



Department
for Environment
Food & Rural Affairs



Llywodraeth Cymru
Welsh Government



Cyfoeth
Naturiol
Cymru
Natural
Resources
Wales



Environment
Agency

delivering benefits through evidence



Long term costing tool: summary of evidence on cost estimation

Report – SC080039/R1

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

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

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

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

This report is the result of research commissioned by the Environment Agency's Evidence Directorate and funded by the joint Flood and Coastal Erosion Risk Management Research and Development Programme.

Published by:

Environment Agency, Horizon House, Deanery Road, Bristol, BS1 5AH

www.environment-agency.gov.uk

ISBN: 978-1-84911-357-1

© Environment Agency – March 2015

All rights reserved. This document may be reproduced with prior permission of the Environment Agency.

The views and statements expressed in this report are those of the author alone. The views or statements expressed in this publication do not necessarily represent the views of the Environment Agency and the Environment Agency cannot accept any responsibility for such views or statements.

Email: fcerm.evidence@environment-agency.gov.uk

Further copies of this report are available from our publications catalogue:

www.gov.uk/government/publications

or our National Customer Contact Centre:
T: 03708 506506

Email: enquiries@environment-agency.gov.uk

Author(s):

Angus Pettit, JBA Consulting
Kevin Keating, JBA Consulting

Dissemination Status:

Publicly available

Keywords:

Whole life costing, cost estimation, flood risk management

Research Contractor:

JBA Consulting
South Barn, Broughton Hall, Skipton
North Yorkshire BD23 3AE
01756 799919

Environment Agency's Project Manager:

Adam Baylis, Evidence Directorate

Collaborator(s):

John Chatterton

Project Number:

SC080039/R1

Evidence at the Environment Agency

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

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

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

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

Miranda Kavanagh

Director of Evidence

Executive summary

This project aims to improve understanding of the implementation of whole life costing in flood risk management and to draw together a number of sources of data and guidance to inform practitioners performing cost estimation. Guidance, indicative data and tools to estimate the costs of flood risk management options are relatively undeveloped even though the Environment Agency has a number of assessment tools with which to estimate the risk and benefits. Practitioners need to understand the costs as well as the benefits to support efficient and effective management options.

The project had two parts.

The first part summarised the evidence and guidance on cost estimation procedures and best practice to educate and guide users involved in cost estimation for flood and coastal risk management. It is hoped this will complement the existing information on damage estimation and project appraisal processes (Multi-Coloured Manual and FCERM-Appraisal Guidance). More specific evidence summaries on a range of flood risk management intervention measures were also produced.

The second part involved the development of a cost estimation tool to support studies requiring cost estimation that is proportional and which complements estimated flood damage outputs. This tool will help appraisers in cost estimation for flood risk measures at the broad scale by extracting cost information from readily available sources and the necessary provision to collate whole life costs for a scenario or policy decision. The tool is available as a Microsoft® Excel spreadsheet.

This report presents the results of the first part of the project. It provides a summary of evidence on the process of cost estimation and provides a summary of guidance and methodologies applicable to flood risk management in the UK. The document also contains a set of 13 evidence summaries for a range of specific flood mitigation measures. The range of flood risk management assets and intervention measures covered by these evidence summaries is as follows:

- fluvial linear defences
- channel management
- culverts
- control assets
- flood storage
- coastal erosion and protection
- managed realignment
- SuDS and urban drainage
- temporary and demountable barriers
- household flood protection
- land use and run-off management
- flood warning and forecasting
- habitat creation

These appendices provide a summary of readily derivable data to allow appraisers to collate unit costs to generate capital and maintenance costs over a project life/appraisal period. Each summary contains information on:

- the types of assets/flood risk measures covered
- available data and unit costs
- guidance and considerations required for cost estimation
- links to relevant R&D and design guidance

Acknowledgements

The authors wish to thank the Project Board (Ian Meadowcroft, Lindsay Hensman and Adam Baylis) and the Environment Agency, local authority and Internal Drainage Board representatives and operational staff who were consulted.

Contents

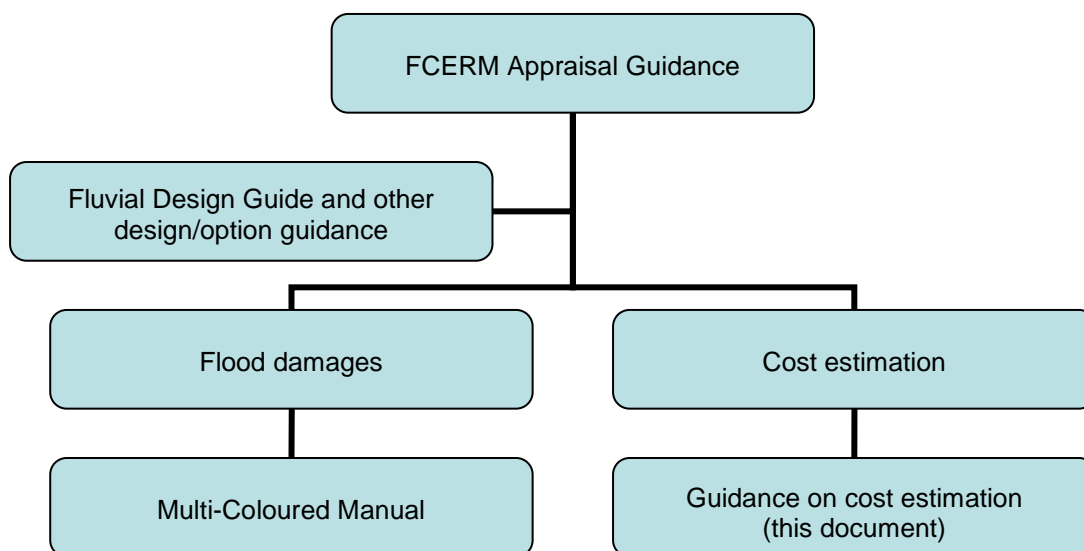
1	Cost estimation – summary of evidence and guidance	1
1.1	The importance of whole life costing	1
1.2	Introduction to the appraisal process and where cost estimation fits in	2
1.3	Target audience	5
1.4	How to use the guidance	6
1.5	Supporting guidance and data sources	7
2	Whole life costing	10
2.1	Definition of whole life costing	10
2.2	Whole life cost methodology	11
2.3	Generic cost types and data requirements for WLC	13
2.4	Other factors	19
3	Uncertainty	23
3.1	Uncertainties in WLC estimation	23
3.2	Uncertainty assessment	23
3.3	Risk analysis	24
3.4	Sensitivity and scenario testing	25
3.5	Contingency and ‘optimism bias’	26
4	Cost types and decisions	27
4.1	Types of flood and coastal erosion management interventions	27
4.2	Overview of FRM evidence summaries documents	28
	References	32
	List of abbreviations	34
	Glossary	36
Table 1.1	Cost estimation methodologies at different appraisal stages	4
Table 1.2	Portfolio of flood risk management measures	6
Table 1.3	Supporting guidance/documents	7
Table 2.1	Fees as a proportion of scheme costs	14
Table 2.2	Current Treasury long-term discount rates	20
Table 2.3	Example calculation of discounted costs	20
Table 3.1	Example qualitative cost weighting	24
Table 4.1	Types of flood risk management measures	28
Figure 1.1	FCERM Appraisal Guidance, flood damages and cost estimation	1
Figure 1.2	The appraisal process	3
Figure 2.1	Conceptual schematic of whole life costs	10
Figure 2.2	Whole life cost estimation procedure	12

1 Cost estimation – summary of evidence and guidance

The process of whole life costing (WLC) fits within the broader process of appraisal for flood and coastal erosion risk management in England and Wales. Appraisal of flood risk management measures is required to ensure that the works carried out are worthwhile – against economic and whatever other objectives happen to be relevant – and the choice of option is sound. Whole life cost estimation is critical for this appraisal.

This document provides an evidence summary and guidance on whole life cost estimation procedures and best practice to inform and guide users. It is intended to complement the existing information on damage estimation provided by the Multi-Coloured Manual (MCM) and Multi-Coloured Handbook (MCH) produced by the Flood Hazard Research Centre at Middlesex University (Penning-Rowse et al. 2013a,b) and project appraisal guidance provided by *Flood and Coastal Erosion Risk Management Appraisal Guidance (FCERM-AG)* (Environment Agency 2010a). Figure 1.1 shows how this document fits into the framework of guidance.

Figure 1.1 FCERM Appraisal Guidance, flood damages and cost estimation



The appraisal process for flood risk management in the UK has a number of assessment tools to estimate the risk and benefits of flood risk management options. However, the tools to estimate costs and guidance on methodologies are relatively undeveloped. Practitioners need to understand the costs as well as the benefits to support efficient and effective management options. This summary of evidence aims to fill the gap in the availability and collation of cost estimation guidance and cost information.

1.1 The importance of whole life costing

In terms of flood risk management, whole life cost estimation is a process that helps to combine cost elements incurred over time for different asset types and alternative approaches to flood risk management (FRM) intervention. Whole life costing in the decision-making process assists the whole systems approach to sustainable asset management and future investment planning.

The use of whole life cost estimation procedures will help to achieve the following aims for flood and coastal erosion management:

- good decision-making about FRM options
- continuous improvement in efficient and cost-effective design
- help ensure that assets remain appropriate to changing conditions and contribute to the management of flood and coastal erosion risk
- encourage planning for the decommissioning of an asset during its inception

Whole life costing is an essential tool to help manage future and ongoing costs associated with capital and revenue/operational costs, and to help make informed choices between different approaches of delivering an option that meets the needs of communities at risk. The choice is often one between high capital and low maintenance or vice versa, and the use of whole life costing and the consistent comparison between options allows an economic valuation of these aspects to be considered and encourages efficient resource allocation.

