HANDBOOK
FOR ECONOMIC APPRAISAL

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FLOOD AND COASTAL EROSION RISK MANAGEMENT

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1 Introduction

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AIM AND PURPOSE OF THE HANDBOOK

This Handbook is intended to be a stand-alone "How to do it" guide to assessing the benefits of flood and coastal erosion risk management (FCERM). When combined with knowledge of the costs of the plans and schemes required in that risk management, the user can assess the relationship between the benefits and the costs of investment decisions. This comparison should enable the users to identify those risk management plans and schemes which maximise the economic return to the nation (England and Wales) and therefore represent "best value for money" by being economically efficient.

The term '**scheme**' here is not meant to imply an engineering scheme but includes both structural engineering ways to reduce flood or erosion risk and non-structural alternatives (flood warning; emergency response; land use planning; etc). The term 'scheme' is used hereafter for simplicity.

Since the 2005 MCM, there has been an important shift in the governance arrangements in England and Wales for FCERM, and hence in the appraisal of investment. This has meant that:

- Defra (2004, 2005) has been more focused on policy development, with *Making Space for Water*, and on appraisal policy in the form of its *Policy Statement on Appraisal of Flood and Coastal Erosion Risk Management (Defra, 2020)*;

- The Environment Agency (EA) has taken over from Defra the role of providing detailed guidance on evaluating investment in FCERM schemes. The latest version of its *FCERM appraisal guidance (FCERM-AG)* can be found at https://www.gov.uk/guidance/fcerm-appraisal-guidance.

Reflecting these changes, the EA commissioned the Flood Hazard Research Centre at Middlesex University to update this Handbook and their MCM database. In Phase 1 (2009-10) the updating has been fairly straightforward, resulting in the **2010 edition** of the Handbook/CD. Phase 2 (2010 to 2013) has been more fundamental, including a complete revision of the non-residential flood damage data (Chapter 5), a new investigation of losses related to breaks in communication links and utility services (Chapter 6), and some significant modifications to the methods advocated to assess agricultural benefits (Chapter 9). Other changes have been the addition of data on park homes and damage to vehicles affected by flooding (Chapter 4). All these new data are now supplied through MCM-Online.

THIS HANDBOOK AND THE 'MANUAL'

This Handbook will allow the user to carry out economic appraisal with the minimum of effort for the majority of flood and coastal erosion risk management schemes to be assessed. However, assessments are not always straightforward and therefore this Handbook is complemented by a much more extensive Manual, colloquially termed the *Multi-Coloured Manual* or, hereinafter, as the MCM or the Manual (Penning-Rowsell et al., 2013).

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The Handbook is designed to be more straightforward to use than the Manual, because that also reports the research undertaken at Middlesex University on which this Handbook and the MCM are based. The Manual also discusses the kind of complications in the appraisal of flood risk management options that can occur when the assessment is not straightforward, and provides suggestions and methods to apply in those circumstances.

Those using this Handbook should therefore appreciate the connection with the full MCM. To help this, the MCM chapters correspond with those in the Handbook and, additionally, the MCM provides further detail on the rationale behind our approaches described here. **Most values in this Handbook and its accompanying MCM-Online data sets have been updated using an appropriate and agreed annual average CPI value (from March 2022 - February 2023), unless otherwise indicated.**

HOW TO USE THE HANDBOOK

This Handbook is aimed at guiding those undertaking Flood and Coastal Erosion Risk Management (FCERM) project appraisals. It offers a step-by-step 'how-to do-it' commentary on the many types of benefits to be assessed, which are a feature of FCERM appraisal.

The Handbook seeks to develop and improve existing approaches, without compromising the principles that underpin current Defra (2020) and HM Treasury guidance (2022).

In the meantime, we believe that the majority (say 75%) of flood and coastal erosion risk management schemes can have their economic benefit assessments undertaken using the guidance provided here. In particular, the Handbook applies to:

- Those undertaking strategy studies who want a 'first cut' assessment of potential benefits;
- Those undertaking initial studies, who should use the methods described for this level of analysis, as covered herein;
- Those undertaking detailed scheme studies, who should generally use the more detailed methods described here and in the MCM.

Importantly, appraisers should always, in cases of doubt, seek guidance or refer to the over-riding policy framework in the Treasury 'Green Book' and the associated Defra and Environment Agency guidance (Table 1.1).

HANDBOOK STRUCTURE

The Handbook is structured to reflect three considerations:

1. The type of scheme, that is to say whether it is aimed at:

    - Flood risk management (**Chapters 2, 3, 4, 5 and 6**);
    - Delaying erosion at the coast (**Chapter 7**);
    - Providing an enhanced flooding and drainage regime for agriculture (**Chapter 9**).

2. In the case of flood alleviation, which economic sectors are under consideration, e.g.:
    - Residential and non-residential properties (**Chapters 4 and 5**);
    - Road disruption etc (**Chapter 6**);
    - Emergency services (**Chapter 6**).

3. Some chapters address both coastal erosion and flood risk management:

   - Recreational impacts (**Chapter 8**);
   - Environmental impacts (**Chapter 10**).

This structure is also followed in the MCM, thereby assisting cross-referencing.

HANDBOOK CONTENTS

The chapters of this Handbook each generally contain:

1. Step-by-step guidance on benefit assessments: "How to do it"
2. Data collection needs, methods and key issues
3. Methods on benefit calculation, including the relevant formulae, separated in some instances into strategic methods, initial and detailed appraisals
4. Guidance as to interpreting the results
5. Details of other relevant aspects to benefit assessment *not* discussed in this Handbook but outlined in the MCM

Because it is designed for 'work-a-day' situations, the Handbook includes no consideration of the complexity of the economic theory behind benefit-cost analysis which is dealt with in the MCM, Chapter 2 (Penning-Rowsell *et al.*, 2013), or of the theory of risk management. But the MCM-Online, of which this Handbook is now part, contains the MCM database on flood impacts and other relevant data.

Table 1.1: *Sources of guidance on appraising flood and coastal erosion risk management schemes and plans*

Source reference	Document	Purpose
HM Treasury 2022	The 'Green Book'	Identifies the preferred approach to public sector investment appraisal
Environment Agency 2022	Flood and Coastal Erosion Risk Management appraisal guidance (FCERM-AG)	How a project appraisal and CBA should be completed for flood and coastal erosion risk management projects
Environment Agency 2021	Partnership funding supporting documents and Transition arrangements	Provides guidance for setting up partnerships for FCERM
Flood Hazard Research Centre and the Environment Agency 2013	The new 'Multi-Coloured Manual' (MCM)	Gives details of relevant research and detailed guidance on benefit assessment methods and data – some of the methodologies and data have been updated since its publication. Look to the most recent version of the Handbook for details.
http://www.mcm-online.co.uk http://www.fhrc.mdx.ac.uk	Middlesex University FHRC MCM-Online	Provides data and other information (including questionnaires) for the support of flood and coastal erosion risk management project appraisals

KEY ACTIVITIES IN ASSESSMENTS

This Handbook is intended to allow appraisals of flood and coastal erosion risk management schemes to be undertaken with the minimum of effort. One important dimension of this is judging the time and resources allocated to those parts of the benefit assessment process that are most important. This importance is gauged in two ways:

- Concentrating on those components of total benefits which are the largest compared with the effort expended on assessing them (e.g. non-residential property where there is a mix of non-residential and residential property at risk, because non-residential damage per unit area is generally far higher than residential damages);
- Ensuring that the data on which the benefit assessment depends is most accurate (or least inaccurate) where it has most effect on the final results (e.g. for coastal erosion, making sure projected erosion rates are as soundly based as possible; in the flooding field ensuring flood probabilities and depths are accurately assessed).

Applying these two principles will be different for different scheme types and in different economic sectors, so that each chapter of this Handbook addresses this issue in its own subject area.

In general, applying such judgement will mean ignoring sources of small amounts of benefit (e.g. road traffic disruption on minor roads) and accepting that some data will be less accurate than others. Sensitivity analysis can be used to test how the decisions that flow from these principles affect particular appraisals.

THE POLICY CONTEXT

This Handbook and the MCM have been designed to support the Defra/ODPM/HM Treasury policy on “Making Space for Water” (Defra, 2004; 2005, 2020). This stresses holistic policies and integrated appraisal, commensurate with sustainable development.

Neither the Handbook nor the MCM explicitly includes the appraisal of urban drainage but could be used in this field. Both recognise the current moves away from narrow benefit-cost analysis (BCA) towards Multi-Criteria Analysis (MCA): see Chapter 10.

This Handbook aligns with the latest Treasury ‘Green Book’ guidance[1] on investment in public sector projects including, for example, the use of weightings to assess and correct for distributional impacts, optimism bias considerations when assessing project costs, and variable discount rates for projects with long lives.

They also build on Defra’s series of Project Appraisal Guidance series (e.g. PAG3) and their replacement by the Environment Agency’s Flood and Coastal Erosion Risk Management Appraisal Guidance (FCERM-AG). ‘Making Space for Water’ (Defra, 2005) has led to updating Defra’s guidance, separating policy guidelines/statements issued by Defra from Environment Agency best practice implementation guidance.

[1] Although all efforts have been made to align with current English Government policy, it is important for users of these data and methodologies to check the relevant national appraisal policy guidelines for any recent updates.

In summary, supplementary guidance now comprises:

- Defra (2020): 'Flood and coastal erosion risk management: Policy Statement';
- Environment Agency (2022): the 'Flood and Coastal Erosion Risk Management Appraisal Guidance (FCERM-AG).

In this respect appraisers of FCERM schemes should be aware of the types of risk management expenditure that Defra currently funds, not least because some benefits might not be supported in this way. Those benefits (e.g. major recreational benefits) might currently need the support of other funding streams where they are not fundamental to the relevant scheme.

Notwithstanding the above, the contents of both the Handbook and the Manual remain the responsibility of Middlesex University (FHRC) and the Environment Agency.

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2 Using Appraisals to Make Better Choices

2 Using Appraisals to Make Better Choices

OVERVIEW

This chapter presents key points on how to improve decisions through project appraisal, and is structured to consider six key questions covering the project appraisal process:

- What is project appraisal?
- Why do project appraisals?
- Why involve stakeholders?
- What is value?
- How to compare options?
- How to make the decision?

A much more detailed discussion of these points is contained in Chapter 2 of the MCM (Penning-Rowsell et al., 2013).

The framework laid out here remains the same as in the Handbook 2010. But between the 2005 and 2013 Manuals, there has been more research done on Multi-Criteria Analysis, with a “scoring and weighting” system being developed for the Environment Agency and Defra by Risk and Policy Analysts (Environment Agency, 2022). The involvement of stakeholders in decision making continues to be strengthened, and is now routine, with the implementation of Defra’s *Making Space for Water (*Defra, 2004). Users are also recommended to consider Defra’s Policy Statement (Defra, 2020).

LESSONS FROM EXPERIENCE

- The role of economic analysis is in supporting the stakeholders in deciding which is the best option;
- Do not look for a mechanical means of making choices; what project appraisal can provide is greater understanding of what the choice involves: decision-support, not decision-making;
- The appraiser is seeking to make ‘better’ choices. One of the central conflicts here may therefore be different understandings concerning what is a ‘better’ choice;
- The option choice process should be appraisal led;
- As a learning process, the appraiser should start by identifying the critical parameters as these that affect the choice between options and concentrate our attention upon those parameters;
- There is no universally superior project appraisal technique; the choice of technique has to be matched to the reasons why the choice is necessary;
- Do not expect all choices to be clear-cut: some will be truly marginal;
- Even though economic analysis is a central component of the appraisal process, it should always be used critically and only as an aid to decision-making; it is not an end in itself.

WHAT IS PROJECT APPRAISAL?

The Environment Agency's project appraisal guidance outlines that project appraisal is the process of identifying and then evaluating options in order to select the one that most likely satisfies the defined project objectives. The purpose of the project appraisal process is to improve decision-making towards making the 'best' choice. Good decisions and the 'best' choice are most likely to result from considering all economic, social, environmental and technical issues for a full range of options.

The methods used in project appraisal are aimed at:

1. Simplifying the complexity of choice;
2. Understanding what choice involves; and
3. Enabling this understanding to be shared by stakeholders.

To ensure that project appraisal is not a mechanical exercise, appraisal led design is essential. Appraisals should drive the design process, with the identification and specification of project options evolving through this appraisal process.

To be useful, appraisal methods should ensure best value and hence the highest rate of return for public monies. They must also provide accountability, transparency of the basis for choice, and result in a rational comparison of the available options and the consequences of these options.

WHY DO PROJECT APPRAISALS?

If the appraiser wants to make better decisions in flood and coastal erosion risk management, we need to start by understanding why we have to make the particular decision in the first place. This commences with identifying the problem and defining the objective/s.

In the simplest terms, a choice is required when there is conflict (i.e. disagreement) and uncertainty about a course of action to meet the defined objective/s. Uncertainty arises because of initial limited knowledge of an option's pros and cons (benefits and costs), and whether the 'best' choice to be made will be the most sustainable.

Economic appraisal enables the comparison of widely differing options, with careful consideration applied to how options are appraised as to their 'value' to arrive at the 'best' choice.

WHY INVOLVE STAKEHOLDERS?

A better decision is one that is both a 'just' decision and one that turns out to be 'correct' in the long run. For a decision to be 'just', it is not only the outcome that must be seen to be fair but so too must the process by which the decision is made. Critical to the achievement of a 'just' process and a better decision is therefore appropriate stakeholder involvement.

Project appraisal therefore has two roles:

1. Stakeholders need informed involvement, with information available to all: the project appraisal technique itself can contribute to creating a shared knowledge base;

2. The project appraisal method must serve as a framework through which stakeholders can explore, argue and negotiate their concerns and explore different options.

Also, relatively new techniques are being developed, including Multi-Criteria Analysis (MCA) which, when appropriately applied, could lead to improved stakeholder involvement in decision-making.

WHAT IS VALUE?

Value is central to benefit-cost analysis and, in economics, all values are subjective: the value of some 'good' is given by the individual and reflects his or her subjective preference for that 'good'. Value does not have to be measured in monetary terms only, although the Treasury Green Book (H.M. Treasury, 2022), suggests that '*real or estimated market prices provide a first point of reference for* estimating *the value of benefits*' (p44), and that '*benefits are valued in monetary terms, unless it is not proportionate or possible to do so (p40)'*.

In this respect, the shorthand term 'good' is used to denote any commodity, resource or item which an individual prefers or desires (for example, a coastal protection project, a flood risk management scheme, a beach, a river, or a recreational experience). The values assigned to any such good then reflect the relative contribution that this good makes to an individual's 'utility' or wellbeing.

Value is also 'sacrificial'. This means it quantifies or reflects the degree to which the individual would be willing to *give up* an amount of that 'good' in order to have *more* of another: more flood risk management means fewer hospitals. Values are, therefore, not absolute but reflect the basis upon which choices are made between enjoying these different goods (which the economist calls 'consumption').

There are three general strategies for deriving values for use in benefit-costs analysis:

1. Using market prices (e.g. the cost of repairing flood damage).
2. Using 'inferential' methods, which use statistical techniques to infer the value of something that does not have an observable market price (e.g. valuing a recreation resource by the distance people are prepared to travel to enjoy that resource).
3. Using 'expressed preference' methods which usually involve questionnaires to elicit a value (e.g. asking people what choices they would make between different recreation venues).

Further information on these techniques and on the issues covering non-use values is provided in Chapter 10 here and in the MCM (Penning-Rowsell et al., 2013). New techniques for Multi-Criteria Analysis could facilitate better comparison of certain monetary and non-monetary values.

HOW TO COMPARE OPTIONS?

Option appraisal should provide an assessment of whether a proposal is worthwhile. However, the steps outlined in the Treasury Green Book involving *Justifying Action* (e.g. identifying need) and *Setting Objectives* should take place before *Option Appraisal*. Once options are developed, the appraisal process assesses option performance, usually by comparing the consequences of '**do something**' options against some baseline option (usually '**do nothing**'). Appraisers should only be interested in these differences. Benefit–cost analysis is normally used to make comparisons and judgments on these differences, whilst other techniques such as MCA can improve this comparison stage.

An initial **sensitivity analysis** should ideally be undertaken at the start of the project appraisal process, and not at the end, in order to understand how sensitive the choice is to the likely accuracy of data or methods being used. An experienced appraiser should be able to anticipate those parameters to which the estimated benefits and costs are most sensitive. It is those parameters that should be progressively refined as the analysis progresses.

The consequences of the different options often differ in terms of:

- Who is affected;
- What is affected;
- How they are affected; and
- When this effect occurs.

Thus, all appraisals should focus on these points, and any comparison between options will involve judgments about how these different consequences can be brought to a common base.

HOW TO MAKE THE DECISION?

According to the Treasury Green Book, the purpose of an appraisal is to indicate that no policy, programme or project is adopted without first having the answers to these questions:

(a) Are there better ways of achieving a given objective (e.g. reduced flood risk)?

(b) Could the resources be put to better use (e.g. building a hospital)?

The appraisal also should explore how confident we can be that one option is better than a range of other options. Two criteria frequently used in comparing the different options are:

- The **benefit-cost ratio**: the ratio of the present value of all of the streams of benefits over the present value of all of the streams of costs; and
- The **net present value**: the difference between the present value of all of the streams of benefits and the present value of all of the streams of costs.

Projects are only economically viable if the benefits exceed the costs (i.e. the ratio of benefits to costs is greater than 1.0). Where benefits marginally exceed costs, there is often high uncertainty as to whether an option is justified, because only a small change or error in either the benefits or costs would tilt the balance the other way. So when comparing a 'do something' option to the baseline option, confidence is needed that a 'do something' option is clearly preferable.

In this regard, the decision process explores whether the best value for money is provided while achieving the most appropriate standard of risk management. This is undertaken by assessing the incremental benefit-cost ratio of each economically viable option. The full mechanics of this decision process for England can be found in the Environment Agency's FCERM-AG appraisal guidance (FCERM-AG, 2022) (https://www.gov.uk/guidance/flood-and-coastal-erosion-risk-management-appraisal-guidance/8-compare-and-select-the-preferred-option *Compare and select preferred option: Decision criteria and decision process*). Users should consult the decision rules appropriate for their context.

The Environment Agency guidance for England (and others may wish to follow the same advice) suggests that the decision should be modified as necessary to take account of factors that are not fully counted in the economic analysis. New techniques which incorporate these other factors into the decision-making process in a more consistent and transparent way, such as Multi-Criteria Analysis, have been tested and developed (see FCERM-AG, 2022).

FUTURE DEVELOPMENTS

The Treasury's Supplementary Guidance Note to their Green Book (HM Treasury, 2005), sets out five principles that government will apply to managing risks to social, environmental and economic aspects of sustainability:

1. Openness and transparency.
2. Involvement.
3. Proportionality and consistency.
4. Evidence.
5. Responsibility.

Future guidance on project appraisal and decision-making will draw on a number of techniques that will contribute to underpinning these principles, as shown below:

- Improved transparency, openness, proportionality and greater consistency of appraisal policy with the 'Green Book' should emerge through the adoption of Willingness to Pay economic approaches. Amongst other changes, these approaches seek to disaggregate benefits and present information on how project and programmes impact on different economic interest groups and financial budgets;

- Improved evidence, involvement, responsibility and transparency should emerge through the application of Multi-Criteria Analysis (MCA). MCA aims to establish preferences between options with reference to an explicit set of objectives and associated criteria for assessing the extent to which the objectives have been achieved. Two of the key advantages of MCA are that, when appropriately applied, it can allow greater stakeholder involvement and provide greater transparency to the decisions being made at all levels of appraisal.

These areas have been the subject of some research and theoretical development. But more work is required to test their feasibility and practical application before recommendations can be made for wider and universal adoption in flood and coastal erosion risk management applications.

REMAINING ISSUES

New edition of the UK Government HM Treasury Green Book

The Green Book sets the rules for UK Government economic appraisal and so is important for our work. A new version was released in 2022[1].

Key definitions: 'Private', 'public', 'collective' and 'individual' goods

- Those goods that are bought and consumed by individuals such that they are then not available to others are termed **private goods**. The assumption here is that individuals make their own purchasing decisions for their own purposes. This applies to most marketed goods, although some goods can be shared between individuals without being used-up (e.g. newspapers and books);

[1] Although all efforts have been made to align with current English Government policy, it is important for users of these data and methodologies to check the relevant national appraisal policy guidelines for any recent updates.

- **Public goods**, by contrast, occur when the provision of a good by one individual necessarily means that it is also provided for others without diminishing its value. The assumption here is that there is no way of excluding others from receiving the benefits of the goods provided (e.g. a lighthouse, or a ring flood embankment around a town);

- There are some goods that any individual, given sufficient resources, can acquire for him/herself and these are termed **individual goods** (e.g. flood proofing a house);

- **Collective goods**, by contrast, can either only, or only efficiently, be provided collectively (e.g. a public flood warning system).

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3 Flood Risk Management Benefits: Theory and Practice

3 Flood Risk management Benefits: Theory and Practice

OVERVIEW

In this chapter we provide pointers as to how a flood risk management benefit assessment should be conducted. This draws on the theory that should guide this and the sources of data that will be necessary. These are not presented as step-by-step guidance, as in other chapters, but as items that need consideration before and during the work. More detail is provided in Chapter 3 of the MCM (Penning-Rowsell *et al*., 2013).

The theoretical framework presented here remains as valid now as it was in the previous MCM (2005). However:

- Major floods in 2007 have led to research that has altered our understanding of the costs of emergency services in flood incidents, and hence questioned the universality of the 10.7% uplift factor recommended in 2005 (see also Chapter 6 herein);
- The 2007 floods also led to substantial disruption of electricity and water supplies, and these need more emphasis now, especially their off-floodplain effects;
- The land use data available for benefit assessments continues to improve, with updates to the Environment Agency's National Receptor Dataset (NRD). This reduces the need for expensive, time-consuming field-based survey;
- Climate change impacts on flood frequency are more fully understood and need to be factored in to assessments of the return periods of future floods. The latest UK Climate Projections can be accessed at https://www.metoffice.gov.uk/research/approach/collaboration/ukcp and potential impacts of climate change on flooding in the UK are evaluated in the latest Climate Change Risk Assessment (HM Government, 2022).

LESSONS FROM EXPERIENCE

- For schemes resourced from public funds the damages averted by flood risk management schemes should generally be assessed as national economic losses, not the financial losses to the individuals and organisations;
- Close attention should be given to accurate determination of the area potentially affected by flooding (the floodplain). Within that exercise considerable effort should be given to determining the extent and annual probabilities of the lesser floods and the flood at which damage begins;
- The different quality of different data inputs needs recognition, using a Data Quality Score (DQS) systems if appropriate to manage the process of benefit refinement targeted at those data inputs that are of poorest quality yet which contribute most to the variation in benefit totals;
- For major schemes involving considerable investment in low-lying areas (i.e. not steep catchments) close attention should be given to the topographic data that defines the thresholds of property flooding;
- Sufficient potential floods should be appraised so that an accurate picture can be developed of the shape of the loss-probability curve including, where appropriate, such events needed to define and quantify any Above Design Standard benefits.
- Particular attention needs to be given to the return period (or annual probability) at which flood damage begins at the site under investigation, as this will significantly influence the calculated Annual Average Damages (AAD) by properly defining that part of the area under the loss-probability curve.

TYPES OF FLOOD DAMAGE AND FLOOD LOSS

The benefits of flood risk management comprise the flood damage averted in the future as a result of schemes to reduce the frequency of flooding or reduce the impact of that flooding on the property and economic activity affected, or a combination of both.

Direct damages result from the physical contact of flood water with damageable property and its contents. Many items of flood damage loss are a function of the nature and extent of the flooding, including its duration, velocity and the contamination of the flood waters by sewage and other contaminants. All these affect damages and losses, and the location of the flood will affect the networks and social activities disrupted, causing indirect losses.

This situation is summarised in Table 3.1. It is important to ensure that for the purposes of benefit-cost analysis we assess only the national economic losses caused by floods and coastal erosion, and their indirect consequences, rather than the financial losses to individuals and organisations which are affected (Table 3.2). Intangible losses are those which are harder to value. However, these are becoming fewer as methodologies develop to assist in their valuation.

It is also important to ensure that benefits are not double counted, such as counting the loss of trade of a factory as well as the consequent loss of business of the factory’s retail outlets.

