2007 data)<br>Additional 30% costs required for feasibility and design. |
| Hazel faggots | £30 per m | AINA (2008) based on information from British Waterways (2007 data) |
| Willow hurdle revetment | £40 per m | AINA (2008) based on RRC case study for a 119 m length project (1995 data) |
| Coil rolls | £37.5 per m | AINA (2008) based on information from British Waterways (2007 data) |
| Plant roll | £130 per m | AINA (2008) based on RRC case study for a 119 m length project (1996 data) |
| Pocket fabric revetment for reed establishment | £100–£200 per m | AINA (2008) based on information from British Waterways |
| Willow spilling | £115 per m | RRC (2002) based on a 75 m length (1996 data) |
| Willow mattress revetment | £164 per m | RRC (2002) based on a 59 m length (1995 data) |
| Log toe and geotextile revetment | £146 per m | RRC (2002) based on a 91 m length (1995 data) |
| Grass and Reed Planting | £100–200 per $m^2$ | SEPA (2008) |
| Live Woody Revetment | £115–125 per m | SEPA (2008) |
| Faggots | £50–120 per m | SEPA (2008) |
| Geotextile | £160 per m | SEPA (2008) |

A number of consultants offer bioengineering solutions for flood and riverbank protection, bankside stabilisation and restoration and/or the provision of riparian, marginal and aquatic vegetative habitats. Salix River & Wetland Services Limited (www.salixrw.com) agreed to provide indicative costs and case study information for the application of its bioengineering products and services to flood protection, river restoration and habitat restoration/creation works. The company has a range of products for use in bioengineered designs, many of which are based on specific vegetation types selected for application in this environment. Examples of costs for supply and installation are provided in Table 1.16.

**Table 1.16 Soft bank reinforcement supply and installation costs**

| Product | Supply unit cost | Install unit cost | Total |
|---|---|---|---|
| Willow spilling | £40–£60 per m | £40–£60 per m | £80–£120 per m |
| Willow brush mattress | £20–£40 per m | £30–£60 per m | £50–£100 per m |
| Live willow faggot/fascine | £7–£10 per m | £10–£20 per m | £17–£30 per m |
| Coir rolls (planted with suitable vegetation) | £18–£25 per m | £8–£15 per m | £26–£40 per m |
| Coir pallet (planted with suitable vegetation) | £18–£25 per m | £5–£10 per m | £23–£35 per m |
| Coir roll (unplanted) | £10–£15 per m | £7–£12 per m | £17–£27 per m |
| Deadwood faggots/fascines | £7m–£10 per m | £10–£20 | £17–£30 per m |
| Plug planting | £4–£7 per m | £3–£5 per m | £7–£12 per m |
| Rock roll | £18–£24 per m | £18–£24 per m | £26–£44 per m |
| Biodegradable coir blanket | £1.50–£2.50 per $m^2$ | £1–£1.5 per $m^2$ | £2.5–£4 per $m^2$ |
| Permanent synthetic geomat | £4–£8 per $m^2$ | £4–£8 per m | £5–£10 per m |

Source: Salix River & Wetland Services Limited

In terms of the bioengineering design elements, indicative costs are given in Table 1.17.

**Table 1.17 Indicative costs for bioengineering design elements**

| Design element | Indicative cost |
|---|---|
| Walkover survey | £1,000–2,000 per 500 m reach |
| Geomorphology survey | £3,000–10,000 per 500 m reach |
| Indicative design | £500–2,000 |
| Detailed design | £2,000–15,000 |

Source: Salix River & Wetland Services Limited

The costs of mobilising machinery, welfare and/or fencing are not included in Table 1.17. These items would typically range from £1,000 to £5,000 for a £20,000–40,000 project. Some examples are provided in the case study section.

## 1.6 Hard bank decommissioning costs

There is growing interest in removing engineered materials and restoring channels to a natural state because of the potential improvement to river habitats. Such restoration options may include the complete removal of reinforcement materials where this does not compromise other river processes such as erosion. In many cases removal requires the addition of some form of soft engineering as described above.

Estimated indicative costs associated with the removal of hard bank reinforcement are summarised in Table 1.17. However, these represent very generic costs that were developed for national level appraisals only. For anything other than national level studies, it is recommended that more detailed costs estimates are obtained by determining the extraction unit costs and productivity rates.