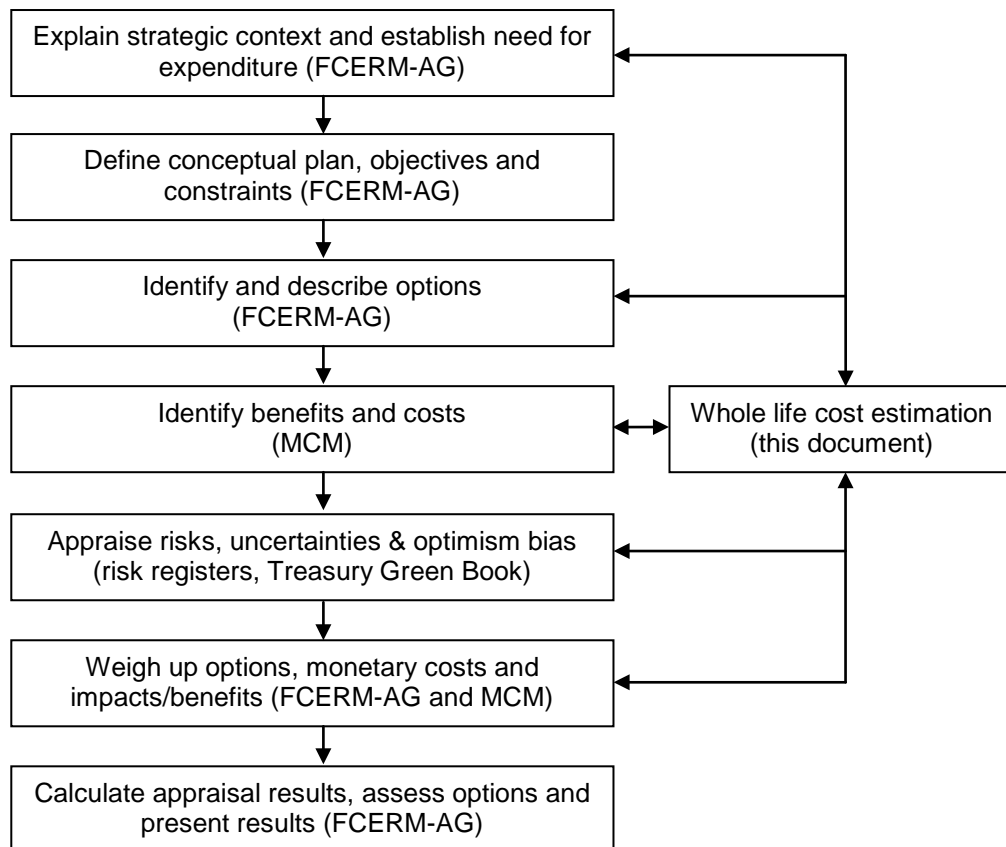
Cost estimation can be difficult, depending on the detail of options and costs under consideration. It will normally involve input from engineers and operators, that is, those with knowledge and experience of the types of systems being considered. The appraisal process needs to identify and communicate the full scope of the option requirements to ensure that all aspects are sufficiently understood.

1.2 Introduction to the appraisal process and where cost estimation fits in

Whole life cost estimation forms part of the overall appraisal process as shown in Figure 1.2. Each of the steps below is fully described in the Environment Agency's appraisal guidance and the other guidance indicated.

This summary of evidence is intended to assist those undertaking cost estimates. It provides guidance and data to support cost estimation and the appraisal process.

Figure 1.2 The appraisal process



1.2.1 Appropriate cost information

Whole life cost estimates should be based on data appropriate and proportional to the level of assessment of options.

Costs are typically based on data assembled from:

- recent tenders
- completed projects
- published articles and estimating price books
- estimates and quotations from companies for specialist work
- the estimator's own experience

At different stages of an analysis, different data will be appropriate for cost estimation as indicated in Table 1.1.

Table 1.1 Cost estimation methodologies at different appraisal stages

Project stage ¹	General approach	Basis for cost determination
1. Initial conception or national appraisal	Gross estimates	Historical data and reference projects
2. Conceptual design or regional/strategic appraisal	Estimates based on unit rates	Approximate unit rates for the completed asset (for example, £XX per metre for a flood wall xx metres in height)
3. Preliminary feasibility/design	Approximate calculation with some element quantification	Typical unit rates and approximate element quantities + administration costs Unit rates consider multiple activities for a particular asset type or option.
4. Detailed design	Engineer's estimate	Defined activities using bill of quantities and price databases rather than unit rates Potential contractor/quantity surveyor involvement Normally excludes whole life costs.
5. Tendering	Target budget/bids	As above, but contractor leads. Often analytical estimate based on actual resources required for project.
6. 'As built' and decommissioned schemes	Recorded quantities and costs	Most accurate as based on real costs but care needed to ensure cost data are comparable with other datasets.
7. Operation	Recorded operation/maintenance costs	Most accurate as based on real costs but recording of data may vary between organisation and may not be asset or scheme specific.

Notes: ¹ This document predominantly covers Stages 1 and 2 but may also inform and provide generic guidance suitable for Stages 3 and 7.

The approach in this summary of evidence is to provide:

- unit rates and case studies for a range of management measures
- additional guidance and supporting information for those measures where data are currently limited

The use of historical data to estimate unit costs is a useful source of cost information for broad level analysis typical of strategic and catchment studies. Various databases are available that have collated outturn costs or presented typical costs derived from

first principals. This information has been reviewed and a summary of this information is discussed further in Section 4.

Calculated costs for each element of a project may require one or a combination of the following three methods.

- **Known factors or rates** –inputs to a WLC analysis of known rates for specific units of a flood risk management solution. This may also include analysis for operation and maintenance activities. For example, staff cost of a service can be calculated based on known costs of different grades of staff and the frequency and number required to provide that service.
- **Cost estimating relationships** –relationships derived from historical or empirical data. For example, if experience had shown that for similar items the cost of an item represents 20% of the total, this can be used for alternative schemes. The results produced by such relationships must be treated with caution.
- **Expert opinion** – this may often be the only method available when recorded data are unobtainable. When expert opinion is used in a WLC analysis it should include the assumptions and rationale that support the opinion. The application of optimism bias will help to capture any uncertainty.

During the early project stages, cost estimates will necessarily be based on the limited information available and on broad assumptions about the scope and nature of the work. Any assumptions should be set down clearly so that they can be verified if necessary and referred to at a later stage. Transparency is crucial and an audit trail should be established to allow checking of errors and the direction of the appraisal with respect to any errors.

1.3 Target audience

This generic guidance is prepared as a companion/‘umbrella’ to more detailed information on cost estimation for individual flood risk measures and the associated costing tool. This generic section covers an overview of cost estimation and whole life costing suitable for a range of scales of assessment and potential users. This will inform appraisers on:

- relevant methodologies
- cost implications
- generic cost types to be considered
- definitions

Potential users of this guidance will include those involved in a range of studies such as national strategies/studies, regional or catchment/shoreline management plans, and application for Defra capital Grant Aid. However, the main users of the guidance are expected will be those embarking on higher level/more preliminary Flood and Coastal Erosion Risk Management (FCERM) option appraisals. Others likely to have an interest in the outputs are Defra policy teams, professional partners, academic organisations, riparian land owners and developers or community-based groups.

1.4 How to use the guidance

The summary of evidence provided is split up into:

- a general introduction to WLC and cost estimation guidance, consideration of uncertainty and risk, and an introduction to the structure and cost information available for specific FRM activities
- specific evidence summaries and cost information to assist appraisers with whole life cost estimation for a range of flood and coastal erosion risk management measures

The general approach required to develop a whole life cost estimate is provided in Figure 1.2.

Chapter 2 explains the overall procedures and provides details on each of the main elements in the whole life cost estimation and how to combine the various elements.

Chapter 3 discusses the risks and uncertainties involved and the methodologies to incorporate and assess these.

Chapter 4 introduces each of the broad flood risk measures assessed and presents the information available and the structure of the data and guidance provided.

The supporting evidence summaries in the appendices provide more specific guidance related to each of the flood risk management options. They include:

- a summary of types of assets/intervention options covered
- available data for each of the most important cost areas (capital and operation and maintenance costs) and critical aspects that will affect the cost values provided
- specific guidance and considerations required to undertake a cost estimate
- risks, confidence, uncertainties and information relating to specific issues with regard to the flood risk management measure
- links to any relevant research and development (R&D) and general design guidance available to practitioners

Table 1.2 summarises the portfolio of FRM measures that may be funded from revenue and capital budgets, and therefore subject to an appraisal process. The differing levels of readily available information and requirements for data gathering for each aspect are discussed further in Chapter 4.

Table 1.2 Portfolio of flood risk management measures

Type	Guidance/supporting documents
Core structural measures	Fluvial flood defences
	Coastal flood defences and erosion control
	Flood storage
Structural and key operational measures	New channels and channel maintenance
	Culverts and screens
	Control structures

Non-structural measures	Temporary and demountable defences
	Property flood resilience/resistance
	Flood detection, warning, forecasting
	Sustainable drainage systems (SuDS)
	Land management

The second part of the project involved the development of a cost estimation tool to support studies requiring cost estimation that is proportional and which complements estimated flood damage outputs. This tool will help appraisers in cost estimation for flood risk measures at the broad scale by extracting cost information from readily available sources and the necessary provision to collate whole life costs for a scenario or policy decision. The tool is available as a Microsoft® Excel spreadsheet.

1.5 Supporting guidance and data sources

Table 1.3 lists supporting guidance/research and data sources.