Table 3.1 Direct, indirect, tangible and intangible flood impacts, with examples

		Measurement	
		Tangible	Intangible
Form of Loss	Direct	Damage to building and contents	Loss of an archaeological site
	Indirect	Loss of industrial production	Inconvenience of post-flood recovery

Table 3.2 Financial and economic damages related to household flood losses

Financial
Takes the standpoint of the individual household involved
Uses the actual money transfer involved to evaluate the loss or gain (e.g. if a household has a new-for-old insurance policy and they claim for a ten year old television, the loss is counted as the market price of a new television)
VAT is included as are other indirect taxes as they affect the individual household involved
Economic
Takes the standpoint of the nation as a whole – one person's loss can be another person's gain
Corrects the actual money transfer in order to calculate the real opportunity cost (e.g. in the case of the ten year old television, the real loss to the country is a ten year old television; the depreciated value of that ten year old television is taken as the loss)
VAT is excluded, as are other indirect taxes, because they are money transfers within the economy rather than real losses or gains

NB: This is Table 4.2 in the MCM 2013

CALCULATING ANNUAL AVERAGE DAMAGES

The methodology for assessing the benefits of flood risk management combines:

- An assessment of risk, in terms of the probability or likelihood of future floods to be averted; and
- A vulnerability assessment in terms of the damage that would be caused by those floods and therefore the economic saving to be gained by their reduction.

Figure 3.1 provides the classic four-part diagram summarising the inter-relation of hydrology, hydraulics and economics as the basis of calculating the benefits of flood risk management. The annual average flood damage is the area under the graph of flood losses plotted against exceedance probability (the reciprocal of the return period in years).

Figure 3.2 gives a simplified flow chart of the stages that need to be followed in order to calculate the benefits of flood risk management (or, put another way, the stages for calculating the present value of flood damages/losses (PVd) that will occur in the future if a "do nothing" option is adopted).

ADDING EMERGENCY COSTS

Research reported in 2002 (Penning-Rowsell *et al*., 2002) showed that flood incidents in 2000 were accompanied by significant emergency costs:

- Police, fire and ambulance service costs;
- Local Authority costs;
- Environment Agency costs.

These costs were quantified at 10.7% of property damages - see Chapter 6 and the detailed research in the MCM (Penning-Rowsell *et al*., 2013). Investigations following flooding in 2007 showed proportionately lower emergency costs, resulting in a 5.6% uplift factor (see Chatterton *et al*., 2010). In any benefit assessment capped annual average property damages should therefore be multiplied by 1.107 (dispersed flood incidents) or 1.056 (concentrated settlements such as large towns and cities) to allow for these costs.

DATA INPUTS: DEFINING THE BENEFIT AREA

The benefit area is the starting point for assessing the benefits of flood risk management; it is the area affected by the flood problem, both directly and indirectly.

Usually the benefit area will be the maximum known extent of flooding in the area or catchment involved. However, it may also be necessary to extend the benefit area beyond the floodplain as conventionally defined by, say, the 1% probability event. This is because the calculation of Above Design Standard benefits generally requires the assessment of the impacts of reducing more extreme flood events beyond any anticipated 'design flood'.

Figure 3.1 *The classic 4-part diagram summarizing the calculation of annual average flood losses*

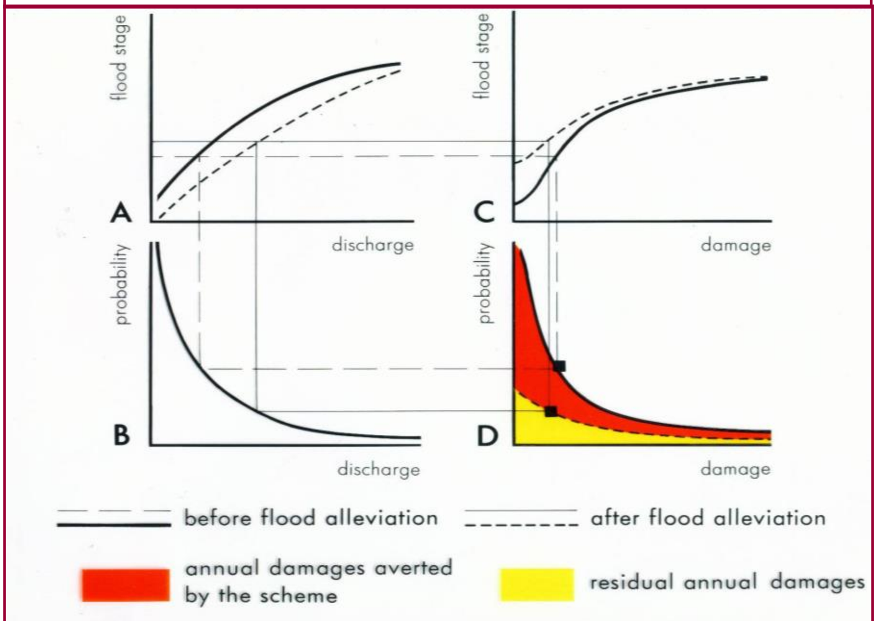
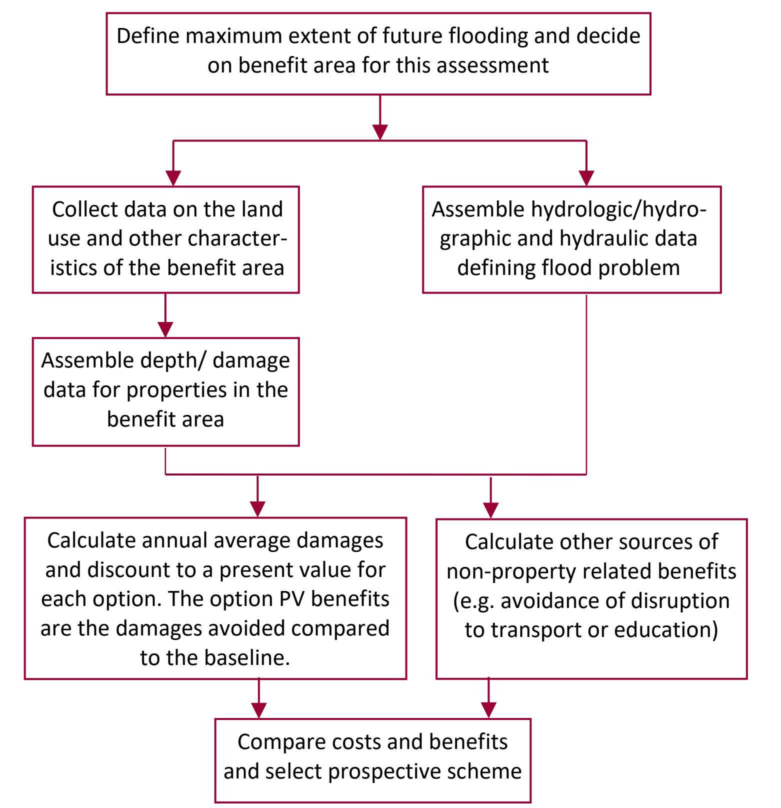


Figure 3.2 *The stages that need to be followed in order to calculate the benefits of flood risk management to compare with scheme costs*



The indirect effects of flooding can also extend well beyond the floodplain. Telecommunications, road and rail traffic disruption can occur many kilometres from the floodplain, as a flood can cause disruption to those communication and economic linkages and that disruption 'spills over' to communication links not themselves flooded. The same can apply to the disruption of water and electricity supplies (see Chapter 6).

In coastal situations it will generally be necessary to assess the floodplain as the area subject to flooding if current defences are breached or overtopped.

DATA INPUTS: ASSESSING VULNERABILITY TO FLOODING FOR THE LAND USE IN THE BENEFIT AREA

The approach to assessing the benefits of flood risk management is through investigating the potential damage to a variety of land uses in the areas to be affected.

A 'classification of land use' is available in the *Additional Resources* section of Chapter 3 on MCM-Online. It is customary within benefit-cost analysis of flood risk management investment to consider only the land use as currently existing (except where the future flood regime is likely to make current use untenable and property is assumed to be 'written off' or subject to change of use, or when agricultural land becomes suitable only for less productive uses).

For a fully comprehensive assessment of property-related benefits it will be necessary to determine:

- The geo-reference of each property (the grid reference);
- The altitude of the threshold of flooding at that property; and
- The area of the property in square metres if the property is non-residential.

Field surveys can identify land uses in the benefit area. Otherwise, the Environment Agency's National Property Dataset is the first source of data that should be consulted, but field surveys may also be necessary to determine the type of non-residential property in the area and its floor area.

Research evidence indicates that the social grouping of occupants of residential properties is a good indicator of damage potential and these differences are reflected in the standard flood damage tables provided with the MCM-Online. This data allows the application of equity multipliers in a structured and transparent way to better reflect the impact of investment decisions on different groups within society (see Chapter 4).

DATA INPUTS: FLOOD DAMAGE DATA: OUR GENERAL APPROACH

The general approach here to assessing the benefits of reducing the risk for properties affected by flooding encapsulates the following principles:

- Data in the accompanying MCM-Online tables assesses the potential damage in the future from a range of severities of flooding, resulting from different depths of flood waters within the property. Only in this way will the shape of the loss-probability curve be accurately determined;
- Much of the flood damage data presented here is "synthetic" (i.e. from a synthesis of many data items). It is therefore not directly derived from an analysis of properties which have been flooded in the recent past, because evidence suggests that post-flood surveys can be very inaccurate;
- The losses to individual properties must represent national economic losses. Therefore, the damage to property components (i.e. inventory items), is based on their assumed pre-flood value – their depreciated value - rather than the cost of their replacement with new items at current market prices;
- Any taxation element within potential flood losses is subtracted, because these are transfer payments within the economy rather than real resource costs. Therefore the VAT element in repair costs is not counted;
- For indirect flood losses, it is necessary to separate financial and economic losses by not including, for example, the loss of income in one particular retail shop if the trade this represents is likely to be deferred in time or transferred to another retail outlet.

Current appraisal guidance (EA, 2021a) now encourages appraisals to seek to identify gains and losses to different sectors.

DATA INPUTS: TOPOGRAPHIC, FLOOD SURFACE AND FLOOD PROBABILITY DATA

Experience with many project appraisals has indicated that one of the most important inputs to benefit assessments is the topographic data describing the floodplain and the accuracy of the hydraulic profiles that intersect this surface.

In Britain, many floods are relatively shallow, slow-moving, and represent water accumulating towards the lower end of catchments. In these circumstances, accurate delineation of the area liable to flooding and the precise depth of flood waters on that flood plain are both essential to accurate benefit assessments. Sources of topographic data (and hence the threshold of flooding for each property in the benefit area) are:

- LiDAR or SAR data;
- Field levelling data using traditional survey methods or modern GPS methods;
- Digital terrain model data;
- Simpler methods as appropriate (e.g. topographic maps).

The estimation of the probability of flood events contributing to appraisals is also critical, particularly the probability of the threshold of flooding.

DATA INPUTS: DATA QUALITY AND “FILTERING”

Experience indicates that the different data elements have different qualities. Our recommended objective is to improve the quality of the data that makes most contribution to calculated benefits, using a system that is transparent and auditable. The description below is for calculating the benefits of flood risk management; see MCM, Chapter 3 (Penning-Rowsell *et al*., 2013) for other situations.

Step A: Data assembly and DQS scores

Assemble the following for each property in the benefit area. The National Property Dataset (NPD3) is a useful source of land use data.

1. The land use category.
2. The floor area (NRPs only: see Ch. 5).
3. The threshold height of the property.
4. The most appropriate level of detail of depth/damage data (from the MCM-Online).
5. The hydrologic/hydraulic profile data (or similar) for each return period analyses.

Assign Data Quality Scores (DQS) for each of the five elements of dataset above: “1” = good; “4” = poor (Table 3.3).

Step B: Procedure

1. Calculate the Present Value of damages (PVd) for each property and rank all properties by PVd;
2. ‘Cap’ PVd at each property’s market value. Market value data sources include:
   a) Residential: UK House Price Index (HPI) accessed via the Land Registry website (See Chapter 4 for details);

b) Non-residential: Valuation Office Agency (www.voa.gov.uk) to gain an approximation of market or capital value (see Chapter 5 for details).

3. Consider the scores assigned to each of the five types of data. If the scores are at levels 2 or 3, or (particularly) level 4, and there is evidence to suggest that data can be improved without disproportionate cost, then clearly there is cause for concern with the existing data-set;
4. Attempt to explore the impact of the lower quality of data and whether improvement will affect the final decision. Appraisers need to question, on a case-by-case basis, whether improving data will affect decision-making, using standard sensitivity testing techniques.

Sensitivity tests may demonstrate that improved data quality will not have an effect on the outcome of the appraisal decision. Whether data improvement is achieved or not, the debate raised will be seen in the audit trail, with reviews/actions documented to support any decision on data and its use. The route to improved data quality will be different for each data item. For example, better quality property area data can come from GIS-based measurement from maps or OS Mastermap/Google 'Street View', or from field surveys.

Table 3.3 The system of Data Quality Scores (DQS)

DQS	Description	Explanation
1	'Best of Breed'	No better available; unlikely to be improved on in near future
2	Data with known deficiencies	To be replaced as soon as third parties re-issue
3	Gross assumptions	Not invented but deduced by the project team from experience or related literature/data sources
4	Heroic assumptions	No data sources available or yet found; data based on educated guesses

NB. This is Table 3.6 in the MCM 2013

LOSS PROBABILTY CURVE ISSUES

RESIDUAL FLOODING AND DIS-BENEFITS

The Environment Agency's project appraisal guidance (FCERM-AG) decision rules seek to optimise the spend considering an acceptable standard of protection and maximising the benefit cost ratio. Schemes therefore may not protect wholly or even significantly against the more major floods.

This leaves residual flooding after the scheme has been implemented, and this damage from residual flooding should not be counted towards the benefits of the scheme.

To assess these residual damages (sometimes called 'dis-benefits') requires the assessment of the impact and damage of the major floods that are not avoided by any of the anticipated interventions/schemes. Such assessments will often be time-consuming, particularly for the very low probability floods which may cover large areas. They can be important, however, especially when the standard of protection offered by these interventions is low, such that the residual damages are quite large.

ABOVE DESIGN STANDARD BENEFITS

Above Design Standard (ADS) benefits accrue where engineered flood risk management schemes result in water levels changing for the whole range of floods experienced on a floodplain, not just the events with annual probabilities up to and including a 'design event'.

These ADS benefits will be most important where there is significant urban development at the outer edges of the floodplain, only affected by the most substantial floods, and where modest schemes can reduce flood water levels and therefore extents at these locations, even if only marginally.

However only certain types of schemes have this hydraulic effect; for example raised defences do not. The most obvious schemes where ADS benefits accrue are by-pass channels and, in most circumstances, flood storage reservoirs.

These benefits can be large. For example, in the case of the Datchet to Walton Bridge reach of the Thames, appraisal results showed that the ADS benefits could amount to some 31.5% of total benefits.

DECISION RULES AND OPTIONS

The Environment Agency (2021a) provides the framework for undertaking an appraisal for flood and coastal erosion risk management in England and includes the procedures for using the benefits assessment in the decision-making process. It explains which procedure is required in different circumstances and is available on the Gov.uk website (https://www.gov.uk/government/publications/flood-and-coastal-erosion-risk-management-appraisal-guidance). Guidance relevant to Scotland is provided by Scottish Government (2016) (https://www.gov.scot/publications/guidance-support-sepa-responsible-authorities/pages/15/).

For other users we suggest you look to see if there are any appropriate guidance for your situation or follow the steps that are advocated for Agency use and tailor the processes advocated there to your local circumstances. Further information on this topic can be found in MCM 2013 (Section 3.7: "Decision Rules and Options").

WRITE-OFFS AND 'CAPPING'

Properties that are projected to be flooded on average more than once every three years are usually considered to be written-off unless they are flood resilient or water compatible. Write-off values are taken as the risk-free market value of an asset because the actual market value of the at-risk property could be lower (where the risk is known, there may be lower demand for the property or higher insurance costs such that the market value is reduced).

'Capping' is different to write-off and users in England are referred to the details on capping in FCERM-AG (Environment Agency, 2021b)[1]. Care should be exercised where the total present value (PVd) of projected flood losses exceeds the risk-free market value of the asset. In the case of residential or commercial property, appraisers should assume that the long-term economic loss cannot exceed the current capital value of the property and to 'cap' the damages if this is likely. Capping will apply to any property if the PVd over the lifetime of the proposed scheme is greater than the market value.

[1] Appraisers are advised to check the specific rules regarding capping in their relevant guidance, as specific rules on capping may vary between countries.

Write-off and capping both use the risk-free Regional average market value to ensure that the risks are not already reflected in the market value of the property. In England, the Environment Agency suggest using the International Territorial Level 1 (ITL1) Regional statistics for capping purposes. For non-residential properties it may be necessary to use its rateable value multiplied by a factor that reflects the added value or percentage rental yield from that property.

Table 3.4 gives prime yields for selected bulk class categories with appropriate rateable value multipliers. It must be recognised that the so-called "market value" does not include 'Goodwill' which is not reflected in the rateable value times the multiplier. Thus, a popular riverside public house with a calculated market value of £200,000, using this method, may have a hefty sales premium to reflect the buoyancy of its trade. Its true market value may be up to 10 times this. However, as per the concept of displacement, according to Green Book rules this 'Goodwill' cannot be included in capping calculations as the trade from the pub's successful business can be transferred to another flood free pub.

Table 3.4 Prime yields of non-residential properties (January 2023)

Commercial property	% yield	Rateable value multiplier[2]
West End Offices	4.00	25
City Offices	4.50	22
South East Offices	6.25	16
Provincial Offices	6.00	17
High Street Retail	6.50	16
Shopping Centres	8.00	12.5
Retail Warehouse (Open A1)	5.50	18
Food Stores	5.25	19
Industrial	5.00	20

Source: Savills Research (https://www.savills.co.uk/research_articles/229130/339194-0)

Appraisers need to proceed as follows:

- Where assets such as properties are flooded more frequently than once every three years - or eroded - they are written-off;
- Where such assets are flooded less frequently than once every three years, it is assumed that damages are incurred on each flood up to the point where the total present value of damages (PVd) equals the risk-free market value of the asset and capped at that value;
- Where such assets are flooded occasionally over the first part of the appraisal period and are written-off at a later date as the frequency of flooding increases (as is usual under the do-nothing scenario), the approach is to determine when properties might be abandoned (i.e. flooded so frequently that their whole value would be lost) and to discount their write-off value, adding to this the present value of damages that would occur in terms of average annual damages up until

[2] The rateable value multiplier is calculated by dividing the 100 by the % yield.

the time of write off. It may be necessary to cap the total damages when they exceed the market value of the property.

- In England, full annual average damages each year should be applied until the present value damages equal the risk-free market value of the property and the total damages should be capped. At this point, it is assumed that the property will be abandoned or made resilient and therefore no further damages, including direct or indirect (health effects, evacuation costs and emergency services costs) damages should be added (Environment Agency, 2021b).

REMAINING ISSUES

- In locations where there is an efficient flood warning system, or local property resilience and resistance measures which results in significantly lower damage and loss values (e.g. from the kind of sandbagging operations as reported in Chapter 6), the assessment of flood damages must reflect those lower values. The flood damage data at MCM-Online represent the maximum potential damage, ignoring the damage-reducing effects of action taken after flood warnings. Data on this can be found herein in Chapters 4 and 5 and in more detail in the full MCM (Penning-Rowsell et al., 2013). Users are reminded that they should not include the benefits of flood warning unless their option also provides a flood warning service and as such includes the associated costs of implementing flood warnings;

- Sufficient potential floods should be appraised so that an accurate picture can be developed of the shape of the loss-probability curve including, where appropriate, such events needed to define and quantify any Above Design Standard benefits. Usually this means that at least 5 floods need to be appraised (e.g. the 5, 10, 25, 75 and 100+ year floods);

- Appraisers should not assume that stakeholders necessarily want to see implemented the standard of flood risk management that is identified as being optimal by the benefit-cost analyses that are undertaken. Stakeholder views and constraints should be gathered and understood as part of the wider appraisal.

- In addition to property damages, other losses should also be considered where benefits may be realised. This may include the avoidance of disruption to utilities, transportation networks and other critical services (schools, hospitals) (see Chapter 6) and recreation (see Chapter 8) and agricultural (see Chapter 9) and environment impacts (Chapter 10).

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4 Residential Properties

4 Residential Properties

OVERVIEW

Residential flood damage is significant in almost all cases of serious flooding in the UK, and remains an area of public and government concern. This damage includes both direct damages and indirect losses, measured as the tangible and intangible impacts of flooding on residential properties and householders.

This chapter addresses the appraisal of the direct damages and tangible impacts of flood waters on household inventory and building fabric items and on domestic vehicles. In addition, information is provided for the cost of evacuation, and for incorporating government guidance on the appraisal of the indirect and intangible impacts of flooding. Information and data are also provided to allow the damage-reducing effects of property-level resistance and resilience measures.

The assessment of direct residential property flood damage potential should utilise the depth/damage data within the Chapter 4 section of MCM-Online. The most detailed standard data provided is for:

- Five house types;
- Six building ages; and
- Four different social grades of the dwellings' occupants.

Data are provided for various water types (see Table 4.1: *Categories of flood water* in the 'Tables & Figures' spreadsheet on MCM-Online), saltwater flooding, wave damage and also reductions following the issuing of a flood warning. We also provide a method for calculating likely vehicles damages and a comprehensive set of flood evacuation costs. Data and methods allowing the estimation of the beneficial effects of property-level resistance and resilience measures are also provided.

Since 2013 most damages have been inflated using an appropriate index (CPI, GDP deflator). In the 2021/22 version a major revision of the damages has been completed, which included cost reviews by flood damage experts and updates to ownership and inventory item price values. Additionally, In the 2022/23 version, the data source for inventory item prices was were revised to include values from price quotes of items in the standardised shopping basket published by the Office for National Statistics (ONS, 2022). The standardized shopping basket provides large samples of item prices collected in all regions of the UK on a monthly basis. However, not all inventory items relevant to flood damage estimation in the MCM are included in the standardised shopping basket. Item prices are therefore determined through online surveys of major retailers, as in previous MCM versions, combined with statistical analysis of price quotes form the standardised shopping basket. The changes to the methodology may have a small impact on values and will ensure more statistically robust annual price updates for future MCM versions.

For the 2023/24 version, damages have been inflated using the appropriate indices.

LESSONS FROM EXPERIENCE

- Residential flood damage data may be used in as detailed or generalised a way as required for the purpose of the benefit assessment. Dwellings and their occupants can be noted without reference to age or type or property or the social grade of resident;
- Whatever level of aggregation is chosen, there will be errors traceable to the original data sources. It is almost impossible to quantify these errors but every attempt has been made to minimise them;
- Damage susceptibility estimates: professional opinion varies on the precise effect of flood water on inventory and building fabric items. Susceptibility must be continually up-dated as more information becomes available;
- Inventory and building fabric data: standard checklists have been devised which are not exhaustive;
- Secondary data sources: applying nationally based data to small areas locally may lead to errors;
- Ground floor plans: individual properties will vary from these specifications to some degree.

UNDERLYING ASSUMPTIONS

The residential potential flood damage data for household inventory and building fabric items is based on economic values not financial values (see Chapter 3, Table 3.2). Financial datasets are provided separately on the MCM-Online.

Flood impacts on households are classified as direct tangible, intangible and indirect (Table 4.2). In compiling the standard flood damage data, the total inventory damage is dependent on the average remaining values (ARV - to depreciate prices), the house type, the social grade and the ownership of household items for each social group (Table 4.3: *Social grade categorisation by occupation*).

Table 4.2: The range of possible flood impacts on households (not exhaustive or necessarily mutually exclusive)

Direct Tangible Losses For Flooded Households	Intangible Losses On Flooded Households	Indirect Losses On Flooded Households	Indirect Losses For Non-Flooded Households
➢ Damage to building fabric ➢ Damage to household inventory items ➢ Clean-up costs	➢ Worry about future flooding ➢ Loss of memorabilia and irreplaceable items and pets ➢ Damage to physical and/or mental health, death or injury ➢ Loss of community ➢ Loss of confidence in authorities and services	➢ Permanent evacuation from area ➢ Disruption to household due to flood damage ➢ Temporary evacuation costs ➢ Disruption due to flood warnings or alarms ➢ Loss of utility services ➢ Loss of income/earnings ➢ Loss of leisure and recreational opportunities ➢ Additional communication costs ➢ Loss of services ➢ Increased travel costs ➢ Increased cost of shopping and recreational opportunities	➢ Increased travel costs ➢ Loss of income/earnings ➢ Loss of utility services ➢ Loss of other services ➢ Loss of leisure and recreational opportunities ➢ Increased cost of shopping and recreational opportunities

NB. This is Table 4.1 in the MCM 2013

The ‘intangible’ effects of flooding are recognised as significant. Defra and the Environment Agency have funded research to establish an economic valuation of the intangible health impacts of flooding. This research confirmed the significance of the health impacts of flooding and led to the publication of guidance (Defra, 2004). This has been added to by recent research and guidance considering the impacts of flooding on mental health (Environment Agency 2021a).