**Table 1.18 Indicative hard bank decommissioning costs**

| Technique | Approximate cost guide | Source |
|---|---|---|
| Removal of hard engineering | Low – £70,000 per km | SNIFFER (2005) |
| | Medium – £80,000 per km | |
| | High – £120,000 per km | |
| Riverbed restoration – re-introduction of natural formations such as boulders or gravel | Low – £5,000 per km | Entec (2008) |
| | Medium – £15,000 per km | |
| | High – £25,000 per km | |
| Bank works – re-profiling of banks to encourage natural vegetation | Low – £14,000 per km | Entec (2008) |
| | Medium – £20,000 per km | |
| | High – £40,000 per km | |

## 1.7 Other cost estimation requirements

In addition to the cost estimates detailed above, other parameters are required to ensure whole life costs are defined correctly for incorporation in an appraisal. The design life and discount rates are used to convert future costs over a scheme life to 'present values' so that they can be compared against the benefits.

### 1.7.1 Appraisal period/design life

The design life is typically defined as the minimum length of time that a scheme is required to perform its intended function. The design life for appraisals is typically taken to be 100 years, though alternative periods can be used.

The design life is also an important consideration in whole life costing as component assets of a design may have a shorter service life and not be last as long as the design life. This has implications for cost estimates to ensure that a whole life cost estimate correctly identifies all long-term maintenance and asset replacement costs over the intended appraisal period.

If no maintenance or intervention is undertaken, a channel banks and bed conditions will deteriorate over time. Good maintenance will ensure that a channel asset will

remain in perpetuity throughout an appraisal period. Where deterioration rates may be useful is for intermittent activities associated with bank repair and protection works.

Channel and bank deterioration rates and the need for repair and protection works will depend on:

- local conditions
- morphological aspects particular to a site
- degree of maintenance carried out
- type of channel and bank protection available

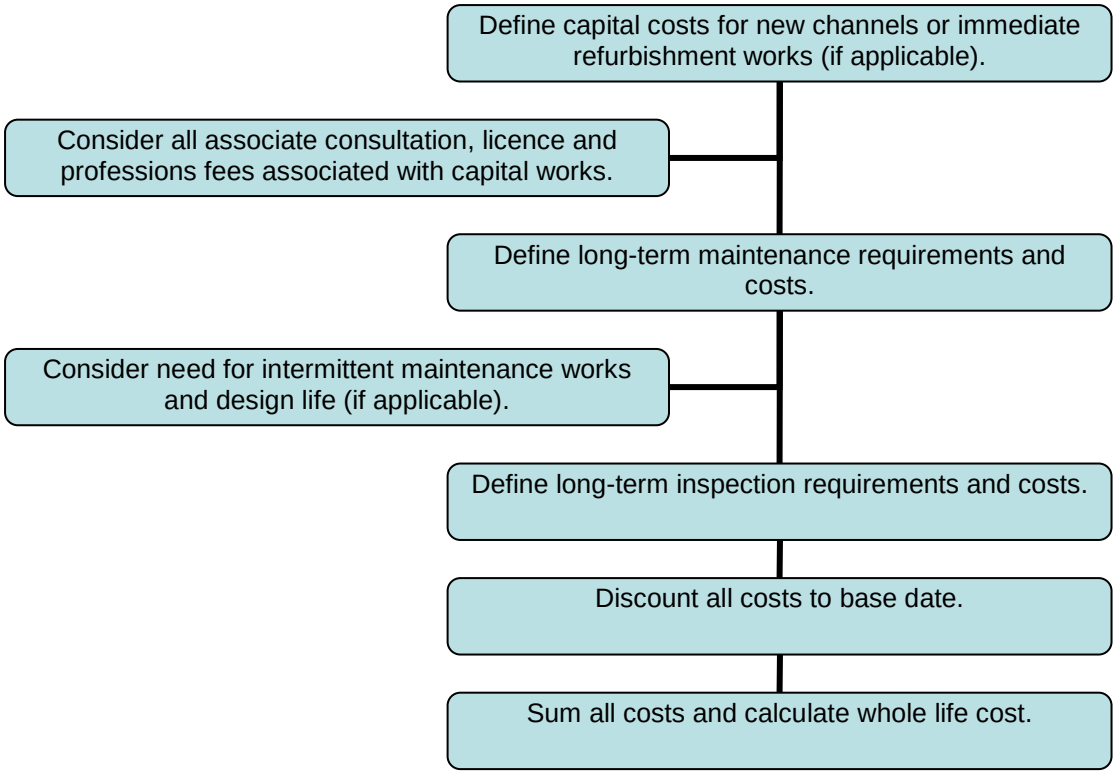
It is recommended that specialist or local knowledge is used to help define whether these works should be included within a cost estimate and the intermittent period of this type of work.

SEPA (2008) suggests that established green bank protection will typically have a design life of more than 10 years.

## 1.8 Cost estimation methodology

Figure 1.2 shows the key aspects required to provide a whole life cost estimate new or existing channels.

**Figure 1.2 Flow diagram for channel whole life costs**



## 1.9 Case studies

The three case studies presented below provide illustrate indicative costs and approaches to channel management. These examples could be developed into whole life costs examples through the addition of longer term maintenance activities and derivation of present value costs.