Table 1.3 Supporting guidance/documents

Guidance/document	Description ¹
Flood and Coastal Erosion Risk Management Appraisal Guidance (FCERM-AG)	Environment Agency guidance on how to put the Defra policy statement, <i>Appraisal of Flood and Coastal Erosion Risk Management</i> , published in June 2008 into practice. It provides best practice implementation guidance on appraisal and replaces the Defra Project Appraisal Guidance (PAG).
FCERM-AG supporting guidance	A range of documents and supporting guidance produced by the Environment Agency to assist with the implementation of FCERM-AG. Includes the economic appraisal spreadsheets and summary tables to assist with economic appraisal, policy documents and a range of linked technical documents aimed at those who undertake and review appraisals.
Flood and Coastal Erosion Risk Management: A Manual for Economic Appraisal (Multi-Coloured Manual) and Handbook for Economic Appraisal	The manual presents methods and data that can be used in assessments of flood damages and benefits for FCERM appraisals. The Multi-Coloured Manual and Handbook are produced by the Flood Hazard Research Centre (FHRC) at Middlesex University and aim to provide a consistent methodology for benefit assessment within FCERM appraisal. The 2013 edition of the Manual is available for purchase from Routledge. The Multi-Coloured Handbook 2013 is a companion volume to the 2013 Manual and complements the Environment Agency's FCERM-AG. Full details of the Manual and Handbook, and how to obtain copies, are given on the MCM website (http://www.mcm-online.co.uk). Error! Hyperlink reference not valid.
Fluvial Design Guide	This Environment Agency guidance is intended for designers, asset managers and professional staff

Guidance/document	Description ¹
	<p>engaged in the design of flood and coastal management assets and services. The guidance supports the early stages of design and alternative solutions through to the delivery and design for construction, maintenance, refurbishment or alteration of flood defence or land drainage assets. The individual chapters of the guide can be downloaded as PDFs from: http://evidence.environment-agency.gov.uk/FCERM/en/FluvialDesignGuide.aspx</p>
Asset deterioration guidance	<p>Guidance produced by the Joint Defra/Environment Agency FRCEM R&D Programme on asset deterioration curves and how to use them to establish the residual life of different types of flood defence assets. The guidance can be downloaded as a PDF from: http://publications.environment-agency.gov.uk/pdf/SCHO0509BQAT-e-e.pdf (2 MB)</p>
HM Treasury Green Book	<p>The 'Green Book' contains official guidance and techniques that should be considered when carrying out appraisal assessments of new policies, programmes and projects involving public resources. The document seeks to encourage a more thorough, long-term and analytically robust approach to appraisal and evaluation. It can be downloaded as a PDF from: https://www.gov.uk/government/publications/the-green-book-appraisal-and-evaluation-in-central-government</p>
HM Treasury Green Book supplementary guidance	<p>Supplementary guidance from HM Treasury on a number of aspects and more detailed guidance on specific issues and applying the Green Book in particular contexts. Includes specific guidance in relation to the application of optimism bias for the adjustment to estimates of capital and operating costs, time profiles and works' duration. The various documents can be downloaded from: https://www.gov.uk/government/collections/the-green-book-supplementary-guidance</p>
Scottish Government. Flood Prevention Schemes – Guidance for Local Authorities	<p>A series of technical documents aimed at local authorities in Scotland and their professional advisors providing guidance and best practice on the promotion of flood protection schemes under the current statutory framework in Scotland. Note that this guidance is not fully complete and likely to be updated. Those chapters that are available can be accessed from: http://www.scotland.gov.uk/Topics/Environment/Water/Flooding/Flood-prevention/guidance-la</p>
Northern Ireland Guide to Expenditure Appraisal and Evaluation (NIGEAE)	<p>Department of Finance and Personnel (DFP) guidance on the appraisal, evaluation, approval and management of policies, programmes and projects in Northern Ireland. This guidance sets out the principles of economic appraisal that must be applied to all proposals that involve spending or saving public money, or changes in the use of public resources. The</p>

Guidance/document	Description ¹
NIGEAE Optimism Bias calculator	<p>guidance is accessed via the DFP's dedicated NIGEAE website at http://www.dfpni.gov.uk/eag</p> <p>Microsoft® Excel spreadsheets designed to facilitate optimism bias calculations for civil engineering projects based on the HM Treasury supplementary guidance on the treatment of optimism bias. The Excel files can be downloaded from: http://www.dfpni.gov.uk/index/finance/eag/eag_resources/eag-optimism-bias-calculator.htm</p>
Office for National Statistics (ONS) Public Works Non-Roads (PWNR) Indices	<p>Indices prepared by ONS to assist with the updating of costs. The price indices from the 2010 edition of the ONS annual construction statistics can be downloaded as an Excel spreadsheet from: http://www.ons.gov.uk/ons/rel/construction/construction-statistics/no--11--2010-edition/chapter-4--price-indices.xls (341 KB)</p>
Office for National Statistics (ONS) CPI Indices	<p>Consumer Price Indices to assist with the updating of costs. The latest indices are available from: http://www.ons.gov.uk/ons/rel/cpi/consumer-price-indices/index.html</p>
Flood and coastal risk management external contributions policy	<p>This document sets out the Environment Agency's policy and a consistent approach within the appraisal process for the use of contributions from private, public or voluntary organisations or communities for flood and coastal risk management assets or service arrangements.</p>
Defra 2011 revisions to funding of FCERM in England	<p>Consultation and responses to changes to capital funding for flood and coastal risk management. Includes information on funding mechanisms and the measurement of performance of government funding in England.</p>

Notes: ¹ All links were accessed on 4 December 2013.

2 Whole life costing

2.1 Definition of whole life costing

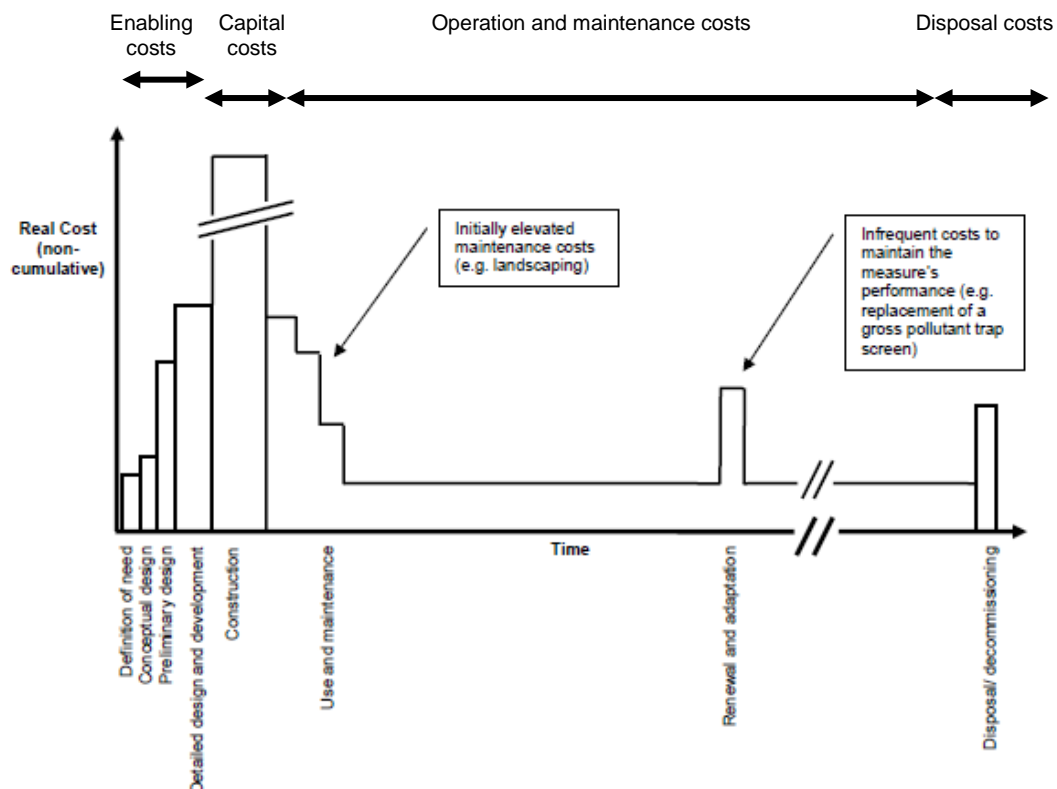
Whole life costing is defined as ‘the systematic consideration of all relevant costs associated with the acquisition and ownership of an asset’.¹

The whole life costs of an asset or facility (also referred to as through-life costs) are:

- the costs of acquiring it – including consultancy, design and construction costs, and equipment
- the costs of operating it
- the costs of maintaining it over its whole life through to its disposal

Whole life costing is a technique that quantifies costs from inception and throughout an asset’s life. Capital and all relevant future costs (for example, operation and maintenance costs) must be considered over the whole life of the asset in the form of annualised cash flows. A conceptual schematic of potential costs is shown in Figure 2.1.

Figure 2.1 Conceptual schematic of whole life costs



Source: Taylor (2003)

This conceptual approach to the estimation of whole life costs illustrates the variability in post construction maintenance costs. The standard approach represents an annual

¹ Whole Life Cost Forum (<http://www.wlcf.org.uk/aboutwlc.html>)

cost associated with operation and maintenance costs, combined with an infrequent or intermittent higher cost. This intermittent cost may be planned or in response to environmental forcing and unplanned repair. While most environmental forcing will be designed for, there may be a requirement to assess alternative options or scenarios based on the probability of environmental forcing or changes to these probabilities. This is discussed further in section 3.3.

2.2 Whole life cost methodology

The ability to assess whole life costs can help to determine investment scenarios over a pre-determined financial period. The validity of a benefit–cost comparison depends on the appropriate (not necessarily accurate) estimation of costs. Initial capital costs are likely to be large, but operational and maintenance costs can also be significant over the life of a scheme.

The degree of sophistication of estimating whole life costs will vary according to the complexity of the goods or services to be procured. The cost of collecting necessary data can be considerable, so where the same items are procured frequently, a cost database can be developed to assist with appraisals.

A basic whole life cost estimation process will include the following fundamental concepts common to all applications once options have been defined as part of a wider appraisal:

1. Determine the cost breakdown structure relevant to the options assessed, including initial estimates to determine which aspects/elements are likely to be crucial in any decision-making process.
2. Calculate the costs for each element to an appropriate level of detail.
3. Define the asset design or residual life and apply replacement costs if relevant.
4. Discount costs based on current standard discount rates.
5. Define the most important risks/uncertainties/sensitivities and scope which to present/assess and complete alternative cost scenario assessment.
6. Sum all costs to derive a Present Value of cost (PVC).
7. Feedback to the wider appraisal process and repeat as necessary/with modified options.