Tables 4.3 Social grade categorisation and weighted factor by occupation

Social Group	Description	Weighted Factor
AB	Upper middle and middle class: higher and intermediate managerial, administrative or professional	0.74
C1	Lower middle class: supervisory or clerical and junior managerial, administrative or professional	1.12
C2	Skilled working class: skilled manual workers	1.22
DE	Working class and those at the lowest level of subsistence: semi-skilled and unskilled manual workers. Unemployed and those with no other earnings (e.g. state pensioners)	1.64

NB. This is based on Tables 4.8 and 4.36 in the MCM 2013

DIFFERENT TYPES OF APPRAISAL

The framework presented below is for appraisals of different types, scale and complexity. The framework includes (1) overview appraisals which are less complex and demanding in terms of damage data requirements and which may be undertaken at the meso- or micro-scales, (2) initial appraisals which are more detailed and demanding and more suited to the micro-scale and (3) full-scale appraisals where site-specific damage data are collected. See Chapters 2 and 3 for a more detailed overview of appraisal types.

Table 4.4 Types of project appraisals (2023 value)

Overview, Initial and Full-Scale methods			
Scale of analysis	**Overview**	**Initial**	**Full-Scale**
Guidance	For rapid MDSF and similar desktop type appraisals: first approximations to identify areas where more detailed work is required	For more detailed appraisals where further assessment of household loss potential is warranted	For the detailed study of potential benefits using the most detailed of the standard data sets
Data requirements for the benefitting area	Number of properties at risk	Number, type and age of house at risk	Number, type, age and social class of houses and householders at risk
		Standard of protection (pre and post scheme for intangible values)	Standard of protection (pre and post scheme for intangible values)
			Government Weighting Factors for distributional impact analysis
Direct/ tangible method of assessment	Annual average direct damages: sector average	Generalised standard residential depth/damage data for type and age of houses	Additional data for type, age and social grade of houses and householders
	Vehicle Damages: 42% of total properties damaged x £5,600 (2021 value)	Vehicle Damages: number of properties at risk above 0.39m x £6,944 (2022 value)	Vehicle Damages: number of vehicles at risk above 0.39m x £5,600 (2021 value)
Intangible method of assessment[1]	Health: £279[1] per property per year for intangibles	Health: Defra's intangibles matrix	Health: Defra's intangibles matrix
Indirect method of assessment	Evacuation per household: temporary accommodation costs (£1,370) plus alternative accommodation costs (£3,921) (2023 value)	Evacuation per household: evacuation costs per property type and flood depth	Evacuation per household: survey on percentage of households evacuated and duration of evacuation. Evacuation costs per property type and flood depth
Vulnerability Analysis	Not required	Where feasible	Where feasible
Property-level resistance and resilience damage - saving	Not required	Where such measures exist their impact should be estimated and deducted from damage estimates where feasible	Where such measures exist their impact should be estimated and deducted from damage estimates where feasible

[1] NB: These are the social health costs (i.e. how much a household is willing-to-pay to avoid health impacts). Users are also now directed to guidance about appraising the Mental Health Costs of flooding (Environment Agency, 2021a) and the associated transitional arrangements for its use.

OVERVIEW APPRAISALS

Where only the number of properties in the benefit area is known, approximate flood risk management benefits can be derived by making some assumptions about the depth of flooding expected with different return periods.

SECTOR AVERAGE DAMAGES

To provide a more refined estimate of direct damages, the depth of flooding across a range of flood events must be known. The absolute minimum number of flood events that can be considered is three:

- The threshold flood event (the most extreme flood event which does not cause any losses).
- An event larger than the possible design standard of protection.
- An intermediate flood.

With a basic understanding of the depths of flooding, appraisers should use the residential depth/data curves provided within the Chapter 4 'Tables & Figures' spreadsheet on MCM-Online. However, during overview appraisals, only the sector average figures should be used.

To employ both these methods, the appraiser needs to determine the size of the benefit area, the number of properties at risk there and, where available, the depth of potential flooding:

- The size of the benefit area is determined by the flood problem being appraised.
- The number of properties can be obtained from the National Receptor Dataset (NRD), from the Environment Agency.
- The depth of flooding is determined from the ground level data and the results of hydraulic modelling or, more likely at this stage, from field-based assessments or historical records.

WEIGHTED ANNUAL AVERAGE DAMAGES (WAAD)

Where the appraiser has little or no understanding of the potential flood depths and return periods, use the weighted annual average damage (WAAD) approach, broken down by warning lead time and the standard of protection (Table 4.5).

The annual average damage to the average house with no flood warning and no flood protection is £5,269. Table 4.5 gives the reduced values provided by different standards of protection and different levels of flood warning (to which householders are assumed to respond effectively by moving portable property inventory i.e. contents).

However, where this value is used in outline studies, as the weighted annual average damage per residential property within a defined benefit area (say, 1 in 200 year floodplain), the number of properties affected by successively more frequent return period floods should be reduced as in Table 4.6.

Table 4.5 Weighted Annual Average Damages (WAAD) (2023 value) assuming variable threshold Standards of Protection (SoP)

Existing SoP	No warning (£)	<8 hour warning (£)	>8 hour warning (£)
No protection	5,269	5,227	5,215
2 years	5,269	5,227	5,215
5 years	3,163	3,136	3,129
10 years	1,615	1,602	1,597
25 years	772	766	764
50 years	326	324	323
100 years	82	81	81
200 years	41	40	40

NB. This is Table 4.33 in the MCM 2013

Table 4.6 Estimate of the number of properties affected by different floods

Return Period	No. of properties as % of **200 year No. of properties**
100	93
50	80
25	25
10	10
5	5

THE 'INTANGIBLE' EFFECTS OF FLOODING

Research into the valuation of intangible health benefits concludes that the potential value of avoiding such impacts is, on average, £279 per household per year. In addition, this research concluded that the most important factor when calculating potential intangible impacts is the flood risk (Defra/Environment Agency, 2004). At the overview appraisal level only, we recommend using this surrogate value of £279 per household to account for the willingness of households to pay to avoid health impacts. Users are also directed to recent Environment Agency (2021a) supplementary guidance for values associated with the impacts of flooding on mental health. At this level of appraisal it is suggested that an average value (rather than one associated with flood depths) is applied.

VEHICLE DAMAGES

Research for the MCM has ascertained the average value for a typical motor vehicle in the UK to be £5,600. Assessing exactly how many vehicles will be damaged during a flood event is very difficult, not least because vehicles are mobile. A method, which could be used for overview appraisals is based on an average property to vehicle damage ratio for the 2007 and 2012 UK floods (ABI, 2012). This method assumes that the total number of vehicles likely to be damaged during a flood occurring at any time of the day will equate to 42% of the total number of residential *and* commercial properties (see Chapter 5) at risk (from a flood of any depth). Once the number of likely vehicles has been ascertained, appraisers can multiply this by £5,600 (the value per vehicle, not the value of vehicles per household). This method does not require an assumption to be made on the presumed location of vehicles when a flood occurs.

Readers are encouraged to view Chapter 4, section 4.5 of the MCM (Penning-Rowsell et al., 2013) for a full explanation of this method. Please note that the values in this handbook are based on a later update and, therefore, are different from the ones presented in section 4.5 of the MCM.

EVACUATION COSTS

Evacuation of flood affected properties is often considered in terms of a short-term emergency response to flooding – to limit loss of life, injury and the stress caused by the flood event - and indeed it is a sensible measure to have in place. In previous versions of the MCM, the costs of emergency response and recovery have been developed to be included in appraisal calculations. In this respect, where properties are affected by flooding, evacuation from the property may also be necessary to allow flood damage to be repaired. In such cases, evacuation requires temporary or alternative accommodation for households affected and this incurs additional costs.

The duration of evacuation has a major impact on total costs, which are accrued over the time period from evacuation to the return to the property. However, to assume that, of the properties originally evacuated, all remain evacuated for the longest duration (i.e. over one year), could result in a greatly overestimated cost figure. Instead, households will return over time and only a small percentage (around 8%), are likely to remain in alternative accommodation over one year.

For overview appraisals only, we recommend using the total average cost of evacuation per household (based on an average evacuation of 23 weeks). The table *'Evacuation Costs – Overview'* on MCM-Online provides the cost for three different scenarios (high, low and average/indicative cost). The total includes average property rents, cost of temporary accommodation, food, additional transport costs and loss of earnings - see MCM, Chapter 4, Section 4.7 (Penning-Rowsell et al., 2013), for the comprehensive method.

INITIAL APPRAISALS

These appraisals require information on flood depths for each flood event being considered, and a more detailed understanding of the properties in the benefit area. In particular, the appraiser will need to know the following:

- The depth of flooding for a range of flood events.
- The type and age of houses in the benefit area, obtained from a more detailed field survey (rather than obtaining the data solely from OS Mastermap/AddressBase, Google 'Street View' and the National Receptor Dataset).

With this information, the appraiser can then evaluate potential direct damages using the residential depth/damage data within Chapter 4 on MCM-Online.

STANDARD RESIDENTIAL DEPTH/DAMAGE DATA

Identifying the variables used to classify dwellings should be a routine procedure in the field. Firstly, identifying the type of dwelling can be done by obtaining the property type from the NRD or, if not available, from direct observation or an online tool such as OS Mastermap/AddressBase or Google 'Street view'. Secondly, by contrast, assessing the age of any dwelling may involve a small degree of subjectivity unless planning departments can provide mapped information. In addition, the ground floor threshold level and the presence of a basement must be clarified using a site survey.

INTANGIBLE BENEFITS AND LEVEL OF RISK

Unlike a strategy study, a more detailed analysis of intangible benefits is required at an outline scale of analysis. Rather than simply applying the weighted average figure of £279 per property per year, the intangible benefits need to be determined using Defra's risk reduction matrix (Defra, 2004), see Table 4.7 *Intangible benefits associated with flood risk management improvements.* Users are also directed to recent Environment Agency (2021) supplementary guidance for values associated with the impacts of flooding on mental health. Flood depth data can be used to assign values at this level of analysis. In addition, it is also recommended that a more detailed vulnerability analysis is conducted (see below).

Government guidance now requires appraisers to consider how the level of exposure to household flood risk varies with and without the proposed scheme. This requires the appraiser to determine the level of risk, such that:

- For areas of uniform risk (such as housing on level ground behind a structural flood defence such as a flood embankment), damages are based on common standards of defence of an area.
- For areas of greatly varying risk (sloping ground away from a river), damages are based on individual levels of property flood risk.

VEHICLE DAMAGES

Research for the MCM has ascertained the average value for a typical motor vehicle in the UK to be £5,600. Based on Department for Transport figures, the average number of vehicles per household is 1.24 (Department for Transport, 2021). We therefore recommend that the average loss value for project appraisals is £6,944 (£5,600 x 1.24 (rounded)) per residential property in the risk area. As vehicles are most likely to be damaged and also written off at flood depths of 0.39m – on health and safety grounds – this only applies to floods greater than 0.39m above ground level (not above property threshold level) at the location of the house in question.

It should be assumed that 25% of the residential properties in the benefit area will not have a vehicle present if a warning has been issued.

EVACUATION COSTS

The cost of evacuation depends on many variables. However, a direct link between the flood depth inside a property and the evacuation rate and time was established (Table 4.8 *The probability of evacuation and duration in relation to flood depth*). In an initial appraisal where flood depth has been calculated per property type, we recommend to estimate the evacuation costs as a function of the flood depth and property type. The table '*Evacuation Costs – Initial*' on MCM-Online provides the required information to perform the calculation for three different scenarios (high, low and average/indicative cost).

VULNERABILITY ANALYSIS

A vulnerability analysis for households comprises a method indicating the likely impact of floods of different severities on the households affected. Users are recommended to assess the following:

- The number of residents in the flood prone area (disaggregated by flood frequency if possible);
- The approximate proportions of households in each social group (from Small Area Census data), see: www.ons.gov.uk/census;
- The proportion of residences which are bungalows, basement flats or ground floor flats (often occupied by the elderly and infirm);
- Predicted flood depths (depths of over 0.6m can be life threatening);
- Flood warning lead-times;
- Other flood characteristics including the location of residences close to defences which may be over-topped or breached.

In undertaking a vulnerability analysis, it is sensible to concentrate on estimating the number of households who will suffer the most severe conditions and who are the most vulnerable. The variables in the SFVI, as well as those above, offer this potential.

FULL-SCALE APPRAISALS

In full-scale appraisals, it is appropriate to differentiate houses in the benefit area by their type, age and the social group of the occupants. This means that the most detailed direct damage data provided on MCM-Online can be used. In order to reflect socio-economic equity considerations this data should, where it is deemed to be 'necessary' and 'practical' (HM Treasury, 2003), be subjected to a distributional impact analysis. Data required for this analysis includes flood history, depth and duration, small area census data and general information on householders' views on the risk they face.

ADDITIONAL RESIDENTIAL DEPTH/DAMAGE DATA

The additional residential depth/damage data on MCM-Online takes into consideration several types and ages of residential properties, short, long and extra-long flood durations as well as different scenarios; saltwater, wave damage and various categories of water (Table 4.1).

To make full use of the additional residential depth/damage data sets, the social group of the occupants of the houses in the benefit area should be established. Because the social group variable derived from census data relates to the census output area (OA) as a whole, and not to the individual dwelling's occupants, the social group of individual occupants is calculated on the basis of averages. For example, if 60% of the dwellings in the OA fall into the C2 category and 40% fall into the DE category, the depth/damage data should be weighted accordingly.

DISTRIBUTIONAL IMPACT ANALYSIS

The Treasury Green Book (HM Treasury, 2022) recommends that, where it is 'necessary' or 'practical', potential benefits should account for distributional impacts to incorporate social equity considerations into flood and coastal defence appraisals. Determining if it is 'necessary' or 'practical' then depends on a number of circumstances, including:

- The likely robustness of any calculation of distributional impacts. Whether a community at flood risk can be identified with reliable data and categorised according to their prosperity or social class;
- The type of project being assessed. Whether the assessment will contribute to an appraisal that demonstrates equity and fairness to people;
- The scale of the impact associated with a particular project or proposal. Whether the time and effort in undertaking the assessment is proportional to the scale of the overall appraisal, either at a strategic or feasibility level.

If a distributional analysis is not required, the standard residential depth/damage curves for the property type and age should be used, without accounting for social group. If a distributional analysis is required, total weighted factors should be applied by social group (Table 4.3). However, the total weighted factors for C1 and C2 will generally have a negligible effect. Therefore, use of total weighted factors is only recommended where AB or DE social class groups are predominant. Total weighted factors may then be applied to adjust the standard depth/damage data to obtain potential damages avoided taking account of distributional impacts.

A number of points are important in this government guidance:

- Both weighted and non-weighted results should be presented;
- Where property 'write offs' are considered, average values should be based on average 'no risk' values of properties of similar type and region;
- In areas with a high proportion of rented accommodation the social group of the owner of the property should be taken into account for building fabric damages and that of the occupier applied to content damages.

INTANGIBLE BENEFITS AND LEVEL OF RISK

At the full-scale level of analysis, the intangible benefits need to be determined using Defra's risk reduction matrix (Defra, 2004), see Table 4.7 *Intangible benefits associated with flood risk management improvements.* Users are also directed to recent Environment Agency (2021a) supplementary guidance for values associated with the impacts of flooding on mental health. Flood depth data can be used to assign values at this level of analysis. In addition, it is also recommended that a more detailed vulnerability analysis is conducted (see below).

Government guidance now requires appraisers to consider how the level of exposure to household flood risk varies with and without the proposed scheme. This requires the appraiser to determine the level of risk, such that:

- For areas of uniform risk (such as housing on level ground behind a structural flood defence such as a flood embankment), damages are based on common standards of defence of an area;

- For areas of greatly varying risk (sloping ground away from a river), damages are based on individual levels of property flood risk.

VEHICLE DAMAGES

For full-scale appraisals it is necessary to ascertain the number of vehicles in the risk area. This may be achieved by contacting local authorities or using ONS Census data (https://www.ons.gov.uk/census) which provides detail at various geographical levels. Once the likely number has been ascertained, this figure can be multiplied by £5,600 (the value per vehicle, not the value of vehicles per household, as above).

EVACUATION COSTS

In a full-scale appraisal the appraiser is expected to have a better knowledge of the duration of evacuation and the percentage of evacuation rather than relying on national averages figures. Based on local surveys and research, it is recommended that the appraiser modifies the input values for the percentage evacuated per depth band (cells B3:B9 in the 'Evacuation Cost – Full-Scale' table on MCM-Online) and for the mean duration of evacuation in weeks (cells C3:C9). The appraiser can then use the updated evacuation costs in the same table to perform the calculation for three different scenarios (high, low and average/indicative cost).

VULNERABILITY ANALYSIS

A vulnerability analysis for households comprises a method indicating the likely impact of floods of different severities on the households affected. Users are recommended to assess the following:

- The number of residents in the flood prone area (disaggregated by flood frequency if possible);
- The approximate proportions of households in each social group (from Small Area Census data), see: https://www.ons.gov.uk/census;
- The proportion of residences which are bungalows, basement flats or ground floor flats (often occupied by the elderly and infirm);
- Predicted flood depths (depths of over 0.6m can be life threatening);
- Flood warning lead-times;
- Other flood characteristics including the location of residences close to defences which may be over-topped or breached.

In undertaking a vulnerability analysis, it is sensible to concentrate on estimating the number of households who will suffer the most severe conditions and who are the most vulnerable. The variables in the SFVI, as well as those above, offer this potential.

"CAPPING" ANNUAL AVERAGE DAMAGE (AAD) VALUES

The capital sum worth investing to reduce the risk of flooding to any residential property should be "capped" at its market value. This is ideally done for all levels of project appraisal but certainly at the most detailed level.

The benefit calculation results should therefore be scanned for such cases, and their values reduced accordingly. The market values used should be the average for each property type for the Region involved, obtainable from the Land Registry. The UK House Price Index (UKHPI) uses house sales data from HM Land Registry, Registers of Scotland, and Land and Property Services Northern Ireland

and is calculated by the Office for National Statistics. Valuation data for England, Wales, Scotland and Northern Ireland and the English regions for all property, detached, semi-detached, terrace and flats is available at: https://landregistry.data.gov.uk/app/ukhpi/

Indicative property valuations for higher level geographic regions of the UK are given in Table 4.9 for information and comparison. The Environment Agency advises users to utilise these values (at International Territorial Level 1 (ITL1)) when undertaking appraisals in England.

The cap should be applied to each property that makes up the PVd (i.e. all properties that are directly affected). Other damages are calculated related to property damages (i.e. health costs, emergency services uplift, evacuation costs, vehicle damages). In these cases, their PVd values should be calculated separately. In England, if the capped value is reached no subsequent damages are added as it is assumed that the property is abandoned or made resilient (see Environment Agency (2022) and Environment Agency (2021b) for specific guidance). However, appraisers should consult the relevant guidance to check the rules on when damages should be capped as there may be some variations between nations.

ESTIMATING THE DAMAGE-REDUCING EFFECTS OF PROPERTY-LEVEL RESISTANCE AND RESILIENCE MEASURES

Property-Level Protection (PLP) measures include resistance and resilience measures. Resistance measures (e.g. flood guards) are designed to exclude floodwater from properties whereas resilience measures (e.g. concrete floors instead of timber ones) assume that floodwater will enter a property but internal features are designed to reduce flood damage potential. Both resistance and resilience measures are sometimes used in conjunction with flood warnings (i.e. their implantation is dependent on action being taken once a flood warning is received) but they may also be designed to be effective independent of warnings.

The following are examples of these measures:

- Barriers for doorways and airbrick covers (automatic or manually operated);
- Non-return valves for domestic and foul drainage systems;
- De-watering pumps;
- Waterproofing and sealants;
- Internal rearrangements for electrical outlets and wiring; and
- Replacement of floors and doors with materials, which have a comparatively low damage susceptibility.

The WAAD data for warnings in Table 5.4 must not be used together with estimates of damage-reduction through the use of PLPs. Instead the ‘no warning’ data should be utilised and from estimates of damages using these data, the damage-reducing effects of PLPs should be deducted.

ESTIMATING THE DAMAGE-REDUCING EFFECTS OF RESISTANCE MEASURES

Two approaches for estimating the benefits of resistance measures are available.

APPROACH 1

Step One

Identify residential properties in the benefit area which have resistance measures installed. Where grant schemes have led to PLP measures being installed records may be available which provide this information or alternatively a field survey may need to be undertaken. For an initial study, if the number of properties with resistance measures is small (say 5% of properties or less), it is probably not worth taking account of the effect of resistance measures in an appraisal. Otherwise (e.g. at the project appraisal level) the estimated damage-reducing effect of resistance measures must be taken account of in the appraisal. This is because PLP measures reduce damage at the more frequent flood return periods and will, therefore, have a significant effect on estimated annual average damages.

Step Two

Increase the ground floor residential property threshold level in the benefit area property database by 0.6 metres for those properties known to have resistance measures installed. Because these measures are only likely to be 75% effective the estimated flood damage savings at each flood return period needs to be factored by 0.75.

APPROACH 2

Step One

Calculate the number and then the total ground floor size (m^2) of residential properties at risk at each return period in the benefit area up to the 1.75 year flood probability threshold where flooding is not expected to be greater than 1m (TGA).

Step Two

The following formulae are, to a degree, progressively more reliable if sound local parameter values are substituted for the national average values (e.g. for UP, OP) are included in them below (Clarke et al., 2015).

The formulae may be used to estimate the total £ damage reduction owing to residential property warning-independent resistance measures (WIRB).

Equation 4.1

WIRB (£) = TGA * DR * UP * EF

where:
WIRB (£) is Estimated damage reduction (i.e. benefit) by employing WIRB measures
TGA is Total ground floor area of residential properties located in benefit area within 1:75 flood risk area and where flooding is not likely to be greater than 1m
DR is Damage reduction: £83.58 per m^2 at 2023 value
UP is Uptake of WIR measures factor: 0.032
EF is Effectiveness factor: 0.75

For warning-dependent resistance measures (WDRB) the equivalent formula is:

Equation 4.2

WDRB (£) = TGA * RA * DR * UP * OP * EF

where:
WIRB (£) is Estimated damage reduction (i.e. benefit) by employing WIRB measures
TGA is Total ground floor area of residential properties located in benefit area within 1:75 flood risk area and where flooding is not likely to be greater than 1m
RA is Reliability and Availability: 0.30
DR is Damage reduction: £43.08 per m^2 at 2023 value
UP is Uptake of WDR measures factor: 0.048
OP is Operated: 0.63
EF is Effectiveness factor: 0.75

Equations 4.1 and 4.2 are only an indicative guide to the value of residential property damage reduction through use of resistance measures.

ESTIMATING THE DAMAGE-REDUCING EFFECTS OF RESILIENCE MEASURES

The formula below may be used to estimate a guide value for the damage reducing effects of resilience measures on residential properties:

Equation 4.3

RISDR (£) = TGA * DR * UP * EF

Where:
RISDR (£) is Estimated damage reduction by employing resilience measures
TGA - Total ground floor area of residential properties located in benefit area within 1:75 flood risk area and where flooding is not likely to be greater than 1m
DR is Damage reduction: £86.16 per m^2 at 2023 value
UP is Uptake factor: 0.02
EF is Effectiveness factor: 0.50

When undertaking a benefit assessment, a decision will have to be made about a) whether or not to take account of the damage reducing effects of resistance and resilience measures (if they exist and are ignored benefits may be exaggerated) or b) to make allowance for them, possibly by using the above formulae. At the project appraisal level, PLP measures must be taken into account unless the proportion of relevant properties is a very small proportion of the total (i.e. say, less than 1%).