A further case study on the River Nith in Ayrshire in Scotland features a new clay-lined 3 km river channel (river diversion) completed in 2000 at a cost of £3.3 million (2000 prices), which equates to £1,100 per metre. Full details are available in the *Manual of River Restoration Techniques* (http://www.therrc.co.uk/pdata/pdfs/p449.pdf).

### 1.9.1 Bioengineering at Gwendraeth Fawr, Carmarthenshire, Wales

Salix was asked by main contractor, NACAP Land & Marine, to assess the potential for using a bioengineering solution to control the eroding riverbanks and bare ground along a 50 m reach of the Gwendraeth Fawr in Carmarthenshire where erosion had been a problem before a new pipeline crossing of the stream. Initially a blockstone revetment was considered before it was agreed that a bioengineering solution would work (Figure 1.3).

The bioengineering design solution involved locally harvested willow material which was used as live stakes and the thinner branches used to form live fascines (faggots). A double rock roll was placed at the toe to prevent the willow plantings from being undercut and to protect against abrasion from the mobile gravel/cobble bedload.

Erosion control and toe protection

Live willow fascines

Established bankside vegetation (one-year later)

**Figure 1.3 Bioengineering on the Gwendraeth Fawr**

The overall cost of these works was about £22,000. This was made up of £1,000 for site assessment, £2,000 for design work, £11,000 of the bioengineering products and materials used and £8,000 to install.

### 1.9.2 Bioengineering on the River Pinn, Ickenham, Uxbridge

Salix was asked by the main contractor, Murphy Pipelines, to assess a degraded reach of the River Pinn near Ickenham with the goal of enhancing the reach's morphology and habitat. The channel had been modified previously and was characterised by slow water flow, being over deep and ponded with a silty bed and steep banks covered in nettles (Figure 1.4).

Salix designed and constructed a 40 metre enhanced channel. Imported flint reject stone was used to create in-channel features, two riffles and a point bar. The gravel has concentrated the low flows and revived water flow in the reach. Diverse marginal and bankside vegetation was established using mature pre-established coir rolls and pallets. Locally harvested tree trunks were used to create a double flow deflector. Additionally, a large backwater was created on line and just downstream of the enhanced reach.

Steep eroding banks

Re-profiled banks and installing pre-vegetated coir pallets

Established vegetation (five months later)

**Figure 1.4 Bioengineering on the River Pinn**

The overall cost of these works was about £26,000. This was made up of £1,000 for site assessment, £2,000 for design work, £12,000 for the bioengineering products and materials used, and £11,000 to install.

### 1.9.3 Bioengineering on the River Ebbw, Risca, Wales

Salix worked with consulting geotechnical engineers to provide design and build proposals to stabilise over 1,000 metres of steep riverbank made up of highly erodible colliery shale. Initial proposals looked at the extensive use of large blockstone to stabilise the bank. Salix proposed a cost-effective bioengineering solution that offered underlying engineering stability while providing an ecological resource and improving the visual landscape (Figure 1.5).

The toe of the river bank was protected using a combination of rock rolls and living willow brushwood faggots. The upper bank was protected using two high-performance erosion control mats. Before laying the matting, the re-profiled upper banks were seeded with a reclamation mix of grass and legume species.

Erosion control matting and toe protection (rock roll and willow brushwood faggots)

Established vegetation (one year later)

**Figure 1.5 Bioengineering on the River Ebbw**

The overall cost of these works was about £250,000. This was made up of £1,000 for site assessment, £15,000 for design work, £125,000 for the bioengineering products and materials used, and £120,000 to install.

## 1.10 Checklist

Use the checklist to:

- identify the key cost elements required for watercourses
- ensure all relevant whole life costs are incorporated into the cost estimate

**Whole life cost estimate checklist for channel management**

| Item | Description | Frequency | Comments |
|---|---|---|---|
| **Planning costs** | | | |
| Professional fees | Initial appraisal and design costs | One-off | Only associated with new channels or diversions |
| Consultation | Including planning, management and agreements | One-off | |
| Licences and consents | Planning permission, land drainage consent and others | One-off | |
| **Capital** | | | |
| Capital costs | Associated with new channels or re-diversions if applicable | One-off | |
| Decommissioning costs | Decommissioning of bank protection works or channel structures | One-off | |
| **Operation and maintenance** | | | |
| Inspections | Asset condition and operational inspections | Annual | |
| Annual maintenance | Frequent or annual works associated with weed control, bank clearance and obstruction removal | Annual | Costs for bank clearance only relevant if not included as part of embankment costs |
| Intermittent maintenance | Intermittent works such as bank protection, scour protection and dredging | Intermittent | |

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