The above concepts can be summarised by equation 2.1:

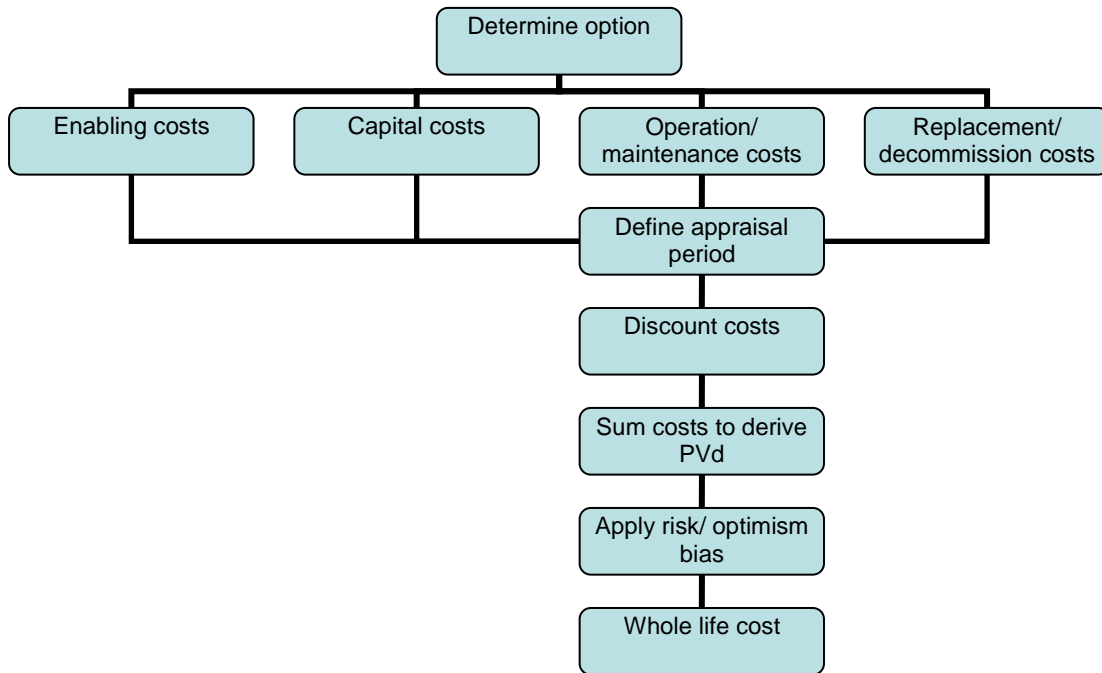
$$\text{WLC} = \text{Sum} [I + \text{PV}(M) + \text{PV}(R)] \quad (2.1)$$

where:

- WLC = whole life cost for a given option or scenario
I = investment costs (enabling and capital costs)
M = operational and maintenance costs (annual and intermittent)
R = replacement, decommissioning or repair costs
PV(_) = Present Value (see section 2.4.2)

Figure 2.2 presents a flow chart summary of the estimation procedure.

Figure 2.2 Whole life cost estimation procedure



Notes: PVd = Present Value cost discounted

Example

The capital costs for a flood defence scheme are estimated at £500,000 and assumed to occur in year 0.

Enabling costs are estimated to be 26% of the capital costs (£130,000) and assumed to occur in year 0. Investment costs are therefore £630,000 in year 0.

Annual maintenance costs are estimated to be £5,000 per year.

Intermittent costs of £15,000 every 25 years are also applicable for asset replacement.

Standard discount rates for a 100-year appraisal period are used, giving a present value cost of £785,000.

An optimism bias of 60% is applied, resulting in a total present value whole life cost of $£785,000 \times 1.6 = £1,256,000$.

2.2.1 Option and scenario testing

Economic appraisals typically assess a range of different options. Appraisers will often need to assess different types of flood defence option, different alignments of flood defences or different standards of protection. The optimisation of options needs to be undertaken carefully and is an important process. Further information on option choice and scenario testing is provided in the FCERM-AG.

A number of additional scenarios and testing may be required depending on the type of assessment being performed. This may include a combination of options or other scenarios related to the management and maintenance/deterioration of assets or the anticipated environmental forcing on flood defence assets.

2.3 Generic cost types and data requirements for WLC

Attention should normally be paid to all relevant costs for each of the options from initial consideration through to disposal. However, the cost types required in a whole life cost estimate need to be proportional to the level of assessment and the relative costs for each element of a proposed option or scheme. If the long-term maintenance costs are low compared with the capital costs, for example, there is less priority to make a detailed assessment of the maintenance costs in a whole life cost estimate.

The appraiser needs to consider when the inclusion of a cost element would either significantly affect PVC or would lead to a potential change in option choice. The difficulty in determining this aspect is the need to consider the whole life impact of costs; routine maintenance costs may not be expensive but the annual recurrence may accrue over the appraisal period (for example, the asset life). Defining the options and main cost elements at the start of a project will help an appraiser to understand the critical cost elements and ensure proportional analysis for each specific cost area.

The four key cost elements that need consideration include (see the Glossary for definitions):

- acquisition or enabling costs (see section 2.3.1)
- capital costs (see section 2.3.2)
- operational costs (see section 2.3.3)
- end life costs (see section 2.3.4)

Operational or end life costs can be either 'one-off' or 'recurring' costs throughout an appraisal period (for example, electrical control systems in pumping stations will be replaced several times during the full life of the asset). It should be remembered that recurring costs can decrease or increase with time (for example, material disposal costs could increase).

2.3.1 Acquisition or enabling costs (pre-construction)

Excluding construction, acquisition costs include:

- planning and administration
- scheme feasibility and appraisal
- site investigation
- design and project management
- consultation and consents (environmental, planning permission, consent for works affecting watercourses or defences, waste management licences and so on)

As a guide for the FRM industry, the *Review of Internal Drainage Boards* (JBA 2006) extracted information from information held by the Department for Environment, Food and Rural Affairs (Defra) on grant-aided schemes on the level of fees paid to Internal Drainage Board (IDB) staff and consultants as a proportion of total costs from 258 completed IDB schemes. Although this dataset included a large range of variable project types and capital schemes, the average proportion of fees for an IDB scheme costs varied between 9 and 16%.

The same analysis was repeated for the purposes of this project but with the inclusion of all projects undertaken by the Environment Agency and local authorities. Projects that represented purely studies, strategies/plans or monitoring projects were removed from the dataset as these were predominantly undertaken by consultants, resulting in fees as a proportion of 'scheme' costs of 100% – highlighting the fact that enabling costs in complex catchments are higher. Projects where the fees for internal staff or consultants were missing from the dataset were also removed from the analysis. The calculated average proportions of fees for FCERM schemes in England and Wales are presented in Table 2.1. In the absence of any additional data these values are recommended for use for projects carried out by the three different types of organisation.

Table 2.1 Fees as a proportion of scheme costs

Type of scheme	All schemes	Total scheme cost		
		<£200,000	£200,000 to £1 million	>£1 million
IDB	10%	11%	8%	8%
Local authority	17%	21%	15%	10%
Environment Agency	20%	32%	26%	9%

Notes: Although IDB schemes have a lower proportion of fees than the local authority or Environment Agency schemes, this may be as a result of these projects being undertaken internally with more flexible or less onerous procurement and funding processes, thus reducing the scope of the project enabling process. IDB schemes may also be limited in type (that have been completed many times before) and complexity.

Sunk costs

Enabling works carried out before an appraisal process such as expenditure on feasibility studies, other incurred expenditure on goods and services, or resources that are already irrevocably committed are often referred to as 'sunk costs' and should be ignored in an appraisal. However, care is needed before assigning a cost as 'sunk'; for example, if land or materials have been acquired, they usually have a value and can therefore be sold.

The decision to remove these costs from a whole life cost estimate will depend on the point of assessment relative to the phasing of works. For example, a scheme development cost assessment will primarily relate to the costs associated with construction works and longer term operation and maintenance costs. While the estimates may include the addition of detailed design, consultation and additional surveys, the feasibility and all planning and consultation undertaken to date will be regarded as sunk costs and excluded as they cannot be changed as a result of the decisions in the appraisal. Further details on sunk costs are provided in the FCERM-AG (Environment Agency 2010a).

2.3.2 Capital costs

Capital costs for various FCERM measures are provided in the specific flood risk measure evidence summaries provided as appendices to this document. Unit costs for capital schemes are available for a range of flood risk management activities based on collated out-turn costs from previous projects. For some measures uncertainty becomes very large without site-specific analysis due to site variations and constraints. Guidance on the factors to be considered is provided to assist those estimating costs.

A range of unit costs suitable for initial broad level or national/regional level assessments such as the Environment Agency's Flood Risk Estimating Guide (Environment Agency 2010b), also referred to as the Unit Cost Database, are provided in each of the separate flood risk measure evidence summaries.

Individual unit rates for constructing each structural element of flood risk measures can be obtained from civil engineering, building or landscaping cost databases such as *Spon's Civil Engineering and Highway Works Price Book* (Davis Langdon 2011) or the *Civil Engineering Standard Method of Measurement* (CESMM4) price database (ICE 2012).

Capital costs should include, as appropriate, the following elements:

- client, project sponsor or project management costs and expenses (including all central support services, site preliminaries, access, accommodation, administration, contractor profit, overheads and so on)
- construction and materials costs
- land purchase/compensation
- licence and consents
- contract administration/construction supervision.

The construction cost of a project is made up of many elements that may include items such as mobilisation and demolition and site clearance, materials, compensation, insurance, diversion of existing facilities, construction and post-construction landscaping. Additional guidance on these standard construction cost elements are provided in the standard CESMM and Spon's estimating guides.

Most of the data relied on in out-turn cost unit rates will include these elements and will not need to be determined for high level or preliminary option cost estimates. Detailed capital cost estimates prepared by qualified engineers would need to consider each of these aspects.

2.3.3 Operation and maintenance costs

When appraisers consider new schemes and strategies, maintenance and inspection aspects are sometimes critical in terms of whole life costs. As a result, there is also a move within the industry to passive design where options to reduce or eliminate operating aspects are designed to reduce total operational expenditure. Design that reduces the need for gates and fitting ramps are examples.

Inspection costs

Inspection of assets is critical to ensure that assets remain at a suitable condition and to record asset condition as part of high level targets.

A number of inspection types may be required depending on the asset type and owner of the asset and are typically broken down into superficial inspection, general inspections, principal inspections and special inspections (Balkham et al. 2010).

Typical inspection activities/costs that may be relevant to flood and coastal erosion measures include:

- visual asset condition assessments (generally visual, but may include automated, destructive or remote sensing tests, surveys, data recording systems)
- public safety inspections (OPUS)
- operational inspections and testing (for example, alarm or sprinkler system check)
- pre- and post-storm inspections

Inspection costs are typically estimated from defined frequencies of inspection, often via risk-based processes. Based on these frequencies and the length/number of assets, together with an estimate of the staff resources required for inspections (and any other costs), an indicative cost of associated with asset inspection can be determined.

Inspection cost example

A system or group of flood defence assets has 10 flood defence linear assets with a total length of 2 km and two trash and security screens requiring operational inspections. The flood defence assets have a defined visual inspection frequency of 12 months. The defined operation inspection frequency is three months for the screens.