SOME "HEALTH WARNINGS"

- Damage estimates: Professional opinion varies on the precise effect of flood water on some inventory items. Susceptibility must be continually up-dated as more information becomes available;
- Inventory and building fabric data: Standard check-lists have been devised which are not exhaustive;
- Average Remaining Values are not empirically assessed;
- Items are generally assumed to be approximately half way through their lives which may distort downwards the potential damage estimates in some newly established households;
- Applying nationally based data to small areas locally may lead to errors;
- There have been recent cases were additional electricity costs for driers, blowers and dehumidifiers have been incorrectly included in appraisals. These were part of older versions of the Multi Coloured Manual but have been excluded since the 2013 update. The rationale is that the increased costs are offset by reduced electricity consumption due to properties being unoccupied. Environment Agency Economists will be monitoring this during assurance of applications for Defra Grant-in-Aid and we advise that you make sure these values are not included.

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5 Non-Residential Properties

5 Non-Residential Properties

OVERVIEW

Flood damage to Non-Residential Properties (NRPs) can be a significant factor when considering major expenditure on flood risk management measures. Chapter 5 of the MCM (Penning-Rowsell et al., 2013) provides methods and data for assessing the direct flood loss potential of NRPs. Guidance on the estimation of indirect losses is also included as is guidance on evaluating the flood damage-reducing effects of property level protection (PLP) measures and the movement of contents of properties prior to flooding and on receipt of a flood warning.

The NRP damage data are available as depth/damage and depth/damage/duration data in which short, long and extra-long flood durations are considered. The data have been selected and compiled to represent 95% of NRPs located in flood risk areas of England and Wales as indicated by the Environment Agency's National Receptor Dataset. The data includes damages from saltwater and wave impact and the damage-reducing effects of flood warnings.

The NRP depth/damage/duration data were compiled by employing an empirically-informed, synthetic modelling approach in which our Building and Quantity Surveyor's (experienced in building refurbishment and replacement as well as in flood damage susceptibilities) were posed a series of 'What if?' questions. For example, what would the flood damages likely to be if a typical or representative supermarket or a warehouse was to be flooded to different depths? And what would be the likely range of damage susceptibilities (i.e. best case (low), worse case (high) and most likely case (indicative)? The method used in Chapter 5 is directly analogous to the now well-accepted synthetic approach used to compile the Residential Property depth/damage/ duration data (Chapter 4).

The categorisation of NRPs is simpler than in pre-2013 editions, as far fewer sub-categories are employed, reducing complexity for users. Using the sector and sub-sector weighted averages ensures the selection of damage data and its assignment to land use/property databases becomes relatively simple, although the user is always advised to have his/her wits about them when matching depth/damage/duration data to property databases as an incorrect assignment to properties may well lead to significant errors in damage estimation.

It is important to recognise that the NRP damage data represent an 'average' or 'typical' set of damage values for England and Wales. They therefore present users with a 'standardised' approach to damage estimation and one which aids comparability across the country. For this reason, and to the extent that users may find that they are presented with examples of NRPs which are not average, then the damage data will under or over-estimate actual damage potential. Deviation from the average is less likely to occur or be significant in the sub-sectors where multiples dominate and where properties have become more standardised over time. This is so in the Retail, Office and Warehouse sub-sectors but standardisation is least likely and therefore significant variance is most likely in the industrial sub-sector where unique factory or workshop premises are most likely to be found. Users should therefore consider the merits of undertaking site surveys in this case.

Where there is sound local evidence to suggest that properties are significantly different to the average or typical, then it is permissible to utilise the ‘high susceptibility’ or ‘low susceptibility’ depth/damage/duration data rather than the 'indicative' case data which should normally be used.

However, in these cases the use of these data in appraisals should be clearly specified and supported with evidence and sensitivity testing around these susceptibility envelopes should be incorporated into the appraisal.

In the 2021/22 version a major revision of the damages was completed, which may have a more significant impact on values. The following revisions were made:

- Building structure and fabric, building services, fixture and fittings, clean-up components costs have been reviewed by quantity surveyors. Stocks have been inflated using CPI;
- Review of the relationship between financial or economic indirect losses and direct losses has been undertaken and updates applied.

The 2023/24 damages have been inflated using the appropriate indices.

LESSONS FROM EXPERIENCE

- The range and diverse function of NRP types, their size, and the varying degrees of susceptibility for each component of damage, make it more difficult to construct these data than other loss data;
- The type and function of an NRP is not the most important determinant of potential NRP flood damage. Flood depth, property size and precautionary measures all come before the category of NRP in the influence they exert on flood losses;
- There will inevitably be errors in the data supplied with this Chapter. It is not possible to quantify all of these errors, although every attempt has been made to keep them to a minimum.
- Data on the Extra-Long Duration and coastal flooding, and on the potential reduction in losses following receipt of a flood warning need to be treated with some caution;
- Data relating to potential damage saving related to property-level protection are tentative and subject to many assumptions;
- Error is present in any flood damage data set and therefore it is wisest in any appraisal (at any scale) to subject these data to sensitivity testing.

DIFFERENT TYPES OF APPRAISAL

The framework presented below is for appraisals of different types, scale and complexity. The framework includes (1) overview studies which are less complex and demanding in terms of damage data requirements and which may be undertaken at the meso- or micro-scales, (2) initial and full-scale studies, the latter of which are more detailed and demanding and more suited to the micro-scale and (3) micro-scale site surveys where site-specific damage data are collected.

HOW DO MCM NRP FLOOD DAMAGE DATA COMPARE WITH REPORTS OF NRP FLOOD DAMAGE?

Since MCM flood damage data are primarily ‘synthetic’ data (i.e. they are constructed by building and quantity surveyors experienced in flood damage independent of actual flood damage reports) it may be considered useful to compare them with reports of actual flood damage in floods experienced in the UK in recent years. Unfortunately, insurance companies are very reluctant to release data for individual properties and post-flood property-by-property surveys of flood damage are time-consuming and costly to undertake and are often not welcomed by those who have suffered damage and have already been visited by insurance loss adjustors. In addition, property owners/managers are known to under-estimate flood damages in the period immediately following a flood because some damages only show up weeks and months later. Another problem with property-by-property surveys of flood damage is that they seldom cover the full flood depth range that is required to construct depth-damage curves: indeed, as the case in the "Non-Residential Properties: Financial or Local Economic Losses and Benefits" chapter shows, only one a very few flood depths are represented. In this 'financial losses' chapter comparisons are made, which are not repeated here, of reported flood damage values with MCM flood damage values on a £/square metre basis. Because the relationship between economic and financial flood damages values is known, the conclusions drawn about the comparison apply equally to this chapter as to the 'financial losses' chapter.

HOW TO USE THE DATA

The potential damage data need to be related to flood probability in order to calculate annual average flood damages which is the objective (see Chapter 3). A property-by-property database is required which identifies the ground floor threshold height AOD above which flooding will start to enter the property. In the case of complex NRPs which comprise a site containing a number of buildings it will normally be necessary to treat each separate building as a separate property. The latest version of the property-by-property NRD database provides the MCM codes used here, but older versions of the NRD use the old MCM codes and these codes have been translated into the latest MCM codes in Table 5.1 (see 'Tables & Figures' spreadsheet for Chapter 5 on MCM-Online). The database should also carry other property identifiers such as grid reference and postal address information. The ground floor area in m^2 of the building footprint only (excluding surrounding grounds) should also be recorded as should the ground floor threshold level. Finally, this database must be linked to a hydro-dynamic model which allows flood depths for a range of floods of different probability to be assigned to each property.

The MCM data includes cellars where it is likely that property types have cellars but not in other cases. It does not include basement data. Normally, for pre-feasibility and outline appraisals only the already included cellar data will be used. However, if there is good reason to believe that properties have basements and those that have them can be easily identified, then basement threshold level could be used as the ground floor threshold level to calculate flood damage potential. Google Street View may be used to confirm existence of basements in some cases.

OVERVIEW STUDIES

The data requirements for NRPs are as follows:

Step One: The number of properties in each of NRP sub-sector or category

This means that the number of properties in each of the following NRP sub-sectors is required: retail, offices, warehouses, leisure, public buildings and industry; together with the number of playing fields, sports centres, marina, sports stadiums, car parks and substations. These are the NRP sub-sectors and categories for which discrete weighted mean depth/damage/duration data are provided. It will also be necessary to identify the number of non-specific, miscellaneous sub-sector 9 properties i.e. where property type is unknown without further research and/or ground-truthing. The NRP sector weighted mean depth/damage/duration data are to be used in the case of miscellaneous; 'unknown' sub-sector 9 properties.

It should be noted that a very low resolution study may just employ the total number of NRPs and the NRP weighted sector mean flood damage data. However, this is much cruder than using the sub-sector and category weighted means indicated above.

Step Two: The ground floor space and threshold level for each NRP

All depth/damage/duration data for NRPs is in £m^2 therefore the area of the ground floor space of each NRP also needs to be entered into the property-by-property database. There are now a variety of sources of information by which property floorspace (meaning the ground floor area of the building or buildings excluding grounds and car parks) may be identified. Use the National Receptor Dataset (NRD) to determine each property's footprint (DQS 1). If unavailable, the following sources of information may be used depending on the resources available:

- Determine area by field measurement (DQS 1) or;
- Use GIS tools to measure the area from OS Mastermap/AddressBase or equivalent (DQS 1) or;
- For specific or unconventional properties use www.royalmail.com to determine property post code, then use https://www.tax.service.gov.uk/business-rates-find/search to determine current valuation which gives the rateable valuation for the property concerned and total ground area (DQS 1). If the specific rateable value data is not available on the VOA website then a good approximation (DQS2) is available by Country and region in a *Business Floorspace Table* at: https://www.gov.uk/government/publications/business-floorspace-rateable-value-per-square-metre-summary-by-region-and-sector (values also provided in Table 5.4) or;
- Use the indicative floor sizes provided in Table 5.2 within the 'Tables & Figures' for Chapter 5 on MCM-Online (DQS 3).

Step Three: The current standard of flood protection provided for the benefit area

Step Four: The Weighted Annual Average Damages (WAAD)

The WAAD (See Chapter 4, Section 4.9.1) are then taken from the table below for each NRP sub-sector or category (or in the case of miscellaneous, 'unknown' sub-sector 9 properties - the weighted NRP sector mean) and multiplied by the appropriate ground floor area. The shading in the table represents the different subsector/category levels.

Table 5.3: Weighted annual average damage by standard of protection (2023/24 values)

		Standard Of Protection						
MCM Code	**Sector Type**	**None**	**5**	**10**	**25**	**50**	**100**	**200**
2	Retail	86.69	42.84	31.22	16.05	7.16	1.79	0.89
3	Offices	84.90	39.06	29.46	14.74	6.48	1.63	0.81
4	Warehouses	97.37	51.33	37.15	18.84	8.53	2.13	1.07
5	Leisure and sport	NOT APPLICABLE - CONSTITUENT CATEGORIES TOO DIVERSE						
51	Leisure	196.48	67.64	53.85	24.45	10.49	2.62	1.31
52	Sport	NOT APPLICABLE - CONSTITUENT CATEGORIES TOO DIVERSE						
521	Playing Field	3.66	1.47	1.17	0.56	0.24	0.06	0.03
523	Sports Centre	45.20	19.56	14.97	7.28	3.18	0.80	0.40
526	Marina	16.34	7.49	5.49	2.79	1.23	0.30	0.16
525	Sports Stadium	11.45	5.58	4.11	2.10	0.93	0.23	0.12
6	Public Buildings	52.35	23.68	17.86	8.85	3.90	0.98	0.48
8	Industry	18.39	9.09	6.62	3.38	1.51	0.38	0.19
9	Miscellaneous	NOT APPLICABLE - CONSTITUENT CATEGORIES TOO DIVERSE						
910	Car park	5.64	2.52	1.87	0.94	0.41	0.10	0.05
960	SubStation	273.27	165.76	118.61	64.85	29.34	7.33	3.67
NRP sector average		90.37	47.28	34.64	18.29	8.32	2.18	1.09

INITIAL AND FULL-SCALE STUDIES

Step One: List the NRPs in the benefit area

For Project Appraisal Reports (PARs) and more detailed Strategy Reports a step-wise approach to data assembly is suggested here. Note that a Data Quality Score (DQS) 1-4 should be allocated for the land use sub sector or category of each NRP, ground floor area, the depth/damage/duration data assigned to the sub sector or category, as well as for property threshold.

- Determine the number by sub-sector or category of NRPs in the benefit area primarily by using the NRD (data quality score 2) and further enhanced by other data sources such as OS Mastermap/AddressBase) (DQS 2), Google Street View (DQS2) and preferably a site survey (DQS 1) for selected properties (see section 5.10.6). Also identify any miscellaneous (sub-sector 9) 'unknown' properties (i.e. the function of which is not known);

- Selective field checks are always recommended to authenticate data quality.

Step Two: Determine each property's ground floor area and property threshold level

Determine ground floor area by using the NRD (DQS 1). If unavailable, use one of the following sources (each with differing DQS). Selection will depend upon available budget and timescale:

- Determine area by field measurement (DQS 1) or;
- Use GIS tools to measure the area from OS Mastermap/AddressBase or equivalent (DQS 1) or;
- For specific or unconventional properties use www.royalmail.com to determine property post code, then use https://www.tax.service.gov.uk/business-rates-find/search to determine current valuation which gives the rateable valuation for the property concerned and total ground area (DQS 1). If the specific rateable value data is not available on the VOA website then a good approximation (DQS2) is available by Country and region in a *Business Floorspace Table* at: https://www.gov.uk/government/publications/business-floorspace-rateable-value-per-square-metre-summary-by-region-and-sector (values also provided in Table 5.4) or;
- Use the indicative floor sizes provided on MCM-Online (DQS 3);
- Determine property ground floor threshold level through the use of a site survey. In some cases it may also be possible to do this using a tool such as Google Street View.

Step Three: Linking NRD (MCM) codes to the MCM data

- Link the NRD (MCM) codes to the weighted sub-sector or category means on MCM-Online. For some categories (most notably sport (52) and miscellaneous (9)) it will be necessary to use the corresponding 3-digit NRP category code instead. Use the NRP sector weighted mean data for any miscellaneous sub-sector 9 'unknown' properties.

Step Four: Allocate depth/damage/duration data

- Within Chapter 5 of the MCM-Online, the preferred depth/damage/duration data for each NRP (MCM) code with appropriate data quality are available;
- Basement data misuse can inappropriately bolster estimates of damage potential and the present value of damage (PVd). The MCM-Online therefore does not provide data for properties with basements. However, data are provided for selected properties which are likely to include a cellar, such as a public house or restaurant. Here we assume that a cellar is a room below ground with no functional use and limited storage. For functional basements that fill completely once ground floor threshold levels have been exceeded by flooding, it is likely that all contents and equipment would be written-off or would need cleaning and repairing, and that refurbishment and redecorating would be necessary. It is therefore recommended that damage data are not assigned to basements unless field based land use checks clearly confirm that basements are present. We recommend in such cases that the basement threshold level is used as the property threshold level in calculating damage potential;

- The *Additional Data* for Chapter 5 section of the MCM-Online provides further depth/damage/duration data for low and high susceptibilities and flood warnings where the data takes into account the potential percentage reductions in damage to moveable equipment and stock only - see MCM, Chapter 5 (Penning-Rowsell et al., 2013). These should be employed wherever there is a functioning formal flood warning system in place which affords a minimum of 4 hours flood warning lead-time to NRPs in the benefit area. The additional data section also provides salt and wave damage date. Where NRPs are likely to be subjected to wave impacts (seafront properties, for example) the wave data should be used, which also accounts for saltwater inundation. If the property is likely to be protected from the force of waves but still inundated by seawater, the 'salt data' should be used.

Step Five: Undertake present value of damages calculation

- Use proprietary software to calculate estimated property present value of damages (PVd).

Step Six: determine market value as required for 'capping' analysis - see MCM, Chapter 3, Section 3.5.4 (Penning-Rowsell et al., 2013).

- As FCREM-AG (Environment Agency, 2022) guidance requires the expected PVd not to exceed the property's market value, rateable value will need to be determined from one of three sources, with varying data quality. Selection, as for Step 2, will depend upon budget and timescale;

- Use www.royalmail.com to determine property post code, then use https://www.tax.service.gov.uk/business-rates-find/search to determine current valuation which gives the rateable valuation for the property concerned (DQS 1). If the specific rateable value data is not available on the VOA website then a good approximation (DQS2) is available by Country and region in a *Business Floorspace Table* at: https://www.gov.uk/government/publications/business-floorspace-rateable-value-per-square-metre-summary-by-region-and-sector (values also provided in Table 5.4)

Step Seven: Filtering

- Rank each property in the benefit area by its PVd or capped value (see Chapter 3). Check the data quality of at least the top 10 contributing NRPs as these from experience contribute a significant proportion of Total PVd representing the potential for significant uncertainty.
- Work to reduce the number of sub-sector 9 'unknowns' by undertaking further Google Street View and/or field checking. A large number of these 'unknowns' can lead to significant inaccuracies (i.e. under or over estimates) in damage estimation.
- If after the filtering process and improvement of data quality any NRP contributes more than 10% of PVd or capped PVd then a site survey should be undertaken to confirm these damages.

SITE SURVEYS

The variety of NRPs is considerable, and average/standard depth/damage data given may be considered inappropriate for one of the following reasons:

1. A property may contribute more than 10% of the PVd; and/or;

2. A property may be so unusual or unique that it warrants the replacement of mean standard damage data by damage data that would be considered to be more reliable.

In such cases a site survey of the property is probably required depending upon the type or scale of appraisal (a standard NRP site survey proforma may be downloaded from the *Additional Resources* section of Chapter 5 on MCM-Online). However, site surveys are time-consuming and require the willing cooperation of the company concerned which might itself take time to acquire. This means that site surveys, where required, are usually reserved for the largest NRPs with high flood frequencies and therefore potentially average annual damage.
For a site survey, the following is a guide as to whom to approach within the business organisation to help complete the site survey questionnaire:

- Small firms - the owner;
- Medium size firms - the plant or company manager;
- Large complex firms - the Managing Director or Financial Director, senior accountant, insurance claims Officer, estates manager or emergency planning officer.

A simplified approach will focus on the following questions making sure that damage or cost estimates exclude VAT:

1. What is the cost of re-build (I.e. the building structure and fabric)?
   Note that this is for the footprint of the building(s) and not the Footprint of the property.
2. What is the value of services installed?
3. What is the value of moveable equipment?
4. What is the value of fixtures and fittings including static machinery and equipment?
5. What is the value of stock, raw materials and work-in-progress?
6. Are losses of trade to overseas competitors likely to be significant (see below)? If so, what are they likely to be?
7. What are the likely costs of clean up after the flood?

Realistic rounded estimates of damage and loss potential are required (e.g. to the nearest £1,000 for smaller firms, or the nearest £10,000 for larger organisations), where indicative values of equipment (moveable and static) and stock etc. may run into £millions.

The values for each damage component are converted to values per square metre of the buildings in question and can these be entered into a spreadsheet (provided in the *Additional Resources* section for Chapter 5 on MCM-Online) for the nearest MCM code of the property in question to obtain correct susceptibility levels. The susceptibility to damage for each component is assumed unchanged from the previous research and depth/damage/duration data are automatically generated based on the revised component values derived from the site survey. In short, valuation of component damages is revised with respect to a specific property and applied to existing susceptibility curves.

INDIRECT FLOOD LOSSES

Obtaining accurate data on indirect flood losses is difficult. Users must decide whether or not to include an estimate of indirect losses. Indirect losses are of two kinds:

- Losses of business to overseas competitors, and;
- The additional costs of seeking to respond to the threat of disruption or to disruption itself which fall upon firms when flooded.

The first of these losses is unusual and is limited to highly specialised companies which are unable to transfer their productive activities to a branch site in this country, and which therefore lose to overseas competitors. The second type of loss is likely to be incurred by most NRPs which are flooded. They exclude post-flood clean-up costs but include the cost of additional work and other costs associated with inevitable efforts to minimise or avoid disruption. These costs include costs of moving inventories, hiring vehicles and costs of overtime working. These costs also include the costs of moving operations to an alternative site or branch and may include additional transport costs.

Chapter 5, Section 5.7 of the MCM (Penning-Rowsell *et al.*, 2013) provides a relatively crude method for estimating and including potential indirect costs where these are the additional costs associated with trying to minimise indirect losses. This is by calculating total indirect losses as an uplift factor of 3% of estimated total direct NRP losses at each return period included within the damage estimation process. This uplift factor of 3% remains as the best estimate of economic indirect flood losses to NRPs even though the uplift factor for financial indirect flood losses has now been revised significantly upwards as a result of new evidence (see Non-Residential Properties: Financial or Local Economic Benefits and Losses).

If an NRP is likely to contribute over 10% of the overall PVd, then it may well be worth seeking to ascertain indirect costs through asking the questions on disruption and indirect losses included in the site survey questionnaire which is recommended in this case. Also if a business appears to be highly specialised and may not have competitors in this country, it may also be worth pursuing an estimate of indirect cost of flooding in the same way.

The site survey questionnaire can be found in the *Additional Resources* section for Chapter 5 on MCM-Online.

ESTIMATING THE DAMAGE-REDUCING EFFECTS OF PROPERTY LEVEL RESISTANCE AND RESILIENCE MEASURES

Currently there is significantly less use of property-level protection (PLP) measures in the NRP sector than in the residential sector where much of the emphasis in national policy has focused (Haskoning UK Ltd, 2012; Merritt, 2012). PLP survey and installation is being increasingly professionalised to ensure effectiveness (May et al. 2015) and small and medium sized enterprises (SMEs) are now being targeted for PLP measures. However, in general, take-up is currently significantly lower than in the residential sector. In Britain, businesses are likely to use various generic coping strategies that support business continuity, rather than property-level protection measures against flooding. Confirming this, Ingirige and Wedawatta (2011) found that SMEs tend to mostly rely on general business continuity and/or risk management strategies, although the uptake of those strategies was also found to be minimal. Generally, the level of up-take was higher among the SMEs with previous flood-related hazard experience, and such businesses were more likely to implement PLP measures than the SMEs without such experience. Obtaining property insurance, having a business continuity plan, using a business data backup system, and obtaining business interruption insurance were the commonly implemented business continuity measures by SMEs (Wedawatta and Ingirige, 2012). Further confirmation of the current low uptake of PLP measures by businesses in Britain, as well as in other parts of Europe is provided by Parker et al. (2012).

In the NRP sector, PLPs are only likely to be relevant for small and some medium sized business properties (i.e. generally those of SMEs). Larger business premises are likely to be more complex, possibly with a number of buildings, and generally other approaches rather than PLPs will be more relevant here.

An assessment of flood damage potential may or may not therefore warrant inclusion of the damage-reducing effects of property-level flood resistance and resilience measures: it depends on the purpose of the assessment, the user's objectives in undertaking the assessment and the size of business premises. If the decision is made to assess and include the estimated impact of these measures, then they are to be entered into any working spreadsheet as deductions of damage potential once damage potential has been estimated using one of the procedures above.

Where it is known that if PLP measures have been installed, their potential impact should be reflected in damage calculations otherwise damage potential will be over-estimated. However, if the number of NRPs protected in this way is small (say 5% of properties or less) it may well not be worth taking account of the impact of these measures in an appraisal. If the objective is to assess the potential for installing PLP measures then a with-and-without appraisal needs to be undertaken and the method below will only provide a very crude estimation of damage-savings which will need to be taken further. Identifying those properties which have already installed PLP measures can be difficult and time-consuming if there is no adequate record already in existence. A field survey designed to identify these properties will be necessary and to identify resilience measures in particular, contact may well need to be made with property occupants. These measures are most likely to be found in the 1:75 year flood extent envelope where the 100 year flood is no deeper than 1 metre.

RESISTANCE MEASURES

If flood resistance measures are identified as installed in NRPs or are being considered, then the damage-reducing effects of these measures may be estimated. A **first method** by which an estimation may be achieved is by raising the ground floor threshold level assigned to the properties in question by 0.6 metres within the land use/property database constructed for the appraisal. The 0.6 metres above property threshold level is considered by May and Chatterton (2012) to be the maximum level at which resistance measures can work effectively. This is, however, likely to lead to some overestimation of damage reduction because other factors such as the effectiveness of resistance measures needs to be taken into account.

A **second method** is to use formulae 5.1 and 5.2 below, although this method also has limitations. When using these formulae locally derived and appropriate parameter values should be used. Only where these do not exist should the default values below (which approximate average values for the nation) be used.

Surveys of the performance of predominantly residential PLP measures in four locations following the 2012 floods revealed that where PLPs were deployed and actually required, these measures have helped to reduce the impact of flooding in 84% of properties (although performance varied considerably between locations) (May et al., 2014). There was also evidence that water will still seep into properties through brickwork generating flooding of up to one inch. For this reason the damage-reducing effects of resistance measures must be factored by 0.84 if a more appropriate locally relevant value is unavailable. This only applies to properties which have a ground floor size of 320m^2 or less. NRPs of more than 320m^2 are much less likely to be protected by PLPs because of the complexity and cost. Instead they may be protected by demountable defences close to properties or more remotely from them. The damage-reducing effects of demountables – if there are firm plans to deploy them – should also be taken into account by raising the ground floor property threshold of the protected property (as in the first method explained above). However, for PLP measures, damage savings at each return period should be factored by 0.84 to take account of reliability issues.

Uptake values (UP) are the proportion of NRPs within the 1:75 year flood envelope which are expected to have PLPs installed (e.g. 10% = 0.1). Because take-up of PLPs is currently significantly less for NRPs than for residential properties, the national uptake factors are reduced here to 0.016 for warning-dependent resistance measures (WDRM) and 0.024 for warning-independent resistance measures (WIRM) (i.e. the values given in Penning-Rowsell et al., 2013 have been adjusted downwards to reflect lower take-up in the NRP sector). Damage reduction (DR) values are derived using economic costing rather than financial costing principles and are intended for use as broad average values. Not all property owners can be expected to operate their warning dependent measures and so an OP variable is included in Equation 5.2 to reflect this.

Step One: Calculate the number and then the total ground floor size (m^2) of NRPs at risk at each return period in the benefit area up to the 1.75 year flood probability threshold where flooding is not expected to be greater than 1m. Include only those NRPs with a ground floor size of 320m^2 or less.

Step Two: The following formulae may then be used to estimate the total £ damage reduction owing to NRP warning-independent measures (WIR):

Equation 5.1

WIRB (£) = TGA * DR * UP * EF

where:
WIRB (£) is Estimated damage reduction (i.e. Benefit) by employing WIR measures;
TGA is Total ground floor area of NRPs located in benefit area within 1:75 flood risk area and where flooding is not likely to be greater than 1m (for each return period in the appraisal);
DR is Damage reduction: (national default value = £85.91 per m^2 at 2023/24 values);
UP is Uptake of WIR measures factor: (national default value = 0.016);
EF is Effectiveness factor: (national default value = 0.84).

The resultant £ value result must then be converted to annual average damages saved.

Step Three: For NRP warning-dependent resistance measures (WDR) the equivalent formula is:

Equation 5.2

WDRB (£) = TGA * RA * DR * UP * OP * EF

where:
WDRB (£) is Estimated damage reduction (i.e. Benefit) by employing WDR measures
TGA is Total ground floor area of NRPs located in benefit area within 1:75 flood risk area and where flooding is not likely to be greater than 1m (for each return period in the appraisal.) Include only those NRPs with a ground floor size of 320m^2 or less;
RA is Reliability and Availability: (national default value = 0.30);
DR is Damage reduction: (national default value = £85.91 per m^2 at 2023/24 values);
UP is Uptake of WDR measures factor: (national default value = 0.024);
OP is Operated: (national default value = 0.63);
EF is Effectiveness factor: (national default value = 0.84).

The resultant £ value result must then be converted to annual average damages saved.

To summarise, the above formulae are only a rough guide to the value of NRP damage reduction through use of resistance measures for the following principal reasons:

- The uptake factor (UP) applies to the number of properties although here we apply it to TGA which is a surrogate measure for property numbers;
- The effectiveness of PLPs varies between locations;
- DR in £m2 is derived from research into detached houses; and
- Only reduction in direct damage is included whereas in practice reduction of stress and anxiety may also be relevant.

A **third method** may only be relevant where local data on the existence of PLP measures are unavailable or the scale and objective of the appraisal does not warrant a more penetrating appraisal, but where the effect of these measures is still considered to be important to include. Here, the average annual damage potential can be factored in some suitable way to take account of the damage-reducing effect of these measures - see Chapter 5 of the MCM (Penning-Rowsell et al., 2013) for further guidance.

RESILIENCE MEASURES

For England and Wales the estimated uptake (UP) of resilience measures for properties in benefit areas up to the 1:75 flood probability England and Wales is 2% (Clarke et al., 2015) although this value applies more to residential than to NRP properties. For this reason, this value has now been adjusted downwards below to reflect significantly lower uptake (0.01). The effectiveness (EF) of these measures is known to be lower than for resistance measures and this is reflected in a value of 0.50 for EF. Again damage reduction (DR) values are derived using economic costing rather than financial costing principles and are intended for use as broad average values.

Step One: A rough estimate of the value of the damage reducing effects of resilience measures on NRPs may be made by applying the following formula and deducting the resultant £ average annual damage value from the potential average annual damage value at each return period used in the appraisal:

Equation 5.3

RISDR (£) = TGA * DR * UP * EF

where:
RISDR (£) is Estimated damage reduction by employing resilience measures;
TGA is Total ground floor area of NRPs located in benefit area within 1:75 flood risk area and where flooding is not likely to be greater than 1m (at each return period);
DR is Damage reduction: (national default value = £69.96 per m2 at 2023/24 values);
UP is Uptake factor: (national default value = 0.01);
EF is Effectiveness factor: (national default value = 0.50).

The resultant £ value result must then be converted to annual average damages saved.

Very similar simplifying assumptions to those applicable to the procedure for estimating the damage reducing effects of resistance measures are also applicable to resilience measures. A further simplifying assumption which can affect the reliability of these estimates is that in some cases resistance and resilience measures may be used in combination. The uptake factor may improve in the future and/or local evidence of uptake of resistance and resilience measures in which case the uptake value can be altered to more closely match with evidence.

SUBSTITUTING LOCAL VALUES INTO EQUATIONS

The national default values which appear in the above formulae (i.e. for calculating WIRB and WDRB) are derived from the best available data within England and Wales and represent mean national level values. Each value should be substituted by local values where there is evidence to support a more customised local appraisal. For example, if it is known that in a particular benefit area that, say 10% of properties have WIR measures, then the UP parameter value may be altered from 0.032 to 0.10 and so on with other parameter values.

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6 *Other Flood Losses*

6 Other Flood Losses

Infrastructure, Transport, Education & Health and Emergency Costs

OVERVIEW

This Chapter presents information and appraisal guidance for indirect flood losses. This includes when floods disrupt utility services and communications, affects transportation networks and public buildings and imposes extra costs on those involved in managing floods and in the recovery phases. The impacts and losses experienced due to the disruption of services and transportation networks will have impacts outside of the flooded area as well as within it, and in some cases the impacts may be geographically far reaching. Understanding and being able to quantify such potential losses can provide a more comprehensive account of flood damages for inclusion in project appraisals.

Proportionality is a key feature of this chapter. The effort in the assessment of any type of loss should be proportional to its impact and although it may be technically feasible to assess the potential of loss to many assets, it may not be effective or necessary to do so. Methodologies for appraisal vary depending on the specifics of the losses but often include an element of the willingness of a consumer to avoid a disruption to a service or a traveller avoiding a delay. There is often little data from which to make an assessment of the potential losses due to flooding and therefore these methodologies draw on experiences from previous flood events (in particular 2007 and 2012) to underpin the approaches identified. The complexity and interdependency of many of these assets mean that when the likelihood of damages due to the disruption of services or damage to infrastructure is likely to be significant a site survey is recommended.

This Chapter is divided into five subsections. The first of which (Introduction) presents a process for filtering and prioritising those assets which should be included within appraisal and it is therefore recommended that appraisers review this introduction prior to other sub-sections:

- Introduction to appraising the losses from utilities, schools, hospitals, transportation networks and emergency services: Prioritisation of losses for inclusion in project appraisal;

- Infrastructure: Estimating the losses to electricity, gas, telecommunications, water and water treatment assets caused by the disruption to supply;

- Transport: Losses due to the flooding of roads and losses from rail disruption;

- Education and Health: Estimating the potential losses due to the disruption of school education and the flooding of hospital services;

- Local Authority, Emergency Services and Recovery costs: Appraising the additional costs of flooding to the emergency services, the Environment Agency and Local authorities.

6 Introduction

To appraising the losses from utilities, schools, hospitals, transportation networks and emergency services: Prioritisation of losses for inclusion in project appraisal

TYPES OF LOSSES

In general losses to infrastructure can accrue in the following ways:

1. The physical susceptibility of a plant and/or its supporting networks. This relates directly to the physical damage potentially caused by flood waters and therefore on the performance of the asset. Henceforth, this will be referred to as the 'direct damages' component of losses.
2. The wider economic impact. This will include the disruption caused to locations both inside and outside of the flood risk zone.
3. Wider less tangible impacts. How these impacts affect those living both inside and outside of the flood risk zone.

Each of these losses may impact services and infrastructure to different degrees, the severity of which may depend upon:

- The **dependency** of properties/businesses/other infrastructure served by utility plants and networks;
- The ease and cost of **transferability** of production to sites not affected by flooding (e.g. the degree of redundancy in the system): if a service can easily be replaced by another service it is said to have high redundancy/transferability;
- The **duration** of any disruption.

(Penning-Rowsell *et al*., 2005 and Cabinet Office, 2010)

The effort and resources used in the assessment of any type of loss should be proportional to its impact and significance. Therefore, although it may be technically feasible to assess the potential of loss to many assets, it may not be effective or necessary to do so. Consequently, the initial step therefore, within any project appraisal is a prioritisation of the potential losses which should be included for quantification within an economic assessment.

PRIORITISATION OF LOSSES FOR INCLUSION IN PROJECT APPRAISAL

The prioritisation process is illustrated in Figure 6.1 (within the *Tables and Figures* for Chapter 6 on MCM-Online) and consists of five steps:

Step One: Identify those assets at risk of flooding

Step Two: Determine the likelihood of flooding of assets

Step Three: Determine the criticality of the assets to flooding

Step Four: Utilise a risk matrix for prioritisation

Step Five: Assess the impact of resistance and resilience

Through this filtering process, a shortlist of assets is prepared as candidates for detailed economic appraisal. This should be viewed in conjunction with the Appraisal Summary Tables (AST) within the Environment Agency FCERM guidance (2010a; 2010b).

Those assets that do not make the short-list should be merely enumerated and described (as illustrated in Table 6.1) to give qualitative weighting to the appraisal and provide details for any prospective Multi-Criteria Analysis.

THE TOTAL RISK MATRIX

One of the key elements of the prioritisation process is the use of a 'total risk' matrix. This provides a classification of the likelihood of damage or disruption and the scale of this impact. This process acts as a risk filter with generally only those assets considered to be at **High** or **Very High** risk being fully quantified within an appraisal: although there may be situations where it is appropriate to appraise other categories.

Table 6.2 *Risk Matrix*

IMPACT**	Significant	Medium Risk	**High Risk**	**Very High Risk**
	Moderate	Low Risk	Medium Risk	**High Risk**
	Low	Negligible Risk	Low Risk	Medium Risk
		Very Low	*Low*	*Medium/High*
			LIKELIHOOD*	

* These follow the Environment Agency's Risk of Flooding from Rivers and Sea likelihood bands.
** The significant, moderate and low impact categories are defined for each receptor type.

Since flooding in 2007 there has been an increased focus on the securing of the continuity of service of utilities and communication networks during flooding. This has meant that many utility and transportation organisations have begun a process of assessing the susceptibility of their assets to flooding and have developed appropriate risk registers. These registers if accessible to appraisers will replace steps 1 to 3 in the prioritisation process and any filtering using the risk matrix.

LESSONS FROM PREVIOUS FLOODS: PERCENTAGE UPLIFTS FOR ASSESSING POTENTIAL LOSSES

A less resource intensive approach to assessing the potential losses due to the flooding of infrastructure which has been adopted by project appraisers has been to 'uplift' the potential direct damages by a percentage factor. These percentage values have been calculated based upon the actual losses estimated from previous national-scale floods in 2000 and 2007 (Penning-Rowsell *et al*., 2002; Chatterton *et al*., 2010).

The appropriateness of use and transferability of the values to different flood situations will primarily depend on the context of the situation being examined. These values have been generated from some of the most severe flooding experienced in England and Wales in the last 50 years and therefore should not be considered typical of all flood situations. Therefore, these percentage values should ***not*** be used blindly as a 'fix' for assessing damages in these benefit categories. Where the likelihood of damages due to the disruption of services or damage to infrastructure is likely to be significant (based on assessment using the prioritisation process) a full appraisal is recommended.

SUMMARY OF THE RELATIVE IMPORTANCE OF UTILITY AND INFRASTRUCTURE LOSSES

A summary of the relative importance of all utility and infrastructure measures adopting the risk matrix approach (with the addition of scale) can be found in Table 6.3. This table provides a qualitative indicator of the proportionality of including the investigation of an infrastructure asset within an appraisal.

There may however be particular circumstances whereby an asset assumes greater significance; for instance when it is likely to be frequently flooded or whereby a disproportionate number of people may be impacted. Appraisers are therefore always recommended to undertake their own filtering approach and if in doubt speak to the infrastructure owners/providers to determine the criticality of assets.

Although not an exhaustive list we suggest a full monetary quantification of utility damages/losses is required (i.e. proportional) and will contribute significantly to the present value of benefits in the following situations. Where there is:

- Tidal inundation of electricity transmission lines greater than 132 kV unless flooding thresholds are less frequent than 1 in 75 years (1.3%);

- Tidal inundation of electricity transmission lines of less than 132 kV but only if flooding is more frequent than 1 in 25 years (4%);

- Flooding of sewage treatment works when the risk of flooding is more frequent than 1 in 75 years (1.3%) and the effluent dry weather flow is greater than 5,000 cumecs;

- Flooding of sewage treatment works when the risk of flooding is moderate (i.e. more frequent than 1 in 200 years; 0.5%) and the effluent dry weather flow is greater than 30,000 cumecs;

- Flooding of water treatment works when the risk of flooding is more frequent than 1 in 75 years (1.3%) and the population affected is greater than 5,000;

- Flooding of water treatment works when the risk of flooding is moderate (i.e. more frequent than 1 in 200 years; 0.5%) and where the dependent population is significantly large (i.e. >20,000);

- Flooding of electricity grid substations (including super grid and bulk supply point installations) when the risk of flooding is moderate (i.e. more frequent than 1 in 200 years; 0.5%) as these serve greater than 125,000 and up to 500,000 customers;

- Flooding of primary and grid substations where when the risk of flooding is more frequent than 1 in 75 years (1.3%); thereby serving a dependent population of greater than 5,000 people.

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6 Infrastructure: Utilities

To appraise the losses from electricity, gas, water, waste water and telecommunications

Electricity and Gas

Estimating the losses to electricity and gas assets caused by the disruption to supply

OVERVIEW

This sub-section introduces methodologies for the estimation of losses to both electricity and gas assets. This focuses mainly on the losses caused by the disruption to the supply of services as well as some comment on direct damages to these infrastructure types. The impacts of the loss of electricity are particularly significant as the consequences can radiate beyond the immediate vicinity of a flood area and the high number of associated interconnections. Appraisal is primarily based on estimating the amounts that customers are willing to pay to avoid the disruption to service.

There are many assets potentially at flood risk with HR Wallingford (2012) reporting that there are 10,600 electricity and 250 gas assets at significant risk of flooding in England which account for 6.6% or 8.3% of all assets. The 2007 floods highlighted the severe consequences and disruption that can occur if electricity infrastructure assets are flooded or threatened and have provided some key lessons for the appraisal of both gas and electricity infrastructure. In total, there were an estimated electricity supply losses of £138-9m which accounted for 20% of all infrastructure losses or over 4% of all economic losses.

LESSONS FROM EXPERIENCE

- Of all the utility assets electricity is the most important to appraise due to the inherent interconnectivity within the system.
- Due to the serious repercussions of severe power outages and high interconnectivity with other essential services, both electricity and gas companies are under a legal duty to ensure security of supply (HM Government 1996; 2002).
- Since 2007, the need for increasing resilience in utility supply has been highlighted and efforts have begun and more are planned (Pitt, 2008; National Grid Gas, 2010). These measures need to be considered within a project appraisal.
- The 2007 floods illustrate that the loss of perceived value to users accounted for more than 90% of the total economic costs of flooding in the electricity sector and highlights the importance of assessing the likely value of this disruption of power supplies to large numbers of customers.
- Prioritisation in appraisal is essential with assets on the Protected Site List (PSL) or large populations having higher priority; however, the higher up the distribution chain for electricity the greater the degree of redundancy. Therefore, the risk matrix should be applied.

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- Flooding risk to gas infrastructure and/or the continuity of supply is considered to be low with high transferability of service within the gas network. The highest risk is posed by a failure of communications or equipment reliant on electricity supplies.

ESTIMATING DIRECT DAMAGES TO ELECTRICITY AND GAS INFRASTRUCTURE

Depth/damage data are not available for the distribution and grid substations because in these instances damage is potentially highly variable and depends on the configuration and siting of transformers, switch gear and other equipment. Site surveys and further discussions with infrastructure owners would be required to assess the direct damages to grid and distribution substations.

Readers are referred to Chapter 5 for guidance on assessing direct damages to primary substations. In addition to this, we recommend that appraisers discuss the costs of direct damage owing to the flooding of gas assets with National Grid Gas or other distributers.

METHODOLOGY FOR ESTIMATING THE LOSSES DUE TO THE DISRUPTION OF A SERVICE

Step One: Identify the locations and types of substations

Identify with the typology all electricity substations in the floodplain under consideration and for which the National Grid or Distribution Network Operator (DNO) is responsible.

The table below illustrates the different types of electricity substation and permits the prioritisation of assets to consider.

Table 6.4 *Types of electricity substations (ENA, 2009; 2018)*

Substation type	Typical Voltage transformation levels	Approximate number in UK	Typical size	Typical numbers of customers supplied
Grid (Super grid)	400kV to 132kV	377	250m x 250m	200,000 to 500,000
Grid (Bulk Supply Point)	132kV to 33kV	1,000	75m x 75m	50,000 to 125,000
Primary	33kV to 11kV	4,800	25m x 25m	5,000 to 30,000
Distribution	11/kV to 400/230V	230,000	4m x 5m	1 to 500

NB. This is Table 6.6 in the MCM 2013

Using Table 6.4 above, identify the risk for each substation based on the likelihood and impact of flooding using the following risk matrix (Table 6.5) to prioritise those assets which should be quantified – only those which are categorised as **high** or **very high** risk should be examined further.

Table 6.5 *Risk matrix for electricity substations*

IMPACT	Sig: Grid substations with serving a population of > 125 000	Medium Risk	**High Risk**	**Very High Risk**
IMPACT	High: Primary substations those with > 10000 *population supplied*	Medium Risk	**High Risk**	**High Risk**
IMPACT	*Mod: Primary substations with 5,000 to 10,000 population supplied*	Low Risk	Medium Risk	**High Risk**
IMPACT	*Low: Distribution substations with fewer than 500 people supplied.*	Negligible Risk	Low Risk	Medium Risk
		Very Low	*Low*	*Medium/High*
		LIKELIHOOD		

NB. This is Table 6.7 in the MCM 2013

Step Two: Estimation of population served

Estimate the population served based on length of perimeter using the table below and the presence of any “Protected Sites” designated as part of the Protected Sites List (PSL) process (from DNO, see Department for BEIS, 2019) examples of which are provided in Figure 6.2.

This is a broad estimate. The results from discussions with National Grid or the appropriate DNO will, of course, be more accurate.

Table 6.6 *Estimations of population served based on the perimeter fence length (after ENA, 2018b)*

Substation type	Average Perimeter Fence	Ratio customers to metres of perimeter
Grid (Super grid)	1000m	225:1
Grid (Bulk Supply Point)	300m	183:1
Primary	100m	150:1

NB. This is Table 6.8 in the MCM 2013

Step Three: Assess whether an asset is defended against flooding

Establish whether the site is within an existing flood-defended area and determine the condition of the defences and their actual standard of protection. Since 2013, there has been a lot of ongoing work to improve the resiliency of substations and associated infrastructure so it is likely that some assets will have protection, with a programme of improvements scheduled to be completed by c. 2026 (National Grid, 2022). The third round of Climate Change Adaptation Reporting in accordance with the Climate Change Act 2008, provides the updated information on climate resilience for each supplier (Defra, 2022).

Where defences are below the Environment Agency's set target condition grade and/or the standard of protection is below the resilience levels set by ETR 138 (Issue 3; ENA, 2018a) and Engineering Design Standard (UK Power Networks, 2019) (Table 6.7) establish the flooding threshold for key parts of the substation that will trigger disruption of supply to customers and critical infrastructure.

If an asset is not in an existing flood-defended area move to Step Four.

Table 6.7 *Resilience levels for electricity substations**

Flood type	Protection level			Allowance for climate change rises	Freeboard
	Grid Substation	Primary Substations† > 10,000 unrecoverable connections	Primary Substation† < 10,000 unrecoverable connections		
Fluvial	1:1000 Flood level	1:1000 Flood level	1:100 Flood level	Flood Depth x 20% or use of EA CC factored levels	300mm
Tidal	1:1000 Flood level	1:1000 Flood level	1:200 Flood level	105mm or use of EA CC factored levels	300mm
Surface	1:1000 Flood level	1:1000 Flood level	1:100 Flood level	Flood Depth x 20%	300mm

Source: UK Power Networks (2019, 10); ENA (2018a, 20).

* Please note that critical infrastructure resilience is a priority area following recent floods and storms and the *National Flood Resilience Review* (HM Government, 2016) and so the resilience levels may be subject to change. Furthermore, some DNOs have issued guidance recommending additional safety factors are applied (e.g. Electricity North West, 2017). In particular, the updated ENA (2018a) suggests that Network Operators should ensure that they utilise the most recent guidance available. It is recommended that appraisers also check for updated information.

† ENA (2018a) suggests that network operators should focus on the resilience of service provision to sites supplying significant local communities (SLCs) (which are defined as those comprising at least 10,000 customers/connections) and to the level of the EA's Extreme Flood Outline (i.e. 1/1,000 flood risk). Therefore, those primary substations which are likely to serve a customer population of over 10,000 should have the same protection level (1:1000) as grid substations.

Step Four: Assess presence and importance of resilience measures

If not in an existing flood defended area establish whether the site has been made resilient against flooding with either permanent or temporary locally-installed measures. If the measures are temporary establish whether the site is in receipt of a flood warning (provided by organisations such as the Environment Agency, Natural Resources Wales or SEPA) and that the erection of temporary measures is practical within the lead-time of warnings provided.

If the site is either not in receipt of flood warnings or these are inadequate to secure the site consider the flooding thresholds for key parts of the substation and the potential for transferring other supply to customers and critical infrastructure. If no flood intervention measures are in place or planned imminently by the DNO establish the flooding threshold for key parts of substation likely to disrupt supply to customers and critical infrastructure.

Step Five: Assess the importance of network interconnectivity

Establish the degree of network interconnection to minimise loss of supply to customers and critical infrastructure. Where transferability of supply is 'seamless' losses associated with flooding are only direct damages to the substation.

Step Six: Identify appropriate flood intervention measures

If the project appraisal is specific to the substation, establish the most appropriate flood risk management system, in conjunction with the DNO, to protect the substation. Table 6.8 provides the potential intervention measures for electricity infrastructure with their advantages and disadvantages.

Step Seven: Cost-benefit analysis

Conduct a cost-benefit analysis methodology of preferred solution(s) including an assessment of societal risks. This includes the evaluation of damages by flood depth for critical plant and equipment and the cost of customer supply losses.

'Customer/minutes' loss as a result of flooding during the accounting period including the 2007 floods were only 4.2% of total (with lightning and wind and gales contributing to over 20%). However, the widespread losses of electrical power extend well beyond the obvious consequences and the following should be included where possible as part of the assessment of societal losses.

- Loss of traffic lights can lead to traffic gridlock with knock-on effects on the ability of emergency services to respond.
- Mobile telephony will overload and fail within 6 hours.
- Domestic central heating (even gas fired) will fail and hypothermia is a real threat during winter flooding.
- Disruption of water supplies and sewage treatment and disposal could pose a serious health hazard.
- Petrol pumps, cash tills and cash machines will fail.
- Radio and TV broadcasts will fail to reach the affected population.
- Use of candles and alternative cooking practices could pose potentially serious fire hazard and dangers of asphyxiation.

The appraiser should create a template about when each of the above benefits is worthy of further analysis. The ratio of property within the floodplain to those outside the floodplain serviced by a distribution substation subject to flooding (within Flood Zone 3) may determine whether induced losses should be assessed. Appraisal is probably only worthwhile if more than 50% of the properties served by a flooded distribution substation are largely flood free (i.e. in Flood Zones 1 and 2).