It is assumed that a two-person team costing £54 per hour and working a 7.5 hour day is required for the inspections and that these can cover 1 km per day. Therefore the cost for the annual visual inspection is £810 plus vehicle costs per year.

It is assumed that a works team can cover five screens a day within the region of interest at a cost of £405 per day. For this particular group of defences that equates to 1.6 days per year or a cost of £648 per year. An additional contingency for weather/travel/data entry time may also be considered.

Maintenance activities

Maintenance costs are sometimes an important consideration in the determination of whole life costs. All schemes will require some form of operation and maintenance costs to ensure assets remain fit-for-purpose and operational risks are managed.

Typical operation and maintenance costs include:

- frequent/regular maintenance to prevent a change in the asset Standard of Service
- intermittent/reactive maintenance
- disposal of waste (for example, vegetation and sediment)
- energy
- insurance and any leasing or rental
- staff (management, operation, support and ongoing training)

A range of the possible maintenance activities and example costs for each flood risk measure is provided in the flood risk measure evidence summaries. In the absence of these costs it may be appropriate to determine an annual cost as a percentage of the total capital costs. For more detailed studies it may be appropriate to determine the activities required, the frequency of maintenance and the costs associated with each activity. Depending on the assets involved, this may require specialist advice and costing.

Maintenance activity example

A group of flood defence embankments has a total length of 2 km.

Broad-scale assessment

An estimated unit cost estimate for a 1 km length of defence is £1,000 per year.

The present value cost over a 100-year financial period (assuming standard discount rates) for the 2 km reach is therefore £57,600.

Detailed assessment

The embankment is assumed to require grass cutting at three-monthly intervals and tree and bush work every other year.

Staff and plant costs are estimated to be £45 per hour for mowing and £27 per hour for tree and bush works.

The embankment requires five passes to mow the inner, outer and crest at a rate of 5 km per hour.

Therefore the total length of embankment will take two hours to mow at a cost of £90 plus a travel time to and from site of one hour (total cost = £135).

The tree and bush works is assumed to require two people working at a rate of 500 m per eight-hour day, with a total embankment cost of £1,728 ($£27 \times 2 \times 8 \times 4$).

Therefore:

Annual grass cutting costs = £405

Annual tree and bush works = £864

Total annual maintenance costs = £1,269.

The present value cost over a 100-year financial period (assuming standard discount rates) for the 2 km reach is therefore £36,600.

Where staff time is a critical factor, staff hourly costs may be needed. For example, operational staff costs are typically charged by the Environment Agency at a rate of £27 per hour or a composite rate of £250 per day for each operative for work undertaken by the Operations Delivery field teams.² This rate includes all management overheads, overtime and transport costs.

Annual and intermittent maintenance can extend the design life of flood defence assets significantly, particularly for structural components. Thus it can be important that assets are maintained to ensure asset performance.

There may be unavoidable costs associated with regular or intermittent costs that reflect legal, safety or environmental aspects. Examples include:

² Personal communication from SAMPs Operational Delivery team/

- where an organisation has a legal obligation to maintain an asset
- maintenance activities that prevent a change in the standard of service of man asset such as water level management, screen clearance and removal of serious structure blockage
- where an asset or associated structure is owned and requires maintenance to ensure safe operation or safe interaction with the public (for example, signage and security)
- unavoidable energy and operating costs
- emergency measures to control flood risk

When assessing maintenance costs in complex systems, it is sometimes useful to be able to understand what are essential costs and what are optional costs (for example, through a management policy imposing best practice that is beyond a legal minimum)

There is a move towards risk-based asset management planning to ensure that assets are maintained to a suitable standard and that priority is given to those assets that protect the highest risk locations. Further guidance on asset whole life cycles and asset management is given in CIRIA guidance (Hooper et al. 2009) and the Publicly Available Specification PAS 55 (BSI 2008).

The Environment Agency's System Asset Management Plans (SAMPs) and the SAMP-IT software represent an initiative to capture maintenance costs on a system (defence groups) basis and are used to plan and report on ongoing maintenance activities. It is hoped that capture of the costs of operational and maintenance activities will be incorporated in the future and help to identify asset or system maintenance costs.

2.3.4 Replacement/decommissioning costs

Replacement and refurbishment works can include reinstatement of an asset's standard of service in full at the end of its design life. Replacement and refurbishment returns the asset to its original design performance, but does not increase or decrease the standard of service.

The alternative to replacement and refurbishment is a 'change in design' or decommissioning. These represent works that intend to alter the standard of service of an asset either at the end of or during its design life (for example, raising an embankment height so as to provide protection for an event beyond that originally designed for asset decommissioning).

Replacement/decommissioning costs should include, where appropriate, the following:

- professional fees
- licences and consents
- land purchase/compensation
- demolition
- disposal of waste
- construction of replacement

2.4 Other factors

2.4.1 Economic versus financial costs

For projects resourced from public funds, the cost of flood mitigation projects must be assessed as national economic costs rather than the financial costs to the organisations that incur the cost.

Economic costs consider those costs that are borne by the national economy. Further information is provided in the Treasury Green Book (HM Treasury 2003a) and the MCM (Penning-Rowse et al. 2013) and is summarised below.

Financial

- Takes the standpoint of the organisation involved.
- Uses the actual money transfer involved to evaluate the loss or gain.
- VAT is included as are other indirect taxes as they affect the organisation involved.

Economic

- Takes the standpoint of the nation as a whole.
- Corrects the actual money transfer so as to calculate the real opportunity cost.
- VAT is excluded as are other indirect taxes (for example, excise duty on fuel) because they are money transfers rather than real resource costs. They are transfers from the payee to the exchequer.

The distinction is important if the costs of a particular project are to reflect the real economic cost to the nation as a whole rather than the financial costs to an adopting organisation. If money is transferred to another company within the UK, it is not an economic cost, but if the money is spent outside UK, it is an economic cost.

Note that costs included in unit rates from out-turn costs may not fully represent economic costs. This is because out-turn costs are currently quasi-financial costs as only VAT is typically removed. However, they may also include taxable labour and fuel costs for instance that represent financial elements. This is an ongoing issue with the approach to generate standard unit costs within the industry against which economic benefits are compared.

2.4.2 Discounting costs and PVC

Appraisals need to compare options that will impact over a period of years into the future. Discounting is commonly used to:

- compare costs and benefits over this time period
- determine how future cost and benefits should be valued in today's terms

Further guidance, explanation and examples of discounting are provided in the FCERM-AG (Environment Agency 2010a) and the MCM (Penning-Rowse et al. 2013). The FCERM-AG supporting guidance includes a standard economic appraisal

spreadsheet³ to assist with economic analysis and calculating Present Value (PV) and Net Present Value (NPV) costs.

The discount rate used is normally as set by HM Treasury and is currently an initial rate of 3.5%, gradually increasing over time. For flood and coastal appraisal studies with an appraisal period of 100 years, the schedule shown in Table 2.2 applies. Appraisers should keep abreast of recommendations on discount rates from the Treasury.

Table 2.2 Current Treasury long-term discount rates

Period of years	Discount rate
0–30	3.50%
31–75	3.00%
76–125	2.50%

Source: HM Treasury (2003a)

Calculation of discounted costs

Table 2.3 provides an example of how current discount rates are used to calculate discounted costs and total present value costs over a five-year period. Further guidance, explanation and examples of discounting are available in the FCERM-AG and the MCM.

Table 2.3 Example calculation of discounted costs

Year	Cost	Discount factor ¹	Discounted costs
0	£500	1.000	£500.0
1	£50	0.966	£48.30
2	£50	0.934	£46.70
3	£50	0.902	£45.10
4	£100	0.871	£87.10
Total PVc			£727.20

Notes: ¹ The Green Book (HM Treasury 2003a)

2.4.3 Inflation and price indices

The FCERM appraisal guidelines suggest that inflation should be ignored when undertaking benefit–cost analysis. Analyses are usually undertaken using real prices where inflation is ignored and the relative prices of different streams of costs and benefits are assumed to be constant over the period of assessment. Therefore all future values should be taken as existing values unless there are good reasons to suppose that one element of a cost estimate may increase disproportionately.

³ <http://www.environment-agency.gov.uk/research/planning/116707.aspx>

In reality, relative prices (for example, the unit price of materials) may change over time and may differ to standard inflationary measures such as the Consumer Price Index (CPI) or Retail Price Index (RPI). Provided inflation for all costs is approximately equal, it is normal practice to exclude inflation effects when undertaking WLC analysis and to only include these aspects as a sensitivity test or when these uncertainties may affect the option choice.

The year used as the basis for pricing should always be indicated in the analysis and be relatively consistently applied across the options and economic damages/benefits. Price indices convert historical prices to the same base date such as the CPI⁴ or Public Works Non-Roads (PWNR) index.⁵ For construction costs, the PWNR index is more appropriate.

Updating prices

A unit rate for a new flood wall is £2,000 per metre based on May 2005 values. The CPI for May 2005 is 100. The index for January 2011 is 116.9.

Therefore the uplift factor required to convert May 2005 values to January 2011 values is $116.9/100 = 1.169$.

Thus the estimated unit rate becomes $£2,000 \times 1.169 = £2,338$.

2.4.4 Design life

The design life of a FRM asset is defined as the minimum length of time that the asset is required to perform its intended function. Within this design life, there may also be a consideration for component life, where a scheme may contain a number of structures that have different (shorter) life cycles to the overall service life of the scheme.

An understanding of the life of each component is therefore necessary for whole life costing and essential to ensure that the scheme will last for its intended service life. Indicative/typical design lives are provided in each of the separate flood risk measure evidence summaries.

2.4.5 Residual life and deterioration

The residual life of an existing asset is the length of time until an asset is no longer able to achieve a minimum acceptable performance. Deterioration rates are used to represent this relationship between performance standard and time.

The effect of maintenance is to sustain the standard of performance of an asset. Ideally, this will retain the initial desired standard. However, this may not be possible in all cases, as deterioration may continue to a point where major replacement or upgrades are required. Various strategies to retain asset life can be employed depending on the type of asset and other factors.

Additional guidance on residual life and asset deterioration is provided in the following Environment Agency reports:

⁴ CPI, October 2011, <http://www.ons.gov.uk/ons/rel/cpi/consumer-price-indices/october-2011/index.html>

⁵ PWNR, ONS Construction Statistics, Annual 2010, Chapter 4 <http://www.ons.gov.uk/ons/rel/construction/construction-statistics/no--11--2010-edition/chapter-4--price-indices.xls> (Excel 341 KB)

- *Operations and Maintenance Concerted Action Report* (Environment Agency 2004)
- *Assessment and Measurement of Asset Deterioration including Whole Life Costs* (Environment Agency 2009a)
- *Guidance on Determining Asset Deterioration and the Use of Condition Grade Deterioration Curves* (Environment Agency, 2009b)

The latter two documents provide detailed assessment and collation of data and theories to support the development of deterioration curves as well as a practical guide and example deterioration curves to quantify the residual life of different asset types. Deterioration curves from these reports are provided in the supporting flood risk measure evidence summaries.

2.4.6 Appraisal period

The FCERM-AG recommends that the appraisal period is taken as 100 years unless the life of the asset(s) (taking maintenance into account) or the potential to predict future events is such that a shorter or longer time frame is more appropriate. Further guidance on justifiable reasons for using a different appraisal period is provided in the FCERM-AG.

Residual asset value can also be important when assets will have residual life beyond the end of the appraisal period.

2.4.7 Multi-functional and partnership approaches

Partnership working approaches are becoming more relevant to achieve multiple benefits and objectives in flood risk management. It is important that the costs of providing these objectives are determined even where they are to be provided by project partners.

2.4.8 Funding contributions

There are two types of contributions:

- a contribution associated with the addition of features that have little or no FRM purpose (that is, outside the Defra FRM policy remit for Grant in Aid funded work)
- non-governmental contribution that brings down the cost of FRM works to the UK taxpayer

Changes in Defra/Environment Agency guiding principles (Environment Agency 2009c) are being introduced to encourage non-governmental contributions as a result of an increasing gap between what can be afforded and FRM needs. Additional information on the incorporation of contributions is provided in the Defra contributions policy (Defra 2009) and the FCERM-AG.

Appraisers should also keep abreast of changes to funding arrangements for FCERM management projects and government policies to reduce the threats of flooding and coastal change.⁶

⁶ <https://www.gov.uk/government/policies/reducing-the-threats-of-flooding-and-coastal-change>

3 Uncertainty

3.1 Uncertainties in WLC estimation

There are a number of uncertainties to whole life costing such as:

- uncertainties related to important aspects of a capital scheme (for example, unexpected ground conditions, poor weather, cost of temporary works, encountering environmental constraints and their mitigation, or the cost of unusual construction materials/components)
- when previous generalised rates are being used to estimate costs there can be problems with inconsistent historic data on which to base cost estimates
- uncertainties associated with future maintenance costs, particularly when introducing new FRM measures to a sensitive/dynamic environment (for example, an outfall to an estuary)
- uncertainties associated with decommissioning and asset replacement costs
- difficulties in defining design life of assets and asset elements

It is vital to consider how best to include this uncertainty in any WLC work. The benefits of doing this include:

- better decision-making – providing an informed option appraisal leading to better decisions on investment choices
- improved budgeting – improved understanding of the potential range of construction and long-term maintenance costs

Depending on why the cost estimate is being produced, it may be important to test its reliability. If uncertainty is significant, there are two main techniques to incorporate it within an analysis. These are sensitivity testing and probabilistic risk assessment.

A typical example of why the reliability of a cost estimate would need to be tested is when exploring whether the preference of one option over another is dependent on certain crucial assumptions or uncertainties.

The assessment can take various forms but this is not the main subject of this report. However, some common examples are provided:

- optimism bias/contingency
- sensitivity testing
- probabilistic risk analysis

3.2 Uncertainty assessment

Uncertainty assessments can be used to determine the best estimate of a scheme's cost together with confidence limits based on the risks and uncertainties associated

with the scheme and the stage of appraisal. The approach requires quantification of the best case cost estimate and the realistic cost ranges.

The estimation of cost ranges can be performed in a number of ways, involving both quantitative and qualitative approaches.

The quantitative approach assigns uncertainty data to input datasets and unit costs.

The qualitative approach involves assigning a certainty category to each cost item or element to reflect the accuracy of the cost estimate, taking into account the stage of assessment and the complexity of the works. For example, each cost element can be scored from one to four (one representing a very high level of certainty to four representing a very low level of certainty). An alternative used by the MCM is a scale of data quality scores (best of breed, data with known deficiencies, gross assumptions and heroic assumptions). Based on these quality scores, upper and lower bands of cost estimates can be defined as shown in the example in Table 3.1.

Table 3.1 Example qualitative cost weighting

Certainty category	Description	Percentage of best estimate	
		Lower limit	Upper limit
1	Best of breed	90%	110%
2	Data with known deficiencies	85%	125%
3	Gross assumptions	80%	150%
4	Heroic assumptions	75%	200%

Each of the cost elements can then be assigned a cost range corresponding to the assigned cost category, and a basic construction cost and cost range can then be provided.

3.3 Risk analysis

In the past uncertainty has tended to be incorporated into cost estimates via the use of contingency based on engineering judgement and typically as a percentage of the total costs. For more complex FRM projects, and in line with wider engineering practice, this method has tended to be enhanced by the use of probabilistic risk assessments in cost estimates, particularly within the Environment Agency.

Although the FCERM-AG (Environment Agency 2010a) replaces the Flood and Coastal Defence Project Appraisal Guidance (FCDPAG) series previously published by Defra, *FCDPAG4 Approaches to Risk* (MAFF 2000) remains a useful document in terms of providing relevant procedures for dealing with risk.

Approaches to risk vary from simple procedures using risk allowances and risk workshops to more statistical analysis using Monte Carlo analysis.

The use of risk registers during cost estimation is a useful tool to identify, quantify and value the extent of the risk and uncertainty relating to a project or scheme, and can help to manage risks throughout the project life cycle. The latter approach can help to provide a best guess and an upper/lower boundary risk budget, but also provide assurance and assign statistical probabilities to the cost of a project exceeding a certain limit. Further guidance on risk budgets/registers and statistical analysis can be

found in CIRIA Special Publication 125 (Godfrey 1996) or the Green Book (HM Treasury 2003a).

The Environment Agency provides additional guidance and advice on risk management in its Operational Instruction 152_10, *Manual of Technical Guidance for Risk Management in NCPMS Projects*. This guidance for the Environment Agency's National Capital Programme Management Services (ncpms) provides:

- detailed information on the Environment Agency's preferred approach to risk management
- guidance on risk management procedures and activities including quantitative risk analysis procedures using Palisade © @Risk software

3.4 Sensitivity and scenario testing

How to focus efforts on those components that constitute a large proportion of the total cost, elements that may vary over time or higher risk components can be assessed by means of sensitivity or scenario testing.

In cases where a particular component of the costs may vary significantly over time or constitute a large proportion of the risk associated with the total costs, a sensitivity analysis that applies variations in these costs can be used to explore the implications on the total cost and option choice. If a particular test suggests that the decision for a particular option is likely, this would suggest the need for additional data collection or design before moving to the next stage in the appraisal process.

While inflation is not typically considered in an economic appraisal, cost rates may change in the future due to changes in efficiency, innovation, working or procurement practices. It may therefore be necessary to incorporate these future variations into a long term costing analysis to enable users to test or vary these aspects as part of a risk or sensitivity test. Growth factors can be used to reflect or test predicted changes in relative prices or demand.

Example of varied relative prices of certain cost types

For example, the supply cost of shingle for a beach recharge scheme may increase throughout the appraisal period if sources become scarcer. In this instance a sensitivity analysis that varies the future real cost of shingle supplies could be used to assess the impact on whole life costs and whether this has implications for option choice or the overall economic effectiveness of the option.

In some instances the variation in long-term maintenance costs may vary and need to be tested. For example, environmental forcing (flood events, storms and so on) may influence intermittent or repair costs if these are not designed for or in cases where these exceed the design case. In this specific case it may be useful to generate an annual average repair cost from an understanding of the probability of damaging events and the likely damage for a particular event. These intermittent costs should be added to the other operating costs and regular maintenance costs.

Further scenario testing on the frequency of environmental forcing could also be considered to determine the costs associated with climate change and increased frequency of maintenance interventions.

3.4.1 Sensitivity to differing inflation rates

If a cost estimate relies significantly on the costs of two very different commodities with differing inflation rates (for example, oil and materials prices, green taxes and labour rates), it may be appropriate for inflation to be considered. However, it is vital to avoid double counting of the effects of inflation. Furthermore, if growth factors are used for one stream of benefits or costs then they should be applied equally for all other streams.

3.5 Contingency and ‘optimism bias’

Adding a contingency to cost estimates to cater for unknowns and to help ensure project promoters retain adequate project budget is an idea that has been used for a long time. The amount of contingency can be generated in various ways from detailed assessment based on risk assessment techniques through to simple judgements by experienced practitioners.

What is new in the FRM field in more recent years is that more formal Treasury rules have been issued. The Green Book indicates that there is a demonstrated systematic tendency for project appraisers to be overly optimistic. This may result from appraisers overstating benefits and understating timings and costs (both capital and operational). Historically the Ministry of Agriculture, Fisheries and Food (MAFF) and then Defra have found that cost estimates in the early stages of appraisal were always too low. This was backed up by studies undertaken by the National Audit Office (NAO 2001) and reported in the MCM (Penning-Rowsell et al. 2005).

Considerable care is therefore needed in assessing project costs to compare them with benefits and a more realistic approach to cost estimation than has been used in the past. Conversely, it is interesting that a similar adjustment is not applied to flood damage benefits in a benefit–cost appraisal.

It is recommended that optimism bias should be added to the total costs in accordance with FCERM-AG methodologies. This process should be carried out for all projects that apply for Grant in Aid funding. An appropriate uplift or optimism bias is recommended at the relevant stage of the appraisal process; the FCERM-AG suggests that an optimism bias of 60% is typically used for projects at an early stage of consideration and a value of 30% at the more detailed project stage.

The Green Book also suggests the use of sensitivity analysis to test assumptions about estimated costs. The procedure is to start with the recommended 60% or 30% value and then consider the key components or risk and whether, for a particular case, action has been taken to reduce the risk contributors or factors specific to the site or operation are higher risk requiring an increase in the risk component contribution.

For generic information on the use of optimism bias in appraisals see the Supplementary Green Book guidance on optimism bias (HM Treasury 2003b). For specific guidance relating to the use of optimism bias on FCERM projects see the Defra supplementary note (Defra 2003). The Northern Ireland Department of Finance and Personnel has an optimism bias spreadsheet calculator⁷ based on this guidance.