Step Eight: Quantify the potential costs due to the disruption of services (using the equation below).

Equation 6I.1

CD = P * EC * WTP * D

where:
CD is Estimated cost of disruption (£)
P is Number of properties affected by power outage[1]
EC is Hourly electricity consumption (kWh)
WTP is Willingness to pay value to avoid power outage (£)
D is Estimated duration of disruption to supply (hours)

Some indicative values of average energy consumption and willingness to pay to avoid a disruption in service are provided in Figure 6.3.

DURATION OF ELECTRICITY DISRUPTION

In general, most repairs to distribution substations would be achieved within a 24 hour period and therefore power restored to properties relatively quickly. However, those properties and businesses which are themselves flooded will suffer electricity outages for longer, because the property-level electrical fittings will also need repair. The specific impacts of these outages will depend upon whether residents are in temporary accommodation (and therefore may be less impacted by the lack of supply) or whether they are remaining in the affected property. Therefore, in some situations it may be appropriate to estimate the number of households that might be flooded within the area served by a distribution substation and remove these from the total number of properties affected by the power outage.

DISRUPTION TO GAS SUPPLIES

Overall, the pressurised gas network is far more resilient than electricity distribution. National Grid Gas have been working to increase the resilience of its assets to flooding including activities such as reinforcing river banks and further research about what the impacts of flooding are on pipelines and other equipment (National Grid Gas, 2010). As part of this process risks have been categorised (on a four point scale) according to the degree of material risk they pose to different assets and how robust business process and/or action plans are to deal with these risks. For flooding, the majority of risks are considered either to be low in terms of the damage likely to be sustained or that the continuity of supply would not be threatened. National Grid Gas (2016) reports on the progress of resilience efforts and the Climate Change Adaptation Reporting (under the Climate Change Act, 2008), third round reports highlight the progress on climate resilience by each supplier (Defra, 2022). However, the following should be considered for appraisal:

- A gas compressor station was considered to be at risk of flooding, but supply was not thought to be threatened if it was inundated.
- National Transmission Pipe work (~70 barg). These were considered to be at risk as there is the potential for these pipes to float if the ground around and above them is flooded. However, the main concern is that there is insufficient information about these risks and therefore further research is required to be able to quantify fully their susceptibility to flood water

[1] i.e. total number of properties served by the substation or infrastructure affected

- The main concern remains the pipework and their pressure gauges where the ingress of flood water may necessitate a mass purge of the affected pipeline.

Should a gas installation be located in a floodplain under investigation then discussions with the National Grid Gas or other distributers may be appropriate on the lines of the step-by-step guide above for electricity. In those situations where further analysis of a loss of gas supply is required the calculation provided for electricity may also be adopted. An estimation of the annual gas energy consumption for the average UK home is provided in Figure 6.3.

KEY ELECTRICITY ASSETS FOR APPRAISAL FROM EXPERIENCE

A summary of the relative importance of all utility and infrastructure measures adopting the risk matrix approach (with the addition of scale) can be found in Table 6.1. Although not an exhaustive list (and appraisers should undertake their own filtering approach) we suggest a full monetary quantification of utility damages/losses is required (i.e. proportional) and will contribute significantly to the present value of benefits in the following situations:

- Tidal inundation of electricity transmission lines greater than 132 kV unless flooding thresholds are less frequent than 1 in 75 years (1.3%).
- Tidal inundation of electricity transmission lines of less than 132 kV but only if flooding is more frequent than 1 in 25 years (4%).
- Flooding of electricity grid substations (including super grid and bulk supply point installations) when the risk of flooding is moderate (i.e. more frequent than 1 in 200 years; 0.5%) as these serve greater than 125,000 and up to 500,000 customers.
- Flooding of primary and grid substations where when the risk of flooding is more frequent than 1 in 75 years (1.3%); thereby serving a dependent population of greater than 5,000.

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Water and Waste Water

Estimation of potential losses due to the flooding of water infrastructure

OVERVIEW

This sub-section provides a methodology for estimating the potential losses due to the flooding of water infrastructure. Appraisal in this sub-section is based on the Ofwat (2008) guidance on the costs imposed on households when water is cut-off and on willingness-to-pay valuation of customers to avoid a disruption to either water supply or waste water services. In addition to this, the Security and Emergency Measures Direction (SEMD) 1998 provision about the minimum requirement of water which should be provided (per person) when water supply is cut-off is also utilised.

HR Wallingford (2012) has reported that there are 970 sewerage and 290 assets located in areas at moderate or significant risk of flooding in England. The floods in 2007 served to highlight the susceptibility of the water supply network and the potential large scale disruption that can occur when only one major single source of water supply serving a large number of users is flooded. The overall costs to Severn Trent Water alone were in the order of £30 million with supply being interrupted for approximately 350, 000 customers (Chatterton et al., 2010).

LESSONS FROM EXPERIENCE

- Generally, sewage treatment and pumping facilities are not as susceptible to flooding as water supply facilities.
- In 2004, the Water UK Council established a mutual aid protocol for all members to ensure delivery of water by companies during an emergency. The protocol (amended after 2007) includes agreements to share emergency equipment and to support affected member companies during incidents and enhances the resilience and contingency options of the sector.
- Regulators have a key role in supporting the UK's resilience agenda, and the Pitt Review recommended that this was recognised by "placing a duty on economic regulator to build resilience". These resilience activities (and future planned activities) need to be included within project appraisal. Of particular use to appraisers are the indicators some companies have used for defining and measuring resilience.
- Similar to electricity the interconnectivity of water infrastructure means that losses can extend widely beyond the flooded area.

ESTIMATING DIRECT DAMAGE TO WATER INFRASTRUCTURE

Readers are referred to Chapter 5 for guidance on assessing direct damages to sewage treatment works. The data contained on MCM-Online provide sector average indicative values only and therefore site surveys or discussions with the infrastructure owner are recommended to verify these estimations and to appraise the potential damages to water supply infrastructure which are not included as depth/damage curves in Chapter 5.

APPRAISAL FOR WATER RELATED ASSETS AT FLOOD RISK

The Cabinet Office (2011, 28) suggests a benchmark that "as a minimum essential service provided by Critical National Infrastructure (CNI) in the UK should not be disrupted by a flood event with an annual likelihood of 1 in 200 (0.5%)". The guide goes on to indicate that the costs and benefits of individual projects should be considered when deciding which projects to fund and whether the benchmark can be achieved. The benchmark does not apply to other infrastructure that is not designated as Critical National Infrastructure. The Climate Change Adaptation Reporting (under the Climate Change Act, 2008), third round reports highlight the progress on climate resilience by each supplier (Defra, 2022a).

There is a fundamental difficulty in creating a definitive listing of water supply and sewerage infrastructure at risk from flooding (or any critical infrastructure, e.g. electricity substations, for that matter). Any reference to sites/assets being critical infrastructure indicates that the asset is important and could provide useful targeting information for those with a 'terrorist' intent. Such information may require a protective marking (e.g. "RESTRICTED"). Consequently, an appraiser must rely on the often incomplete data provided by the Environment Agency's National Receptor Dataset as a starting point and follow up the results with direct contact with the water supply and sewage treatment providers.

The process of evaluating the contribution of a water supply or water treatment works to the total flood losses of a community is similar to the step-by-step procedure outlined for electricity installations (Section 6b) but with different impact filters to account for.

Step One: Apply the relevant risk matrix

Identify the risk based on likelihood and impact of flooding using the appropriate risk matrices for sewage treatment and water supply works below. Using this as a decision filter – only consider steps 2 onwards for High and Very High Risk assets.

Table 6.9 *Risk matrix for sewage treatment works*

IMPACT	*Sig: > 30,000 cumecs effluent dry weather flow*	Medium Risk	**High Risk**	**Very High Risk**
	Mod: 5,000 to 30,000 cumecs effluent dry weather flow	Low Risk	Medium Risk	**High Risk**
	Low: < 5,000 cumecs effluent dry weather flow	Negligible Risk	Low Risk	Medium Risk
		Very Low	*Low*	*Medium/High*
		LIKELIHOOD		

NB. This is Table 6.12 in the MCM 2013

Table 6.10 *Risk matrix for water supply*

IMPACT	*Sig: > 20,000 population supplied or PSL customers*	Medium Risk	**High Risk**	**Very High Risk**
	Mod: 5,000 to 20,000 population supplied	Low Risk	Medium Risk	**High Risk**
	Low: < 5,000 population supplied	Negligible Risk	Low Risk	Medium Risk
		Very Low	*Low*	*Medium/High*
		LIKELIHOOD		

NB. This is Table 6.13 in the MCM 2013

Step Two: Assess whether an asset is defended against flooding

Establish whether the site is within an existing flood defended area and determine the condition of the defences and their actual standard of protection. Where defences are below the Environment Agency's set target condition grade and/or the standard of protection is below the optimum design standard proposed by the Environment Agency establish the flooding threshold for key parts of the works likely to disrupt supply to customers and critical infrastructure (see Protected Site List established for electricity in Figure 6.2).

Step Three: Assess the presence and importance of resilience measures

If not in an area already benefiting from flood risk management measures, establish whether the site has been made resilient against flooding by the Water Company with either permanent or temporary locally installed measures. If the measures are temporary establish whether the site is in receipt of flood warnings and that erection of temporary measures is practical within the lead-time of warnings offered.

If the site is either not in receipt of flood warnings or these are inadequate to secure the site consider the flooding thresholds for key parts of the works and the potential for transferring other supply/treatment capacity to customers and critical infrastructure. If no flood intervention measures are in place or planned imminently by the water company establish the flooding threshold for key parts of works likely to disrupt supply to customers and critical infrastructure.

Step Four: Assess the importance of network interconnectivity

Establish the degree of network interconnection to minimise loss of supply/treatment to customers and critical infrastructure. Where transferability of supply is 'seamless', losses associated with flooding are only direct damages to the works.

Step Five: Identify appropriate flood intervention measures

Establish the most appropriate flood risk management system in conjunction with the water company (see Table 6.8 for examples established for electricity which provides a starting point for these)

Step Six: Cost-benefit analysis

Apply a conventional cost-benefit analysis of preferred solution(s) including societal and environmental risks. This includes the evaluation of damages by flood depth for critical plant and equipment and the cost of customer supply losses using cost of water under Security and Emergency Measures Direction (SEMD) (Defra, 2022b) provision as a minimum cost, supplemented with willingness to pay data/surveys as appropriate. MCM (2005) (Penning-Rowsell et al., 2005) provides an example of appraisal for the Newport Waste Water Improvement Scheme which highlights the process that could be applied.

Under the Guaranteed Standards Scheme customers are entitled to financial recompense when water is disconnected without prior warning (Ofwat, 2008; Ofwat, 2017a). Ofwat (2017b) provides a minimum amount that companies must provide; £20 for domestic customers plus an additional £10 for each 24-hour period the supply remains cut-off and for non-domestic customers £50 plus an additional £25 for each 24-hour period the supply remains unrestored. This compensation agreement is often waived in extreme weather conditions or exceptional circumstances; however it may be used to estimate the potential costs of disruption of supply. Water UK (2017) provides a Technical Guidance Note detailing operational principles to be considered by water undertakers when fulfilling their responsibilities under licensing requirements (Defra, 2022b as per Section 208 of the Water Industry Act 1991) which requires all water companies to provide 10 litres of water per person per day or 20 litres per person per day in incidents lasting more than 5 days.

KEY WATER ASSETS FOR APPRAISAL FROM EXPERIENCE

A summary of the relative importance of all utility and infrastructure measures adopting the risk matrix approach (with the addition of scale) can be found in Table 6.3. Although not an exhaustive list (and appraisers should undertake their own filtering approach) we suggest a full monetary quantification of utility damages/losses is required (i.e. proportional) and will contribute significantly to the present value of benefits in the following situations:

- Flooding of sewage treatment works when the risk of flooding is more frequent than 1 in 75 years (1.3%) and the effluent dry weather flow is greater than 5,000 cumecs.
- Flooding of sewage treatment works when the risk of flooding is moderate (i.e. more frequent than 1 in 200 years; 0.5%) and the effluent dry weather flow is greater than 30,000 cumecs.
- Flooding of water treatment works when the risk of flooding is more frequent than 1 in 75 years (1.3%) and the population affected is greater than 5,000.
- Flooding of water treatment works when the risk of flooding is moderate (i.e. more frequent than 1 in 200 years; 0.5%) and where the dependent population is significantly large (i.e. >20,000).

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Telecommunications

Appraising potential losses owing to the flooding of telecommunications infrastructure

OVERVIEW

This sub-section explores the potential losses caused by the flooding of telecommunication assets. CIRIA (2010) report that British Telecom has approximately 8,000 sites including telephone exchanges, with 500 major assets located within floodplain areas. It is unclear how many assets from other telecommunications providers are located in areas at risk. The 2007 floods highlighted that “the interconnected nature of the network provided a degree of resilience and helped prevent significant failures” (Pitt Review interim report, 2007; 97) and Chatterton et al. (2010) reported that during the 2007 floods there were few reports of failures or damages to the telephone network or exchanges.

In general, most telecommunication assets are considered to be quite resilient to flooding and there is a higher degree of redundancy than in other infrastructure sectors. There is much uncertainty about the total damages within the telecommunications sector in the 2007 floods as there is little data available; however they were considered to be lower than £1 million (Chatterton et al., 2010). This sub-section describes those situations where an appraisal might be appropriate and proportional.

LESSONS FROM EXPERIENCE

- There is in general very little data about the impact of flooding on the continuity of other communications infrastructure (e.g. broadband services), the possible length of any disruption and the subsequent impacts in particular on local businesses.

- However, there is considered to be a great deal of redundancy in the system, in particular in relation to telephone systems and the transfer of services to mobile communications.

- The largest potential danger from flooding is the knock-on impact of a loss of electricity supply on telecommunications, rather than flooding directly impacting the telecommunication assets.

- The Pitt Review (Pitt, 2008) discusses that flooding did cause some degradation of local network infrastructure; however British Telecom reported that there was less failure and impact occurred than was expected. This was in part due to the increasing use of glass fibre (rather than copper cabling) which is more resilient to water damage. This highlights that the network may become even more resilient in the future.

ROLES AND RESPONSIBILITIES OF TELECOMMUNICATION PROVIDERS

Telecommunication providers have responsibilities as part of the Civil Contingencies Act 2004 and as Category 2 responders include: any person who provides a public electronic communications network which makes telephone services available (whether for spoken communication or for the transmission of data) (HM Government, 2004; 25).

Additionally, the Communications Act 2003 (HM Government, 2003) permits the telecommunications regulator Ofcom the scope to impose specific requirements regarding the availability and use of the communications network and services during an emergency situation. There are also standard requirements as part of licensing conditions to maintain services and restore services as quickly as possible, where practicable.

INCREASING TELECOMMUNICATION RESILIENCE

CIRIA (2010; 90) identify the components most vulnerable to flooding include the following:

- *Telephone exchanges*: Back-up generators, diesel supply storage, cables entry, IT software, any other equipment located at a low level.
- *Broadband antennae*: Transmitters, cables, IT software, control systems (switch gear) and the structure itself.

The telecommunications sector, similar to other utility and communication providers, has many legacy assets potentially located at risk from flooding (CIRIA, 2010). However, they remark that it is unclear how vulnerable or resilient the ‘next generation’ of networks are to flooding nor how or whether flooding is being considered into the design and implementation of the updated systems. Therefore, appraising the potential impacts of flooding on these new types of networks is problematic.

In recent years much work has been done to ensure the resilience of the telecommunications sector (Cabinet Office, 2009); however much of this work has rightly prioritised ensuring a continuity of service for critical services such as the 999 service and other needs by emergency responders. Telecoms companies work across company boundaries and have provided much telecommunications assistance during flooding (e.g. BT civil resilience teams) including efforts during the 2007 and 2012 floods (FloodProBe, 2011 British Telecom, undated 1).

British Telecom (as well as other providers) have well-formulated plans for reacting to flooding including the use of Emergency Response Teams (ERT) and adopt an internal Bronze, Silver, Gold structure during a flood. This permits them to more effectively liaise and support the multi-agency response, to assess potential risks to their assets, where possible try to maintain a service and to plan recovery efforts (British Telecom, undated 2). BT has also invested in emergency infrastructure to enable them to better respond to a telecommunications failure. This includes pre-training over 500 staff to deal with incidents as well as purchasing hardware (such as containerised exchanges and investing in back-up power supplies) which can be deployed to maintain services.

APPRAISING THE POTENTIAL FOR DISRUPTION TO TELECOMMUNICATIONS

Chatterton et al. (2010) describe the origin of the additional costs due to flooding in this sector as including:

- Repair costs due to direct damage of the infrastructure asset.
- Additional maintenance costs.

- Extra operating costs during an emergency.

Disruption costs due to the loss of a telecommunications service are difficult to appraise. Many communications providers suggest in their customer charters or terms and conditions that customers are entitled to compensation (via a reduction in their bill or service charge) if their service is discontinued for any lengthy period of time. However, the majority of these agreements have exclusion clauses related to severe weather and it is unlikely therefore that a customer would receive much or any compensation.

Additionally, telecommunication providers are also able to temporarily 'reroute' or divert an existing telephone number to another device (such as a mobile telephone or other landline number); thereby establishing continuity in the service with little increased cost to the supplier.

There is less clarity about the costs of the disruption to broadband services; in particular to businesses that were not directly flooded. Evidence from telecommunications providers in 2007 suggested that any disruption was minimal and that service was restored relatively quickly; however there might be considerable knock-on impacts to the local economy (and potential claims for compensation) if disruption to services affected a number of businesses. More research however, is needed in this area.

Telecommunication assets are generally considered to be quite resilient to the effects of flooding as although the dependency of assets might be considered to be of a medium risk, the susceptibility of many assets is low. Additionally, there is a high degree of redundancy in the network; particularly in the case of telephone communications. Proportionally, damages to this sector will be lower than to other utility and transport networks and indeed the telecommunications providers argue that a power failure may be more problematic than direct flooding of their network.

Therefore, appraisal investigations are only recommended if there are major telecommunication assets located within the benefit area (e.g. major exchanges). In these situations we strongly propose speaking with infrastructure owners to understand the vulnerability of the asset from flooding and potential damage and losses accruing.

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6 Transport:

To appraise the losses from electricity, gas, water, waste water and telecommunications

Road disruption

OVERVIEW

This sub-section provides methodologies to estimate the potential losses due to the flooding of road networks. The Environment Agency (2009a) estimates that 10% of main roads are in areas at risk from flooding; with two thirds being at moderate or significant risk. Therefore, flooding has the potential to cause significant damage to roads and disruption to both travellers and businesses with the resulting losses being some of the highest non-property losses from flooding experienced.

Assessing the losses occurring from the disruption to routes is difficult and complex as it requires assessing the numbers of vehicles potentially affected and an appreciation of how their journeys may change under flooding conditions. Therefore, four approaches to the estimation of the impacts of road traffic disruption are presented. These vary in their level of complexity and therefore the appraisal resources that they require. The selection of the most appropriate method to use will depend upon the scale of the likely disruption; where losses are likely to be significant the more in-depth and detailed approaches are recommended.

LESSONS FROM EXPERIENCE

- The key factors for estimating traffic disruption costs include flood duration, the number of roads likely to be impacted and the importance of those roads affected (i.e. whether a flood causes a significant knock-on effect to other parts of the network).

- As the responsibility for roads falls between the Highways Agency, for major roads and motorways, and Local Authorities for local roads, and therefore it may be necessary to consult with these organisations when considering quantifying the potential losses from roads, depending on the types of roads affected.

- Although in general the greatest losses will occur on the roads with most traffic (i.e. motorways, or A roads). The 2012 floods highlighted the importance of connectivity and the presence of alternative routes as some roads (in particular the A361) were closed for weeks rather than hours or days.

- Adopting a proportional approach to appraisal is critical for appraising the losses emanating from the flooding of roads. It must be stressed that the first three methods highlighted below should be used to obtain an informed disruption cost which can be used to ascertain whether a more detailed analysis is required using sophisticated traffic modelling and specific, local data.

DIRECT DAMAGES TO ROAD INFRASTRUCTURE

Road reconstruction costs following flooding will vary depending upon the type and scale of damage, the type of road impacted and the location of the required repair. Unit reconstruction costs for resurfacing a local road range between approximately £15/m^2 for a quiet road to up to approximately £50 m^2 for a busier road (which require a thicker surface layer and road works may need to occur at night or off-peak and thus incurring overtime costs) (Hertfordshire County Council, undated; Conway County Borough Council, 2013).

If severe damage occurs or other road structures, such as bridges, are affected, costs may be considerably higher and will need to be evaluated on a case-by-case basis. The Highways Agency should be contacted separately for roads under their management as they will have different unit costs for repair and reconstruction.

LOSSES DUE TO ROAD TRAFFIC DISRUPTION

Estimating traffic disruption based on previous flood events is inadvisable as the severity of disruption can vary dramatically. Traffic disruption cost estimates for the summer 2007 floods, for example, highlighted a large range of between £22 and £174 million (Chatterton et al., 2010). As a percentage of direct damages, traffic disruption for the 2007 floods was approximately 10% of property damages (using the highest estimates for both), whereas for the autumn 2000 floods, this figure was nearer 2% (Penning-Rowsell et al., 2002).

The chief determining factors for traffic disruption costs include flood duration, the scale of the area affected (and therefore the number of roads) and specifically which roads are impacted (whether a flood causes significant knock-on effects to other parts of the network). Therefore, estimates based on previous events could lead to drastically over- or under-estimated figures as losses are highly location specific.

The three situations when the calculation of traffic disruption costs are most likely to be justified are when any of the following (or a combination of the following) are present:

1. When the annual probability of the flood event that causes traffic disruption is greater than 20%;
2. When a significant part of the local network is affected;
3. When the duration of the flooding is several days or even weeks/months; as happened on the A361 in Somerset in 2012.

Four approaches for appraising road traffic disruption costs will be described and the suitability of each will depend on available resources and the likely severity of the road disruption:

Method 1: The delayed-Hour Method: An average cost per hour for a delay on an average Highway's Agency road.
Method 2: The diversion-Value Method: The value of time based solely on the length of diversion (assuming that there is no reduction in traffic speed).
Method 3: The speed-Time Method: Reduced speeds are considered and a value of time applied for each diverted vehicle.
Method 4: Origin–destination matrix Method: Using sophisticated transport appraisal and modelling tools (e.g. SATURN/PARAMICS).

METHOD 1: THE DELAYED-HOUR METHOD

A very crude disruption cost could be ascertained using averages of Highways Agency (HA) data and Department for Transport estimate of the values associated with travellers' time.

Assuming an average speed of 100kmph (approximately 60mph), a single car delay of one hour on a motorway or trunk road will cost the UK £15.00. According to the Highways Agency National Operations Group, the average vehicle flow per hour on the strategic road network is 1,794 vehicles (see Chatterton et al., 2010). Based on this, we can estimate that the average delay of one hour on a road will cost the UK approximately £26,910.

This figure can be refined if specific data about the hourly flow rate of the particular road being appraised is available and weighted accordingly if other vehicles (e.g. LGVs and HGVs) are included. The averaged figure should only be used on Highways Agency roads (i.e. motorways and major trunk roads in England) as it will vary considerably at lower average speeds and on other road types.

A table of resource costs is available in Table 6.11 and can be used to refine the hourly cost per vehicle based on the average speed for the road(s) in question and these can then be multiplied by the calculated traffic flow for each particular road. This hourly figure will then need to be multiplied by the estimated duration of disruption. Indicative delay durations at different return periods are provided in Table 6.12. These are relatively basic estimations and local knowledge should be used to refine these where available.

The *Delayed-Hour* method is considered to be superior to the use of a percentage uplift estimate of property damages, however it will still provide a very crude estimate. More refined modelling should be undertaken where possible and if an appraiser thinks it is proportional to do so.

The following three approaches each adopt the same following basic principle: that if a road is closed; traffic will be diverted around this disruption point in the network. Essentially, Methods 2 and 3 are extensions of the same approach, but it is the level of detail which increases including how costs are attributed.

In both Methods 2 and 3 additional costs incurred due to a flood can be estimated using Equation 6T.1:

Equation 6T.1

$$CD = VD * AC * D$$

where:
CD is Estimated costs incurred during disruption (£)
VD is Number of vehicles delayed per hour
AC is Additional cost per vehicle (£)
D is Flood duration (hours)

When using this equation it is the estimate of the total number of vehicles that will take longer to make journeys that is important. This includes not only those vehicles which have been diverted due to flooding but also will include the traffic on those roads onto which traffic is travelling to avoid the flooded roads. However, excluded from the equation are those vehicles that are travelling to or from an address that is also flooded.