Optimism bias based on the approach summarised above can take the place of current general contingency estimates at the strategy and scheme level. However, optimism bias should not replace the allowance for contingencies added to estimates of costs to allow for uncertainties or items one is aware of but cannot account for at the level of detail of the appraisal being undertaken.

⁷ <http://www.dfpni.gov.uk/eag-optimism-bias-calculator>

4 Cost types and decisions

4.1 Types of flood and coastal erosion management interventions

FCERM practitioners have a wide portfolio of measures at their disposal. FCERM options may consist of one or, more commonly, a combination of flood risk management measures which can be grouped under the following headings:

- **Structural measures:** defined as ‘any physical construction to reduce or avoid possible impacts of hazards, or application of engineering techniques to achieve hazard-resistance and resilience in structures or systems’
- **Non-structural measures:** defined as ‘any measure not involving physical construction that uses knowledge, practice or agreement to reduce risks and impacts, in particular through policies and laws, public awareness raising, training and education’ (ISDR 2009, p. 28)

As expected the understanding of structural responses, particularly traditional engineering solutions like walls and embankments, are better understood than many of the non-structural responses.

In addition to differentiating between structural and non-structural responses, it is worth considering other sub-divisions. The FCERM-AG defines the following categories of options based on the source–pathway–receptor approach:

- options that reduce flood risk at the source (for example, options that aim to alter the behaviour/frequency of flood events)
- options that influence the pathway of flood risk (for example, options that aim to alter the way in which flooding travels from its source to a sensitive receptor, thereby reducing its impact) risk from the source interacts with the receptor areas and communities at risk).
- options that reduce risk to flood receptors by local action (for example, floor raising or flood resistance)

Table 4.1 lists different types of FRM measures grouped according to these three options.

Table 4.1 Types of flood risk management measures

Broad categories	Flood and coastal erosion risk management options
Options that reduce flood risk at the source	<ul style="list-style-type: none">• Flood storage• Removal of constraining structures• Land use management (source control)• Reshaping the coast and its behaviour (offshore breakwaters, reefs, headlands)• Sustainable drainage systems (SuDS)
Options that influence the pathway of flood risk	<ul style="list-style-type: none">• Construction of linear defences (for example, floodwalls and embankments)• Rehabilitation or improvement of existing defences• Flow diversion• Channel works• Coastal recharge/nourishment• Temporary and demountable flood defences• Managed realignment
Options that reduce risk to flood receptors	<ul style="list-style-type: none">• Detection, forecasting and warning• Individual building resistance and resilience measures• Flood resistance and resilience measures• Resilience measures such as removal of furniture in response to a flood warning• Emergency planning and exercising• Targeted and improved public awareness and preparedness• River restoration and floodplain rehabilitation• Development control

4.2 Overview of FRM evidence summaries documents

The FCERM measure-specific evidence summaries in the appendices cover:

- fluvial linear defences
- channel management
- culverts
- control assets

- flood storage
- coastal erosion and protection
- managed realignment
- SuDS and urban drainage
- temporary and demountable barriers
- household flood protection
- land use and run-off management
- flood warning and forecasting
- habitat creation

These summaries collate readily obtainable data to enable users to produce unit costs to generate capital and maintenance costs. The following steps were taken by the project team to ensure this information is presented appropriately for each measure:

- Review available data.
- Decide which data are the most suitable and relevant to particular project types/users.
- Determine the approach to costing (cost curves, provision of example indicative data or guidance only).
- Derive guidance document for each flood risk management measure.

Each aspect has differing levels of readily available information. Where possible, the aim is to present the available information together with a discussion of the uncertainty associated with the data. Depending on the level of information available these aspects may be included only as guidance and as user-specified input into the cost tool.

Each measure-specific summary contains:

- a summary of types of intervention options covered
- available data and aspects that affect each important cost components for each intervention option
- specific guidance and considerations required in cost estimation for each intervention option
- links to any relevant R&D and relevant design guidance available to practitioners

The following sections provide an introduction to the measure-specific guidance.

4.2.1 Linear fluvial flood defences

This summary provides indicative costs and guidance on two of the main structural elements used for flood risk management: flood walls and flood embankments.

Data for capital and maintenance works for fluvial flood defences are well understood and there are no significant data gaps for high level or early stage cost estimation. The Environment Agency's Unit Cost Database and Maintenance Standards provide a good basis for assessment.

4.2.2 Channel management

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

4.2.3 Control assets

This summary provides indicative costs and guidance on a number of channel, flow and level control assets typical of those used by operating authorities for watercourses in England and Wales. Costs are typically site-specific due to bespoke requirements and sizing, and generally increase with the size and complexity of the asset.

4.2.4 Culverts

This summary provides indicative costs and guidance on culverts and associated trash and security screens typical of those used by operating authorities for watercourses in England and Wales.

4.2.5 Flood storage

This summary provides indicative costs and guidance for flood storage measures. The level of information is insufficient to provide suitable cost curves for different flood storage measures such as reservoir construction, flood embankments and storage ponds, although guidance and collated indicative costs are provided for very high level options.

4.2.6 Coastal

This summary provides indicative costs and guidance for coastal erosion and flood management activities. Coastal environments are often very dynamic and are highly variable in terms of the severity of exposure to natural conditions. Producing collated cost information is therefore challenging.

4.2.7 Managed realignment

This summary provides indicative costs and guidance for managed realignment measures. The level of cost information is highly variable due to the range and scale of options available within this broad category. It is therefore not possible to provide suitable cost curves for different approaches to managed realignment, although guidance and collated indicative costs are provided for very high level appraisal.

4.2.8 Urban drainage and SuDS

This summary provides indicative costs and guidance for SuDS and other drainage infrastructure.

4.2.9 Demountables and temporary defences

This summary reviews available information and indicative costs for demountable and temporary defences. Although these types of defences are quite different, the approach to cost estimation is similar and they have therefore been grouped together.

4.2.10 Household flood resistance and resilience

This summary provides a review of indicative costs and guidance on household flood resistance measures (those that attempt to prevent flood waters from penetrating a property) and resilience measures (those taken inside a property to minimise the damage caused by floodwaters that enter into a property).

4.2.11 Flood warning and forecasting

This summary provides examples of costs associated with flood warning and forecasting where available. Insufficient cost information is currently available to provide unit costs for specific cost components to build up a whole life cost for establishing or improving a flood forecasting and warning system for a community at risk. This section therefore provides available costs and case studies to guide appraisers when producing cost estimates for this aspect.

4.2.12 Land use and run-off management

A number of case studies have been carried out in the UK at a variety of scales which review a number of management methodologies and the costs of land use and run-off management. It is hoped these case studies can provide information and guidance for those commissioning or developing strategies and plans for similar projects and to help define indicative costs that can be used for broad scale cost estimation studies. The benefits of such FRM measures are the subject of ongoing assessment but comments are not provided in the guidance as it is outside the scope of this project.

4.2.13 Habitat creation in relation to FRM work

A number of UK research projects and case studies have reviewed the costs associated with habitat creation in relation to FRM measures. As out-turn costs for this aspect are poorly recorded, the guidance aims is to provide a summary of these costs and case studies and advice to support appraisers dealing with works where habitat creation may be required.

References

- BALKHAM, M., FOSBEARY, C., KITCHEN, A. AND RICKARD, C., 2010. *Culvert Design and Operation Guide*. CIRIA C689. London: CIRIA.
- BSI, 2008. *Publicly Available Specification 55-1:2008. Asset Management. Part 1: Specification for the optimised management of physical assets*. London: British Standards Institution.
- DAVIS LANGDON, 2011. *Spon's Civil Engineering and Highway Works Price Book*, 25th edition. London: Spon Press.
- DEFRA, 2003. *FCDPAG3 Economic Appraisal. Supplementary Note to Operating Authorities. Revisions to economic appraisal procedures arising from the new HM Treasury 'Green Book'* [online]. London: Department for Environment, Food and Rural Affairs. Available from: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/181443/fcd3update0303.pdf [Accessed 2 December 2013].
- DEFRA, 2009. *Appraisal of Flood and Coastal Erosion Risk Management. A Defra policy statement*. London: Department for Environment, Food and Rural Affairs.
- DEFRA and ENVIRONMENT AGENCY, 2004. *Operations and Maintenance Concerted Action Report*. Joint Defra/Environment Agency Flood and Coastal Erosion Risk Management R&D Programme. R&D Technical Report W5A-059/3/TR. Bristol: Environment Agency.
- ENVIRONMENT AGENCY, 2009a. *Assessment and Measurement of Asset Deterioration including Whole Life Costing*. Joint Defra/Environment Agency Flood and Coastal Erosion Risk Management R&D Programme. Science Report SC060078/SR2. Bristol: Environment Agency.
- ENVIRONMENT AGENCY, 2009b. *Guidance on Determining Asset Deterioration and the Use of Condition Grade Deterioration Curves*. Joint Defra/Environment Agency Flood and Coastal Erosion Risk Management R&D Programme. Science Report SC060078/SR1. Bristol: Environment Agency.
- ENVIRONMENT AGENCY, 2009c. *Flood and Coastal Risk Management (FCRM) external contributions*. Policy 284_09. Bristol: Environment Agency.
- ENVIRONMENT AGENCY, 2010a. Chapter 7.3 Describe, quantify and value costs. In *Flood and Coastal Erosion Risk Management Appraisal Guidance (FCERM-AG)*. Bristol: Environment Agency.
- ENVIRONMENT AGENCY, 2010b. *Flood Risk Estimating Guide – Update 2010*. Bristol: Environment Agency.
- GODFREY, P.S., 1996. *Control of Risk: A Guide to the Systematic Management of Risk from Construction*. CIRIA Special Publication 125. London: CIRIA.
- HOOPER, R., ARMITAGE, R., GALLAGHER, A. AND OSORIO, T., 2009. *Whole-life Infrastructure Asset Management: Good Practice Guide for Civil Infrastructure*. CIRIA C677. London: CIRIA.
- HM TREASURY, 2003a. *The Green Book: Appraisal and Evaluation in Central Government*. London: HM Treasury.
- HM TREASURY, 2003b. *Supplementary Green Book guidance: Optimism Bias*. London: HM Treasury.

ICE, 2012. *Civil Engineering Standard Method of Measurement (CESMM)*, 4th edition]. London: ICE Publishing.

ISDR, 2009. *2009 ISDR Terminology on Disaster Risk Reduction*. Geneva: International Strategy for Disaster Reduction.

JBA, 2006. *Review of Internal Drainage Boards*. Final Report. Skipton: North Yorkshire: JBA Consulting.

MAFF, 2000. *Flood and Coastal Defence Project Appraisal Guidance: Approaches to Risk. FCDPAG4: A Procedural Guide for Operating Authorities*. London: Ministry of Agriculture, Fisheries and Food.

NAO, 2001. *Inland Flood Defence: Report by the Controller and Auditor General*. HC 299 Session 2000-2001. London: National Audit Office.

PENNING-ROUSELL, E., VIAVATTENE, C., PARDOE, J., CHATTERTON, J., PARKER, D. AND MORRIS, J. (2005). *The Benefits of Flood and Coastal Erosion Risk Management: A Manual of Assessment Techniques*. London: Flood Hazard Research Centre, Middlesex University.

PENNING-ROUSELL, E., PRIEST, S., PARKER, D., MORRIS, J., TUNSTALL, S., VIAVATTENE, C., CHATTERTON, J. AND OWEN, D., 2013a. *Flood and Coastal Erosion Risk Management: A Manual for Economic Appraisal*. London: Routledge.

PENNING-ROUSELL, E., PRIEST, S., PARKER, D., MORRIS, J., TUNSTALL, S., VIAVATTENE, C., CHATTERTON, J. AND OWEN, D., 2013b. *Flood and Coastal Erosion Risk Management: Handbook for Economic Appraisal 2013*. London: Flood Hazard Research Centre, Middlesex University. Available from: <http://www.mcm-online.co.uk> [Accessed 9 December 2013].

TAYLOR, A.C, 2003. *An Introduction to Life Cycle Costing Involving Structural Stormwater Quality Management Measures*. Technical Paper. Melbourne, Australia: Cooperative Research Centre for Catchment Hydrology.

List of abbreviations

CAM	Condition Assessment Manual
CAP	Common Agricultural Policy
CMMS	Computerised Maintenance Management System [Environment Agency]
CPA	Coastal Protection Act
CPI	Consumer Price Index
CSO	combined sewer overflow
Defra	Department for Environment, Food and Rural Affairs
EIA	Environmental Impact Assessment
FCERM	Flood and Coastal Erosion Risk Management [R&D programme]
FCERM-AG	Flood and Coastal Erosion Risk Management Appraisal Guidance
FDGiA	Flood Defence Grant in Aid
FEPA	Food and Environmental Protection Act
FEWS	Flood Early Warning System
FRM	Flood Risk Management
HLO	High Level Option
IDB	Internal Drainage Board
IFFS	Initial Flood Forecasting System
LWD	large woody debris
MAFF	Ministry of Agriculture Food and Fisheries [now part of Defra]
MEICA	mechanical, electrical, instrumentation, control and automation
MCM	Multi-Coloured Manual
NRG	National Review Group [Environment Agency]
O&M	operation and maintenance
OMReG	Online Managed Realignment Guide [ABPMER]
OPW	Office of Public Works [Ireland]
PDM	Probability Distributed Model
PFFS	Preferred Flood Forecasting System
PV	Present Value
PWNR	Public Works Non-Roads
PVc	Present Value cost
R&D	research and development
SAC	Special Area of Conservation

SAMP	System Asset Management Plan
SEA	Strategic Environmental Assessment
SEPA	Scottish Environment Protection Agency
SMP	Shoreline Management Plan
SPA	Special Protected Area
SSSI	Site of Special Scientific Interest
SuDS	sustainable drainage systems
TE2100	Thames Estuary 2100 [study]
UCD	Unit Cost Database [Environment Agency]
UKBAP	UK Biodiversity Action Plan
WLC	whole life costing

Glossary

Official definitions and useful terms are also available in the supporting guidance listed in Table 1.3. Official definitions are also provided in FCERM-AG, the Fluvial Design Guide and the Green Book. The following definitions in relation to cost estimation and useful terms referred to elsewhere in this guidance are provided for completeness.

Acquisition or enabling costs

- Appraisal period** The period over which costs and benefits are assessed. This period is defined by guidance from HM Treasury and is normally 100 years for capital assessments.
- Benefit–cost analysis** Analysis that seeks to quantify all of the costs and benefits of a proposed scheme in monetary terms, including items for which the market does not provide a satisfactory monetary value. Sometimes referred to as cost–benefit analysis.
- Benefit–cost ratio** A ratio of the present benefits and costs of an option, calculated as the total benefits divided by the total costs. A BCR of >1 indicates benefits are greater than costs.
- Capital costs** Costs incurred during detailed planning, design and construction of an asset or service. Also referred to as **Capital Expenditure (CAPEX)** – public expenditure defined by the Office for National Statistics as being within the remit of capital for Treasury allocation purposes.
- Cost-effectiveness analysis (CEA)** Analysis that compares the costs of alternative ways of producing the same or similar outputs.
- Design life** The design life of a new structure or structural component under normal loading and environmental conditions before replacement or major rehabilitation is expected.
- Discounting** The conversion of future costs or benefits to present values using a discount rate. It is often necessary to compare options that will impact over a period of years into the future, which raises the question of how future cost and benefits should be valued in today's terms. Normally people prefer to receive cash sooner rather than later and to pay bills later rather than sooner. This is true even after allowing for inflation. For an individual this time preference may be indicated by the real interest rate on money lent or borrowed. In the public sector, likewise, social time preference is reflected by giving more weight to earlier than to later costs and benefits. This process of 'discounting' is usually given effect by applying a 'discount rate' to future costs and benefits.
- Discount rate** The annual percentage rate at which the present value of a future pound, or other unit of account, is assumed to fall away through time. It is currently set at 3.5% per year in real terms. Mathematically, a discount rate is the opposite of a compound interest rate. The discount rate defines how rapidly the value today of a future pound declines through time in real terms, just as a real rate of interest determines

how fast the real value of a pound invested now will increase over time.

Enabling costs	Costs incurred between the decision to proceed with the procurement and the entry of the FCERM asset to operational use. Some of these may represent sunk costs depending on the point of appraisal within the whole life cost process.
End life costs	Costs associated with the disposal, decommissioning, termination or replacement of the asset or service. These costs can be split between replacement/refurbishment costs (where an assets standard of service is not altered) or change works (where the intention is to alter the standard of service of an asset).
Frequent maintenance	An Environment Agency term specific to System Asset Management Plans (SAMPs) to define activities that support the Standard of Service of an asset by reducing the rate of deterioration. Frequent maintenance provides for efficient, effective and safe operation in a cost-effective manner. It normally includes annual costs associated with planned proactive activities.
Intermittent maintenance	An Environment Agency term specific to SAMPs to define infrequent and one-off activities that support the Standard of Service. Infrequent maintenance covers infrequent planned and recurring activities identified when the asset was commissioned as being required within its design life.
Internal Drainage Boards (IDBs)	Local drainage authorities established in some areas of the country, historically in low lying areas with particular land drainage problems.
Maintenance	Work that sustains the desired condition and intended performance of an asset. In some circumstances maintenance may accept a gradual decline in standard. For existing assets that have no residual life, maintenance may not result in an acceptable Standard of Service and only refurbishment or replacement will reinstate an acceptable Standard of Service.
Net Present Value (NPV)	The discounted value of a range of costs and benefits. Calculated as the PV benefits minus the PV costs. NPV is used to describe the difference between the present value of costs and benefits in future years. NPV is a primary investment decision criterion. NPV is defined as the difference between the present value of a stream of benefits and that of a stream of costs. A positive NPV occurs when the sum of the discounted benefits exceeds the sum of the discounted costs. A negative NPV is usually called a Net Present Cost (NPC). The decision rule is to select the option that offers to maximise NPV or minimise NPC. This is subject to assessment of those impacts that cannot be valued in money terms. NPV takes account not only of social time preference through discounting but also, by combining capital and recurrent cost and benefits into a single present day value indicator, enables direct comparison of options with

very different patterns of costs and benefits over time.

Operational costs	The costs incurred through the day-to-day management of an operation, and maintenance of an asset or a scheme. Also known as Operational Expenditure or OPEX.
Optimism bias	The demonstrated systematic tendency for appraisers to be over-optimistic about key project parameters, including capital costs, operating costs, works duration and benefits delivery.
Present Value	The present day value of a future stream of costs or benefits. Calculated by discounting a stream of future costs or benefits. See also Net Present Value and discount rate.
Price Index	A measure of the amount by which prices change over time. General price indices cover a wide range of prices and include the Consumer Price Index (CPI) and the Retail Price Index (RPI). Special price indices apply to one commodity or type of commodity.
Residual life	Residual life is the time until assets need replacing. Residual life can be extended or reduced by altering maintenance practices. The point at which the asset requires replacement may be estimated by a condition grade or performance measures that reflect an unacceptable Standard of Service.
Resilience measures	Resilience measures are designed to reduce the impact of water that enters property and businesses. They could include measures such as raising electrical appliances.
Resistance measures	Resistance measures are designed to keep flood water out of properties and businesses. They could, for example, include flood guards.
Risk register/ risk log	A useful tool to identify, quantify and value the risks and uncertainties relating to a proposal.
Sensitivity analysis	Analysis of the effects on an appraisal outcome of varying the projected values of important variables.
Sunk costs	Expenditures that have already been incurred on goods and services, or resources that are already irrevocably committed. These costs should be ignored in an appraisal. Sunk costs may include items such as previous investment in defences and expenditure on feasibility studies.
Unit rates	The cost per unit measure (number/length/area/volume) to replace an asset or part of an asset.
Whole life cost	The total cost of managing an asset over the design life of the asset. For assets that the Environment Agency owns and manages, this will include the full cost of construction, use, maintenance and replacement/decommission. All reasonably foreseeable costs over the whole life period should be included.

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

Then call us on

03708 506 506 (Monday to Friday, 8am to 6pm)

email

enquiries@environment-agency.gov.uk

or visit our website

www.gov.uk/environment-agency

incident hotline 0800 807060 (24 hours)

floodline 0345 988 1188 / 0845 988 1188 (24 hours)

Find out about call charges (www.gov.uk/call-charges)



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