When considering the traffic disruption caused by flooding, the first question is whether it is worth calculating these benefits at all. The above equation should be used to derive an initial crude estimate of the likely benefits of alleviating traffic disruption, since otherwise the costs of calculating these benefits can exceed the present value of the traffic disruption benefits is disproportionate.

METHOD 2: THE DIVERSION-VALUE METHOD

The simplest way of applying the above equation is to assume that cars will be diverted on to neighbouring roads and therefore the distance that they travel will increase; however their speed will be unaffected. For example, suppose that 15,000 vehicles travel through the local network each hour and will have to travel on average 2 kilometres further but their average speed (40 kph) will not be reduced. In this scenario, the cost of that flood event will be equal to 15,000 * 0.48[1] * 2 for each hour of the disruption due to flooding. If the flood lasts six hours, the costs of traffic disruption amounts to £86,400. In this instance, the figure is small and therefore it is disproportionate to refine this value further using more sophisticated modelling.

METHOD 3: THE SPEED-TIME METHOD

The MCM (2005) provides a more in-depth method for calculating traffic disruption, and where possible this should still be used in conjunction with the updated figures provided here. In line with experience since 2005, we have attempted to produce a simpler and less time-consuming method which will give an adequate estimate of traffic disruption costs. More detailed modelling of local traffic conditions and driver behaviour may be the preferred option where the likelihood of road traffic disruption due to flooding is significant; for example the Somerset floods of 2012.

Step One: Determine which roads will be disrupted by floods of different annual probabilities and the durations of closure in each case.

As an approximation, a road should be assumed to be closed when the middle of the lane is inundated and certainly when the crown of that road is flooded. Although this may be considered quite cautious it is consistent with Environment Agency advice which attempts to prevent the public driving through flood waters.

Step Two: Estimate the volume of traffic using each road in the local network (e.g. including those roads on to which traffic is likely to be diverted in a flood).

Annual average daily traffic flows for all major and minor roads in Great Britain are available from the DfT website: https://data.gov.uk/dataset/208c0e7b-353f-4e2d-8b7a-1a7118467acc/gb-road-traffic-counts. The data are disaggregated by category of vehicle (car, LGV, HGV etc), which is relevant for calculating the different costs of travel for each vehicle type (covered in Step 5 below). An appraiser might also consult the Highways Agency and/or Local Authority who retain a large amount of data about traffic flows. It is also possible to utilise sources which provide data on 'live' traffic conditions to estimate "normal" traffic flow (e.g. Google Maps, Bing and Open Routing Service). Users should think carefully about the representativeness of any dates or times that are utilised and document the decisions which are made.

[1] (see Table 6.11 *Total Resource Costs*)

Step Three: Calculate the costs to traffic of using the local network under normal conditions.

The Department for Transport provides free flow speeds for all built-up and rural road types: https://www.gov.uk/government/collections/speeds-statistics. Free flow vehicle speeds provide information on the speeds at which drivers choose to travel and their compliance with speed limits, but should not be taken as estimates of actual average speed across the road network. Alternatively, column 1 "Free Flow speed" in the *Speed-Flow Relations* in Table 6.13, can be used for this purpose.

Step Four: For each flood event, determine the routes that diverted traffic will take.

For diversion distances, and where local expertise is absent, an online tool can be used. For example, the 'Get directions' feature on Google Maps provides distance information on the length of a selected stretch of road. As different traffic flow values are applicable to different types of road (single carriageway built-up roads; dual carriageway rural roads; motorways; etc) it is necessary to ensure that the diversion route is calculated using a separate distance value for each particular road type used (see Step 5). There are many assumptions that need to be made when establishing the likely routes for diversion and there is the need to concentrate primarily on diversions using major routes rather than minor roads.

Step Five: Calculate the costs to traffic of using the network under these flood conditions

The most difficult aspect here is to calculate how the non-flooded network will cope when the diverted traffic is added to it. Each road type has a free flow limit (see column 2 in Table 6.13 *Speed-Flow Relations Table*) and a capacity limit (see column 3 in Table 6.13) and when this is reached speed flows will be reduced linearly. The following equation can be used to calculate the reduced speed of vehicles on the diversion routes above the limiting capacity (QM; Table 6.13).

Equation 6T.2

$$\text{Speed} = \frac{\mathrm{VM}}{1 + \frac{\mathrm{VM}}{8\,\mathrm{DIS}} \times \left(\frac{\mathrm{F}}{\mathrm{QM}} - 1\right)}$$

Where:
DIS is the length of the road between junctions (in km);
F is the traffic volume in the pcu (per car unit) equivalents; and
VM and QM are as defined in the *Speed-Flow Relations Table* (Table 6.13)

When the reduced speed has been calculated for each diversion route, a cost per vehicle type must then be assigned using the Resource Costs Table (Table 6.11). This includes the value of time and the cost of running a vehicle (excluding indirect taxes and fuel duty etc) and is based on TAG Unit 3.5.6 (Department for Transport, 2012). It is now possible to calculate the total traffic disruption for the flood event using the equation below:

Equation 6T.3

EP = VA * L * C * D

where:
EP is Estimated potential costs of road traffic disruption (£)
VA is Number of vehicles affected (for each vehicle type)
L is Length of diversion (km)
C is Total cost of travel per km (for each vehicle type) (£)
D is Flood duration (hours)

An estimate of flood duration (in hours) for each return period is provided in the table of Indicative delay durations (Table 6.12). This should not be used as a substitute for detailed flood modelling but should be applied cautiously where no site-specific probabilities and durations are available.

METHOD 4: THE ORIGIN–DESTINATION MATRIX METHOD

The most sophisticated method of assessing road traffic disruption costs employs an origin-destination matrix and complex traffic modelling results. This would provide the most accurate of approaches. If an origin-destination traffic matrix is available for the area, then the flows on the different roads can be calculated using transport models such as SATURN (which is a general traffic assignment model) or PARAMICS (which is a more commonly-used micro-simulation model, like the old DRACULA model). Given the complexity of transport modelling, we recommend the support of a specialised transport modeller. More details can be obtained from https://www.gov.uk/transport-appraisal-and-modelling-tools.

Unless the network being modelled is small (e.g. less than 20 roads between junctions) then it is tedious to carry out an analysis without an available origin-destination matrix.

HIGH FREQUENCY EVENTS AND FLOODS WHICH AFFECT A SIGNIFICANT PART OF THE NETWORK

Roads are often the first points to flood in a floodplain, either because they run along the riverbank or because they cross the floodplain. Consequently, they may be flooded in very frequent events and perhaps be flooded several times a year. This needs to be accounted for within any calculations. However, in many cases the costs of raising the road and therefore solving flooding problems via a road engineering solution may be lower than a flood risk management option. In these circumstances it may be appropriate to cap the Present Value Damage (Pvd) due to road traffic disruption at the least cost solution of raising the road above the flooded level.

When considering floods which affect a significant part of the network, there are two sub-categories:

1. Disruption to sparse rural networks where diversion routes are long (e.g. 10 kms); and
2. Dense, heavily trafficked urban networks.

The former can be handled through the methods just described. However, the latter often involve dozens of links and, to be feasible, analysis of such networks requires the existence of an origin-destination matrix and a traffic model.

LONG DURATION FLOODS

Since traffic disruption losses are calculated on an hourly basis, the total losses from floods lasting several weeks can obviously be very significant, as experienced in Somerset during winter 2012/13.

During longer flooding events, awareness of road closures will increase and drivers will themselves begin to find alternative routes, may vary their journeys to less busy times of day, may select alternative transport options or choose not to travel and therefore traffic on the diverted routes may begin to ease. Additionally, not all diverted routes will be full to capacity at all times of day and therefore traffic speeds may vary and there is the need to ensure that the costs of traffic disruption is not severely overestimated in these circumstances.

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Rail disruption

OVERVIEW

This sub-section details a methodology for estimating the potential damages and losses caused by the flooding of railways. The Environment Agency (2009a) 21% of railways are at risk from flooding; with two-thirds of these being located in areas of significant or moderate risk of flooding. The 2007 floods caused estimated losses of £36 million in the rail sector of which £10.5 million were direct damages to the track or other infrastructure, with the remaining £25.6 million being attributed to disruption costs. This equated to 5% of the economic losses to infrastructure.

Appraisal of the potential losses owing to the disruption of rail services are quantified in two ways: estimates of the compensation paid to Train Operating Companies (TOCs) by Network Rail following a delay in service or performance as a result of severe weather and the Value of Time (VOT) approach which quantifies the value of a delay. Each of these depends upon an estimate of the likely number of services affected and the likely duration of the flooding.

LESSONS FROM EXPERIENCE

- Site surveys are recommended in many cases as the specific circumstances of the flooding and the siting of equipment and other assets may significantly impact the losses experienced.

- Since the 2007 floods Network Rail has increased their focus on the current and future flood resilience of the rail network. This has included drainage improvements and other work to improve the resilience of assets to flooding as well as the mapping and assessment of assets at risk. Therefore, discussions with Network Rail are critical to clearly understand the potential impacts and losses of flooding on rail infrastructure.

- When appraising the benefits of schemes to reduce rail disruption owing to flooding, care is needed to calculate costs which can actually be prevented by any flood management interventions: rail service disruption may be caused simply by heavy rainfall which cannot be prevented by flood risk management investment.

- Experiences in 2012 in South-West England highlighted the importance of the specific line impacted to the losses generated and the density of the rail network and therefore alternative routes. In 2012, both of the main lines into the South- West were disrupted, thereby effectively cutting all rail travel to the region.

- The inter-dependency of the railway assets (e.g. signalling, track, buildings) means that appraisal should be considered as soon as any there is the potential of flooding on any of Network Rail’s land.

TYPES OF LOSSES EXPERIENCED

Flooding of the rail track and associated infrastructure will cause some services to be cancelled and others to be delayed. The more severe the flooding the more severe will be the disruption and the larger the number of services cancelled.

Losses due to flooding can arise in the following areas:

1. Damage to assets. Network Rail incurs direct damages to infrastructure assets including track and circuits, embankments, structures and stations. There is also the potential for TOC rolling stock to be damaged although generally these losses are likely to be relatively minor.

2. Performance delay/cancellation costs. These occur as a result of delays and or cancellations in the train service and will involve costs to Network Rail for compensation to Train Operating Companies (TOCs) and to TOCs for loss of revenue and compensation to reimburse inconvenienced passengers.
3. Costs of alternative travel arrangements. When trains are cancelled owing to flooding the TOCs are under an obligation to enable passengers to continue their journey and provide alternative transport (such as replacement bus services). Although these are noted here as a separate category of loss, Network Rail's compensation to TOCs will include an element to reimburse for these losses.

ESTIMATING DIRECT DAMAGES TO RAIL ASSETS

Direct damage to rail assets is difficult to quantify as it varies considerably depending upon the circumstances of the flooding and the particular element of infrastructure affected; e.g. embankment, track, signalling etc. Therefore, to estimate potential direct damages a site survey is highly recommended along with discussions with local Network Rail engineers. However, to inform estimates the following indicative unit reconstruction values for Network Rail assets might be used: £4,000 per metre for embankments, £3,000 per metre for soil cuttings and £4,000 per metre for rock cuttings.

A METHOD OF BENEFIT ASSESSMENT FOR DISRUPTION TO THE RAIL NETWORK

The mapping of assets at risk has been improved by Network Rail's Asset Management with the development of a GIS system which is used to identify and categorise risks to assets. Network Rail has a much improved understanding and categorisation of both the location and potential impacts of flooding on their systems and it is strongly advised that FRM project appraisers make use of this knowledge and that any significant assessment of rail damage and disruption should include a site visit and discussions with the appropriate Network Rail route engineer.

The appraisal method described below is based on, and adapted from, that described in MCM (2005) and that undertaken for the Meteorological Office (Posford Duvivier et al., 2002) and is based upon analysing the number of services or passenger journeys impacted by flooding. Two methods are presented; firstly estimating the compensation payments made to TOCs/FOCs by Network Rail to recompense for delayed or cancelled service, whereas the second method uses a Value of Time approach accounting for how much time travellers would pay to avoid a delay. The first approach uses the total number of likely services impacted by flooding; whereas the latter utilises the number of passenger journeys impacted by flooding. If no information on the number of passenger journeys per 24 hours is available then the average number of passenger journeys per train, 182, (Burr, 2008) might be used to provide an estimated value based on the likely number of services affected.

The following steps should be used to calculate the costs of disruption:

Step One: Identify assets at risk of flooding

Obtain or create a map of the rail network running through the area at risk of flooding or the potential flood risk management benefit area. This should include the specific Train Operating Companies (TOCs) which run services on the affected part of the network. Information on the routes that each of the TOCs operate can be found on the National Rail website (http://www.nationalrail.co.uk/stations_destinations/maps.aspx).

Step Two: Determine the number of services impacted and/or the passenger journeys for the rail line at risk from flooding per 24-hour period

This information can be difficult to identify as the Office of Rail Regulation (ORR) only presents global annual passenger numbers for each of the rail companies for detailed assessment in their National Rail Trends Portal (ORR, 2013) (these averaged data are provided in Table 6.14). Therefore, it is necessary to approach each TOC operating on the rail lines within the appraisal area to refine these global passenger numbers and to identify the relative significance of the line.

Step Three: Estimate how many services will be cancelled and how many will be delayed

The Met Office research (Posford Duvivier et al., 2002) provides some benchmark data for delay and cancellation. This suggests using a 40/60 split for passenger train between delay and cancellation in this simplified algorithm.

Table 6.15 *Percentage delay/cancellation due to flooding (Posford Duvivier et al., 2002)*

Rail Service	Delay %	Cancellation %
Passenger service	40	60
Freight service	45	55

NB. This is Table 6.19 in the MCM 2013

Apply the relevant split from the table above to the number of services/passenger journeys per 24 hours which would be affected by flooding. An estimate of the likely length of a delay to a service is also required. This can be quite complex and we recommend discussions with Network Rail engineers to identify the average number of delay minutes that a service might suffer if a route is affected.

Step Four: Quantify the losses

Two methods are described below for quantifying these losses. The first relies on estimating how much compensation will be paid by Network Rail to TOCs and FOCs and therefore represents the additional costs due to flooding. The second method uses the Value of Time (VOT) approach adopted by the National Audit Office (Burr, 2008) in their investigation of rail delays.

Step Five: Convert the costs calculated per hour to annual average disruption

This requires an assessment of the depth and extent of flooding likely at different probabilities. Owing to the complexity and context-specific nature of the rail network it is preferable to undertake a site survey to understand fully the likely impacts of flooding and the likely length of a delay. Where this is undertaken, site-specific annual flooding probabilities should be applied. The inundation of areas around the track may also critically affect other assets such as signal infrastructure and affect the stability of embankments. Therefore, potential losses should be considered as soon as any Network Rail property is affected by flooding (including property assets; embankments; drainage; culverts; bridges; other crossings). These estimates can then be refined through discussion with local Network Rail route engineers.

In the absence of site-specific annual flooding probabilities (which are to be preferred) use road traffic return period disruption durations (Table 6.12). Disruption will escalate significantly as flooding becomes regional or if a key junction or station in the network is affected. Situations where widespread disruption occurs – and therefore where both rail response and repair teams and rail replacement infrastructure are stretched – are likely to have losses disproportionate to the sum of the aggregated flooding incidents. Therefore, disruption figures calculated using the approach presented here represent a minimum economic cost of disruption, relating to the separate flooding of individual floodplain areas and rail links, rather than all-region impacts.

QUANTIFYING DISRUPTION COSTS DUE TO SERVICE DELAY AND CANCELLATION

UTILISING NETWORK RAIL COMPENSATION PAYMENTS

This first method uses the compensation payments made to TOCs/FOCs by Network Rail to recompense for delayed or cancelled services. This utilises the average compensation costs that Network Rail pays to the TOCs under Schedules 4 and 8 of the Track Access Agreements. Standard costs set out in these agreements are assigned to the delay/cancellation depending on the type of route affected, the operator affected and the location of the incident; with the busiest routes allocated the highest weighting. Thus, a delay close to London in peak rush hour will be assigned a higher delay cost than, say, a delay in rural Wales. Indicative compensation values per delay minute and per cancelled service are provided in Table 6.16.

A low, medium and high value is provided for passenger services performance delays (per minute) and cancellations (per service) to account for the wide variation between TOCs and the lines impacted. These values could be used to provide a range of the potential losses due to rail disruption. Alternatively, it may be appropriate to select one of the values depending on the significance of the rail line within the assessment area. For instance, if a busy rail line (such as a main commuter route or east/west coast mainline) will be impacted the higher value should be applied. Conversely, if a less busy, rural route is within the assessment area the low value may be more appropriate.

A single indicative value for delay and cancellation for freight is provided, as these compensation values appear to be more constant. These values should be multiplied by the likely minutes of delay and estimated number of services impacted, to provide an approximation of the potential losses due to flooding.

A VALUE OF TIME APPROACH (VOT) TO QUANTIFYING THE LOSSES

Similar to the compensation approach, this method also calculates loss based on the number of delay minutes experienced. However, this approach utilises willingness-to-pay approaches presented by the New Approach to Transport Appraisal (NATA) (Department for Transport, 2011b). A monetary value is provided in Table 6.17 (based on willingness-to-pay surveys) for different types of transport user (e.g. commuter; business user and other) based on how much they would pay to avoid a travel delay.

These values can be used to approximate the costs of a delay to different passenger types and therefore to calculate the costs of travel disruption when multiplied by the length of any delay. If a local analysis is to be undertaken, data needs to be gathered on the proportions of the different types of passengers travelling per train which will vary by train line as well as the average number of passenger journeys per train (see Step 2 above).

Averaged data is available on these proportions for each TOC (Table 6.18) and a national and regional breakdown Table (6.19) by journey purpose is available here. Although these data can be used for a general assessment, specific lines and services may vary considerably in their composition and so a per railway line analysis should be undertaken where possible.

It is also possible to use average data for an approximation of the value of time costs of rail disruption. Burr (2008) utilised data from Department for Transport, Network Rail and the ORR to calculate the average number of passengers per train and an average estimation of the type of passenger split for all journeys throughout a week. This identified that an average train contained 14 business travellers, 95 commuters and 73 'other' passengers. They then applied these to the VOT figures for 2007 and calculated an average value of £73.47 for every minute a train is delayed. Applying the updated VOT figures in Table 6.17 provides an updated figure of £88.62 per delayed minute of a train.

Each of the methods above provides a slightly different estimate of the potential costs of disruption. The compensation payment method provides an estimate of disruption due to the delay of a service and is broadly related to the value of the fare being paid by a passenger. The second approach provides an estimate based on the value of time and attempts to quantify the inconvenience or lost work time caused by a delay or cancellation. Combining these estimates provides an upper estimate on the value of a disruption. This arguably includes some degree of double counting as the compensation value - which if reclaimed by affected passengers – does provide some recompense for their inconvenience, however may provide a closer estimate to the true costs of the disruption of rail services.

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6 Education and Health

Estimating the potential losses due to the flooding of Schools and Hospital Services

Schools

Estimating the potential losses due to the disruption of education in schools

OVERVIEW

This sub-section provides a methodology for assessing the potential losses owing to the flooding of schools. There is a high potential for schools to be affected by flooding. There is a high potential for schools to be impacted by flooding. HR Wallingford (2012) estimated that there are over 1,600 schools in areas of flood risk; 740 of which are at moderate or significant risk with over 200,000 enrolled pupils. The floods in 2007 had widespread impacts with schools in Kingston-upon-Hull and East Riding of Yorkshire being particularly badly affected with the total costs of the repair and replacement of school buildings being estimated at £12.2 million (Chatterton et al., 2010).

Direct damages occur due to the flooding of school buildings, the cost of temporary classroom accommodation and additional costs such as student counselling. The methodologies presented here to assess the potential losses caused by the disruption to education are based on estimating the likely number of pupil days lost due to the closure or part closure of a school. Estimates of losses are then based upon accounting for assessing the 'value' of those education days lost as well as any losses that may occur due to parents' absenteeism from work while they care for children who are unable to attend school.

LESSONS FROM EXPERIENCE

- A school does not have to be directly flooded to be impacted by flooding. Due to access issues (both by teachers and pupils) schools close to, as well as within, a benefit area should be considered within an appraisal.
- Schools are likely also to be closed due to the disruption to essential services such as electricity, water or waste water.
- It may proportional in most cases to enumerate the losses for those schools which are likely to be closed for more than two days. However, if there are several schools which suffer only minor flooding or disruption the cumulative losses at these multiple sites may be significant.
- The duration of disruption should be minimised by school or Local Authority contingency planning to source temporary or alternative classroom accommodation and therefore the maximum time a school is closed is estimated to be 5 days. After this period it is likely that alternative or temporary accommodation would be secured.

ESTIMATING DIRECT DAMAGE TO SCHOOLS

Readers are referred to Chapter 5 for guidance on accessing direct damages to schools.

Other direct costs which appraisers may need to include are the:

- Costs of additional temporary classrooms and/or other accommodation costs.
- Costs to the school/Council of added support services to pupils affected by flooding (e.g. the cost of additional counselling services).

These costs are difficult to estimate and will vary depending on the severity of the flooding experienced and the length of time pupils need to be taught elsewhere. Where available it is recommended that appraisers should use local estimates for the costs of mobile classrooms or alternative buildings.

There are some lessons however, that can be learnt from the experiences in Hull in 2007 where the average cost for classroom accommodation was £15,000 per school. This is calculated by taking the total alternative accommodation estimate of £700,000 (Chatterton et al., 2010) and dividing it by the 46 most severely impacted schools. However, in all likelihood the most severely affected three schools should be assigned a much higher proportion of these temporary accommodation costs. Despite this, this estimate does provide a starting point for appraisal and might be considered to be a minimum estimate.

An average cost of approximately £150 per pupil for additional counselling might also be adopted as a crude estimate. This is based upon the Chatterton et al. (2010) estimate of total additional costs of £514,000 spent in the Hull case in 2007 divided by the estimate of 3,000 pupils most directly impacted by flooding (Coulthard et al., 2007).

ESTIMATING LOSSES DUE TO THE CLOSURE OF A SCHOOL

Losses from a school closure may include:

- The loss of parents' earnings (or number of staff days lost) due to the need to take time off to care for dependent children.
- The value of the loss of a pupil's education.
- Additional travel costs to alternative schools or temporary school locations (this is very difficult to establish as it would require knowing the additional journeys of all pupils/staff).

An estimation of each of these losses is a function of the duration of closure and subsequent disruption to the school and assessment of the number of pupils affected (and in particular younger pupils).

The following steps should be followed to assess the disruption losses due to the flooding of schools:

Step One: Identify the location of schools within and close to the flood risk area

Schools directly adjacent to the flood risk area should also be considered within this process. These schools may be impacted by flood warnings, any emergency actions and transport problems. Assess whether there are alterative flood-free routes to access the schools. Use this information to create a shortlist of schools for consideration for appraisal.

Step Two: Identify the type of each of the schools on the shortlist and the number of pupils enrolled

Information about every school (including mapped schools, school type and numbers of pupils) is available within the Department of Education's Performance Tables (https://www.compare-school-performance.service.gov.uk/)[1] (Department of Education (DoE), 2022). Alternatively, the average figure for the number of pupils in a primary school in England is 267 and a secondary school is 1027 (DoE, 2022) and these may be used as indicative estimates, however actual values should be collected and used where possible.

Step Three: Assess the likely impact of flooding on each school under different flooding likelihoods

This assessment needs to focus on the severity of the impact and the duration. This should address the following questions:

- Will the school be directly flooded or is it only likely to be impacted by access issues?
- Is the entire school site impacted by flooding? Or would it be possible to continue to educate children in other school buildings once flood waters have receded and while buildings are being repaired?
- How long is the school likely to be closed or partially closed? Note that half of all schools affected in Hull were able to open after one week.

As described in the lessons from experience it may be appropriate and proportional only to enumerate the losses for those schools which are likely to be closed for more than two days. However, if there are several schools which suffer only minor flooding or disruption the cumulative losses at these multiple sites may be significant. The maximum disruption time for a school to be closed should be assessed at five days. After this period it would be expected that a school would be re-opened or alternative accommodation secured (whether in another location or temporary classrooms).

Step Four: Calculate the number of pupil days lost due to flooding for each school

This can be achieved by multiplying the number of pupils in each school likely to be impacted (i.e. this will be all pupils if the whole school is closed or only a proportion if a school is partially closed) by the number of days the school is likely to be impacted.

Step Five: Quantifying the value of the loss of education

The first loss to calculate is a value attributed to the loss of a day of education (Equation 6E&H.1). This step provides a minimum estimate of the value of the school days lost. It is based on estimating the equivalent daily costs to the Local Authority to educate a pupil as adopted by both the National Audit Office (2005) and Chatterton et al. (2010). Values of annual pupil expenditure for every school in England and Wales can be found at the Department of Education's Performance Tables (https://www.compare-school-performance.service.gov.uk/) (DoE, 2022) and/or via the Schools Financial Benchmarking data (https://schools-financial-benchmarking.service.gov.uk/).

[1] NB: The 2021-2022 data are the latest released by the Department of Education as of April 2023.

Alternatively, national averages can be used, which for 2021/2022[2] are calculated at £29.88 for primary schools and £32.98 for secondary schools per pupil per day, based on median values for all national (England) schools and 190 school days a year[3].

The following equation should be applied to all pupils irrespective of age.

Equation 6E&H.1

$$LD = PD * E$$

where:
LD is Estimate of the value of school days lost (£)
PD is Number of pupil days lost due to flooding
E is Average daily expenditure per pupil (£)

Step Six: Quantifying the paid productivity loss from parental absenteeism from work during the period of school closure

This second loss utilises estimates of the costs of parents missing work days due to the closure of school (based on Coulthard et al. (2007) and Sadique et al. (2008)). This method also utilises the estimate of the total pupils days lost due to closure; however we must adjust this value to account for various mitigating factors which reduce the overall number of pupil days lost due to flooding.

Firstly, not all school-age children will require supervision if a school is closed. Therefore, secondary schools should be excluded from an analysis of the parent work days lost as it would be expected that the majority of children at these schools would be able to remain at home without parental supervision. Schools which educate a mixed range of children should be included but only an appropriate percentage of the pupil affected days should be taken to represent primary-aged children.

Secondly, there is also the need to account for the following:

- The presence of siblings within a school population (i.e. to avoid double counting a parent's work days missed);
- That one parent may already be at home looking after younger siblings;
- That one parent may be unemployed;
- That some parents may choose to take annual leave (and therefore will not cause an economic loss);
- The fact that some parents may have alternative childcare arrangements (i.e. grandparents or childminders).

Indeed, the longer a school remains closed the increased likelihood that many parents will be able to find alternative arrangements and a reduction in the wider impact on the economy through work days lost.

[2] NB: As stated above the 2021/2022 data are the most recently released data as of April 2023. Averages have been calculated using combined financial benchmarking data for both Academies and Local Authority Maintained Schools (https://schools-financial-benchmarking.service.gov.uk/Help/DataSources). It is suggested that users check at time of appraisal for their school(s) of interest most up to date and specific data (https://www.find-school-performance-data.service.gov.uk/).
[3] NB: Data are also available for more specialist types of school such as Pupil Referral Units.

Sadique et al. (2008) provide a more in-depth and complex way of analysing the percentage of the workforce that would be impacted by a school closure. This approach may be adopted if a more comprehensive analysis is required. However, Coulthard et al. (2007) divides the number of pupil days by two to account for the presence of siblings at the same school. However, we suggest that this is insufficient to account for all of the conditions described above and therefore dividing by a factor of three is recommended here.

The following equation can be adopted to calculate the potential loss of work days due to the closure of a school.

Equation 6E&H.2

VL = (PPD / 3) * W

where:
VL is Value of loss (£)
PPD is Total number of primary age pupil days lost
W is Value of a day's wage (£)

There are various values which could be attributed to the loss of a working day and appraisers may wish to provide estimates based on local information about average wages. A minimum estimate might use the value of a day's wage lost at minimum wage or an average wage in the UK and current estimates are provided in Table 6.20. Economic values have been provided to give daily wage estimates net of income tax and National Insurance contributions.

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Hospitals

Estimating the potential losses due to the flooding of hospital services

OVERVIEW

The flooding of hospitals can have social widespread impacts. This section describes approaches to the assessment of potential losses including the direct impact of flooding on hospital buildings, as well as due to the disruption and/or cancellation of hospital services. In 2007 there were only two instances of direct flooding to hospitals reported. The 2007 floods highlighted the high interdependency of hospitals on other services (including power and water supply) and transport networks; all of which can be impacted by flooding.

Despite very minor direct damage being experienced, the flooding led to the cancellation of some hospital services with over 1,200 surgery operations and approximately 8,000 outpatient appointments being cancelled in Gloucestershire alone, primarily due to the disruption in water supply (Gloucestershire Hospitals, 2008).

It is therefore dependency and the interconnectivity of services which makes hospitals particularly susceptible to the impacts of flooding as disruption may not occur directly to the hospital site; but to one of the essential services. This dependency on external services and service providers which may be located off-site, coupled with the complexity of NHS funding arrangements, means that it can be extremely difficult to appraise any potential losses due to flooding. Therefore, the methodologies presented here include a qualitative description of potential losses as well as quantification. Quantification is proposed to estimate the potential losses due to the redundancy of a particular service or piece of equipment and utilises the cost of running that service as a proxy to loss. Additionally, in the cases where evacuation of patients will be necessary, appraisers should quantify the additional costs of transporting patients.

- A site survey and discussion with hospital managers is strongly recommended when appraising any hospital sites. This is due to the complexity and range of hospital services as well as the wide variation in hospital layout. It is likely that a hospital's administration will have investigated particular risks and identified potential contingencies which may assist in loss appraisal.

- Understanding the dependency (and redundancy in the system) of the hospital services is critical to a decision about whether a hospital needs to be investigated further and whether the potential flood related losses are significant. Hospitals close to, as well as within a benefit area, should therefore be considered for appraisal. Hospitals are likely also to be closed due to the disruption to essential services such as electricity, water or waste water and the knock-on impacts of traffic disruption.

- Assessing losses due to the closure/disruption of services is difficult as in some instances a closure of a facility will mean just a transfer within the NHS system (and therefore no net increase in cost) or even a reduction in overall running costs.

- In the absence of complex economic modelling, in many situations a qualitative description of the potential losses is recommended at least initially, to recognise and capture the complexity.

- One of the key elements is whether flooding will critically affect services, such as those for medical emergencies (e.g. Accident and Emergency and other critical care) as alternative provision will be necessary in these cases.

DIRECT DAMAGES TO HOSPITALS

The complexity of the layout of hospital buildings and assets means that a site survey is highly recommended to attribute both direct damages and disruption from losses. However, readers are referred to Chapter 5 for guidance on assessing direct damages to hospitals.

LOSSES DUE TO THE FLOODING OF HOSPITAL SERVICES

Hospitals are complex facilities to investigate. As discussed above they often comprise a number of buildings and/or sites and can have unique footprints. As well as being dependent upon the usual range of services and networks (i.e. electricity, water, sewerage, communications and transport) hospitals are also dependent on a range of other services which are critical to the running of a hospital and the continuity of care. These include amongst others: catering; waste disposal services; clinical waste disposal; laundry and various different stores services (including pharmaceutical, general stores, equipment, sterile goods). The situation is further complicated by the fact that in some instances these services are performed on site and directly by the NHS Trust and in other circumstances they rely upon external private-sector organisations and are located off-site.

In theory, there are a number of different ways in which the services of a hospital may be impacted, each of which may have economic cost implications. Some of these losses are direct in nature (such as the direct flooding of hospital infrastructure), whilst others are indirect (such as flooded roads leading to staff shortages and patients unable to reach their appointments). The total losses will also depend upon the scale of a closure (i.e. where a part or all of a hospital site is affected) and the duration of any impacts.

Potential losses/costs:

- Direct damage to the building and fabric of the hospital.
- Damage to equipment and the closure or wards and other facilities (operating theatres, scanners, etc.) due to the direct flooding of hospital buildings.
- Costs of evacuation/transfer of patients, to other hospitals or, in the case of some long-term care elderly patients to temporary alternative accommodation.
- Losses attributed to the redundancy of hospital infrastructure (e.g. scanners and other equipment which is not able to be used).
- Increased costs due to the transfer of services elsewhere (some of these may be transferred within the NHS and therefore only the increased cost should be included, whereas others may be provided by private hospitals).
- Increased staff and out-patient travel costs to alternative sites.
- Increased staff costs – if flooding prevents some staff from getting to work it is likely that agency staff may be required to cover positions, with an increased cost.
- Closure of wards/equipment and the cancellation of appointments due to staff shortages.

Assessing the losses to a hospital is in itself very complex. Although there will be social costs to individuals through the cancellation of services or operations and a general reduction in the total available hospital resources, quantifying these impacts is complicated. In some situations, for instance where acute care is closed (such as Accident and Emergency departments or emergency operations), other health care facilities will need to cover these activities and so the direct costs will be transferred to these providers. In the most part these costs remain within the NHS and so there may be little increase to the UK as a whole. Also, strictly speaking in the short-term the closure of a ward may lead to an overall reduction in the direct costs to a hospital trust as running costs will be avoided. The difficulty of assessing losses due to flooding is compounded by the complexities of the NHS funding. For instance, the cancellation of services may have longer-term implications for an NHS Trust as it may fail to reach performance targets; thereby affecting their next period's government funding. As a result however, a Strategic Health Authority or Primary Care Trust may choose to cover this shortfall, resulting in no net decrease in funding due to the flooding disruption. In addition, although hospitals may save money through a reduction in running costs, there may be many capital assets (such as scanners, theatres, etc.) lying idle and so there will be an overall loss to the country due to the non-operation of this equipment. It is this redundancy in equipment that we aim to quantify for closed or disrupted services.

Understanding the dependency (and redundancy in the system) of the hospital services is critical to a decision about whether a hospital needs to be investigated further and whether the potential flood-related losses are significant. This includes the size of the hospital and the likely numbers of patients impacted as well as the presence and location of alternative service providers.

One of the key elements is whether flooding will impact the NHS providing a service for emergencies (e.g. Accident and Emergency and other critical care), as these are the services which need to be maintained and transferred to alternative providers. Impacts are therefore proportional to those key services which are being provided as well as the transferability of those services.

The following illustrates the basic steps that might be followed in order to appraise losses to hospitals:

Step One: Identify the location of hospitals

Hospitals (and hospital services) located within the floodplain and close to the periphery of the floodplain need to be identified (as these may also be impacted if major transport routes are cut). It is strongly advised that this is undertaken in consultation with the Hospital Trust to fully understand the interdependencies of services as they are likely to have already identified critical infrastructure at risk.

Step Two: Assess the assets likely to be affected by flooding

For quantifying direct damages**,** identify the footprint of the hospital and those services at ground and basement level that may be impacted directly by flooding (i.e. number of wards and potentially numbers of beds impacted that may be closed at different flood return periods). Readers are then referred to Chapter 5 for guidance on assessing direct damages to hospitals. These data should be refined where possible through discussion with hospital authorities; especially if the hospital Present Value Damages (PVd) constitutes a significant proportion (e.g. greater than 10%) of the total potential losses.

Step Three: Assess the likelihood that wards will need to be closed

This should identify how many patients these wards care for and therefore the numbers that might need to be transferred to alternative hospital/nursing home/hospice providers (e.g. if there is some redundancy on site, some patients may be moved to unaffected areas).

Step Four: Estimation of losses due to care service closure

Where possible, enumerate the loss in value through the closure of a ward (i.e. the loss of bed space) or other service/facility. This method of enumeration utilises the average cost of that asset per day to the NHS. Although not strictly an economic loss; it can provide a proxy value for the loss of use of a particular asset.

Based on the level of care and staffing required, different NHS beds have different associated costs, examples of which can be found in Table 6.21. So for ward closures, identify the number of beds of a particular type that might be affected and utilise the following equation to estimate the costs due to the redundancy of beds. Where possible it is also preferable to divide the number of beds not able to be used between general and surgery and critical care as the costs are quite difficult.

Equation 6E&H.3

$$CR = N * CB$$

where:
CR is Costs due to the redundancy of beds (£)
N is Number of beds not available to be used
CB is Average cost per bed (divided if possible by the type of bed)

The same procedure can be applied if whole procedures or other out-patient procedures are cancelled. NHS Reference Cost information is provided annually and provides an average cost of a procedure in England and Wales. These can be accessed via the government's website (https://www.england.nhs.uk/national-cost-collection/) and if appropriate used to enumerate the cost of cancelled services. For instance, the average unit cost of Treatment in A and E in 2021-2022[4] is approximately £225, taking account of the numbers attending A and E and the total cost of treatment in A and E Departments. A figure such as this might be used to give a very approximate loss estimate to the closure of this emergency service if multiplied by the number of people usually treated over the period a service is likely to be closed.

Step Five: Patient Transportation Costs

If evacuation of patients would be necessary, quantify the transport costs of transferring the patients to alternative healthcare providers.

Equation 6E&H.4

$$CT = (P – BR) * CPT$$

where:
CT is Cost of transporting patients (£)
P is Number of patients to be evacuated
BR is Number of beds available elsewhere in the hospital (bed redundancy)
CPT is The average cost of a patient transfer (£)

[4] NB: From 2021/22 this is entitled Emergency Medicine Service in the National Cost Collection.

Some indicative values for the cost of patient transfers are provided in Table 6.22.

Step Six: Qualitatively investigate other impacts

Discuss with the Hospital Trust the likely effects of flooding on the continuity of services. The continuity of the following essential services needs to be included within the narrative:

- Electricity supply
- Water supply
- Sewerage services
- Laundry services
- Catering services
- Waste disposal services
- Clinical waste services
- Sterile services

In addition, investigate other aspects such as whether sufficient staff are able to access hospital buildings.

Step Seven: Identify what the hospital will do under different scenarios and how long disruption is likely to last

Learning from 2007 the likely impacts include:

- The closure of wards which are threatened with flooding
- The closure of Accident and Emergency services
- The cancellation of operations
- The pre-emptive cancellation of outpatients and cancellation of other non-urgent treatment

Broad annual statistics for hospitals in England and Wales can be found at NHS Digital (https://digital.nhs.uk/). This includes information such as the annual number of inpatients/outpatients, the numbers of hospital admissions and the total number of annual patient contacts. These can be used to calculate average daily contacts and be used to contextualise the level of likely disruption. Target and performance statistics (such as at how close to capacity a hospital runs) can also be used to understand broadly the level of redundancy in the system and the ability of the services to be transferred.

REFERENCES AND DATA SOURCES

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6 Local Authority, emergency services and recovery costs

OVERVIEW

Emergency and recovery costs during flood events such as autumn 2000 and summer 2007 are substantial, but not all these costs are allowable as contributing to the benefits of flood risk management schemes. This is for two reasons: a) some of these costs are covered elsewhere in the benefit assessment; b) some items, such as sandbagging, prevent damage in themselves, and project appraisals can assume that this damage does not therefore occur. For this reason, identifying and highlighting the costs related to emergency activity and recovery can be very difficult.

Flood-related expenditure varies between Local Authorities; depending on those assets which were affected by flooding. Overall, the most significant category of flood-related expenditure in 2007 was the cost of repair and reconstruction of infrastructure assets which accounted for close to three-quarters of Local Authority costs. Indeed the total recovery cost for the sixteen most affected Local Authorities was £194.3million.

These expenses included the considerable costs necessary to repair assets such as highways, schools and other council owned property.

LESSONS FROM EXPERIENCE

- There will be circumstances in project appraisals where the use of the standard data is not appropriate, or not considered accurate enough for project appraisal purposes;
- There are clear relations between flood emergency costs and the numbers of properties flooded. However, while this is interesting (and logical), it is not always sensible to use this approach for scaling purposes, not least because much of the emergency costs are spent in preventing property being flooded, such that it is perfectly possible for there to be substantial emergency services costs without any property being flooded at all;
- There is a difficulty in estimating marginal costs for many organisations as these can vary significantly. For instance, during the 2007 floods the expenditure for the sixteen most affected Local Authorities ranged from £2.2 million to £29 million.

TYPES OF COST

The benefits of flood risk management include reducing the costs incurred by a number of organisations in tackling flood incidents and in the recovery process. Depending upon the severity of the flood event, several emergency services may be involved in both emergency works and clean-up operations, during and after the flood event. Extra staff time and materials may be required, and additional administrative costs may be involved. Authorities and bodies providing emergency services include the following:

- local authorities;
- police authorities;
- fire services;
- ambulance operations;
- the Environment Agency/Natural Resources Wales;
- voluntary services; and
- the armed forces.

Care should be taken in this exercise to separate fixed costs from marginal costs. Local authorities and the Environment Agency have staff who are employed specifically to deal with emergencies, and a reduction in flooding will not necessarily lead to a reduction in these costs. Similarly, both the police and the fire authorities are themselves emergency services, and the reduction in flooding or coastal erosion would not necessarily reduce the costs to the nation of these services. Therefore, their fixed costs cannot legitimately be included within the benefits of flood risk management. Nevertheless, all these emergency services may incur extra costs as a result of particular flood events (marginal costs), which may be counted in the benefits of flood risk management.

STANDARD DATA

Organisations active in the flood management and recovery phases are allowed to recoup a proportion of their costs from central government under what is termed the Bellwin Scheme. This process insists that eligible expenditure be made 'on or in connection with the immediate action to protect life or property,' (HM Government 1989, Section 155). The system of thresholds is based on the judgement that prudent authorities should budget to cover a proportion of the costs of emergencies from their own reserves and resources. Annual guidance provided by the Ministry of Housing, Communities & Local Government describes the procedures and rules that Local Authorities must adhere to when claiming Bellwin assistance (DLUHC and MHCLG, 2023[1]).

Local authorities in England and Wales are also eligible to apply for financial aid from the European Union Solidarity Fund (EUSF) in the event of major natural disasters, including floods (Council of the European Union, 2002). The summer 2007 floods qualified as one of the forty-nine EUSF interventions since 2002, whereby €162.3 million was granted in aid to the United Kingdom (European Commission, 2013). Both the Bellwin claims data and the applications to the EUSF provide data from which to estimate the costs of emergency and recovery activities.

The approach adopted by the MCM has been derived from research taking the total emergency costs incurred by local authorities, the severe weather payments such as to Highway Authorities, and the Environment Agency's emergency costs and recovery, and allowing only those costs appropriate to project appraisals (i.e. deducting for betterment).

[1] NB: Guidance is provided when specific Bellwin Schemes are initiated and therefore guidance may be updated. Different guidance documents on the Bellwin Scheme are available for Scotland and Wales.

Expressing this amount as a percentage of the total economic property losses in Autumn 2000 gave a percentage of 10.7%. This, therefore, represents a multiplier on top of property damages that accounts adequately and appropriately for emergency costs and recovery.

The same approach was adopted for assessing the total emergency costs and recovery during the summer 2007 floods in England. The total emergency costs (Table 6.23) are £110 million, that is 5.6% of the total economic property losses.

The difference in terms of percentage between 2000 and 2007 floods may be explained by an effect of economy of scale. Indeed the 2007 summer floods affected a higher number of properties (up to 73,000 versus about 10,000 properties) but a lower number of Local Authorities claiming under the Bellwin scheme (38 versus 87 Local Authorities). In other words the figure obtained from autumn 2000 reflects dispersed flood affected communities whereas the figure obtained from the Summer 2007 floods reflects more densely populated communities.

The capped AAD (residential and non-residential) property values calculated in project appraisals of flood alleviation schemes should therefore be multiplied by a factor ranging between 1.107 and 1.056 to allow for the emergency and recovery costs that can be justified as real economic costs, not counted elsewhere in the benefit assessments. This figure should be applied for floods at all annual probabilities and for all scales of flood alleviation scheme, in the absence of better information. We recommend that the lower factor should be applied in urban areas to reflect economy of scale in emergency services.

SITE SPECIFIC ASSESSMENTS

There will be circumstances in project appraisals where the use of the standard data as given above is not appropriate, or not considered accurate enough for project appraisal purposes.

In this case, it will be necessary to collect data from the authorities relevant to the area in question. This is not easy, particularly in the absence of a recent flood, and care needs to be taken to ensure that fixed and marginal costs are separated, in order to identify just the latter for counting within project appraisals.

Notwithstanding the above comments, a standard checklist is provided in the Additional Resources for Chapter 6 on MCM-Online as a guide to obtaining these data.

Table 6.23 *Overall emergency costs as applicable to project appraisals (Summer 2007 Floods)*

Emergency costs applicable to project appraisals (based on Summer 2007 Floods - England)			
Cost item	**Amount**	**Allowed* amount (%)**	**Allowed amount**
Total Bellwin and roads:			
Bellwin	£30.20	42.5	£12.84
Roads infrastructure	£175.00	50	£87.50
Environment Agency costs+:			
Emergency repairs**	£14.80	50	£7.40
Emergency response	£2.20	100	£2.20
TOTAL	**£222.20**		**£109.94**
As % of economic property losses of £1,942m =			5.57%

* Judged to be proper economic costs, not counted elsewhere in Benefit-Cost Analyses. The figure for roads recognizes some betterment after repair (hence the 50% taken).
** As for roads, some element of betterment here, hence 50% taken.
+ England and Wales

Source: Chatterton *et al*. (2010).

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7 Coastal Erosion: Potential Losses and Benefits

7 Coastal Erosion: Potential Losses and Benefits

OVERVIEW

This chapter gives the procedures and techniques for assessing the potential benefits of investment in coastal erosion risk management. These benefits principally arise from delaying the processes of erosion, and thereby delaying the loss of land and property for the duration of the life of any proposed protection works.

Key points to understand are:

- Erosion is effectively permanent and irreversible;
- This means that future uses of that land or property are lost;
- Decisions about investment versus no investment must start from a realistic evaluation of the "do nothing" option.

Coast protection works, which are designed to arrest this process of erosion, normally have a finite life.

- Hence the benefit from a particular coast protection project should be seen as a temporary - but usually lengthy – extension to the useful life of the land and property protected;
- The most reasonable assumption thereafter is that the original long-term erosion rates as before will start again;
- Coast protection projects are compared with a 'do nothing' option. This 'do-nothing' option may involve 'walk-away' and hence the prospect of substantial erosion of coastal property (see the Environment Agency guidance on 'do nothing');

The approach to assessing these losses and benefits has not altered significantly since the MCM 2005. The changes here only comprise providing up-to-date data on average property annual rental values in the UK (Tables 7.3 and 7.4), where there have been some net reductions in these values since 2005 (then expressed as property prices). Given that, generally, there have been increases in the costs of coast protection works over this time, this means that it is now less likely than in 2005 that protecting property from loss to the sea will be economically viable.

Recent research and guidance "acknowledges that there is a likelihood of increased rates of depression and anxiety for people whose homes are at risk of erosion". Please refer to Environment Agency (2021) for carrying out the mental health impact of erosion assessment.

LESSONS FROM EXPERIENCE

- Flooding and erosion are often inextricably inter-linked; probabilities can become very complex to calculate;
- Unless they are very near the edge of cliffs, houses alone generally provide a poor base for the justification of major coastal risk management works;
- Accurate and realistic erosion rates and probabilities are the key to accurate benefit estimation;
- The prices of houses situated on the tops of cliffs do not accurately reflect their risk of falling into the sea and the loss of one person's view is another person's gain: the view itself is not lost;
- The environmental benefits of coastal risk management are mixed: some assets gain (e.g. eroding cliffs revealing important archaeological or geological sites), others involve losses (e.g. the loss of habitats for bird species);
- The recreation benefits of coastal risk management have been widely ignored and yet they are often a key reason for scheme implementation;
- Delay is a real option that should be considered seriously;
- A systematic comparison of investment versus no investment must start from a realistic evaluation of the "do nothing" option.

THE RECOMMENDED APPROACH

The recommended approach for assessing the benefits of coast protection is summarised in Figure 7.1. The key points about this approach are as follows:

1. Estimates are needed of erosion rates and cliff top edges projected for 50 or even 100 years into the future.

Alternatively, a probabilistic approach to erosion can be taken, resulting in a range of probabilities that a particular parcel of land or property will be eroded and therefore lose its use value.

2. A procedure is provided for evaluating the losses due to erosion, or the extension to the expected life and use of the property and land due to a delay in the erosion process resulting from investment in coastal risk management. Techniques are provided for finding the appropriate values for properties (residential and NRPs) whose market prices are likely to be affected by perceived erosion risk.

Figure 7.1 *Flow Chart of the assessment process*

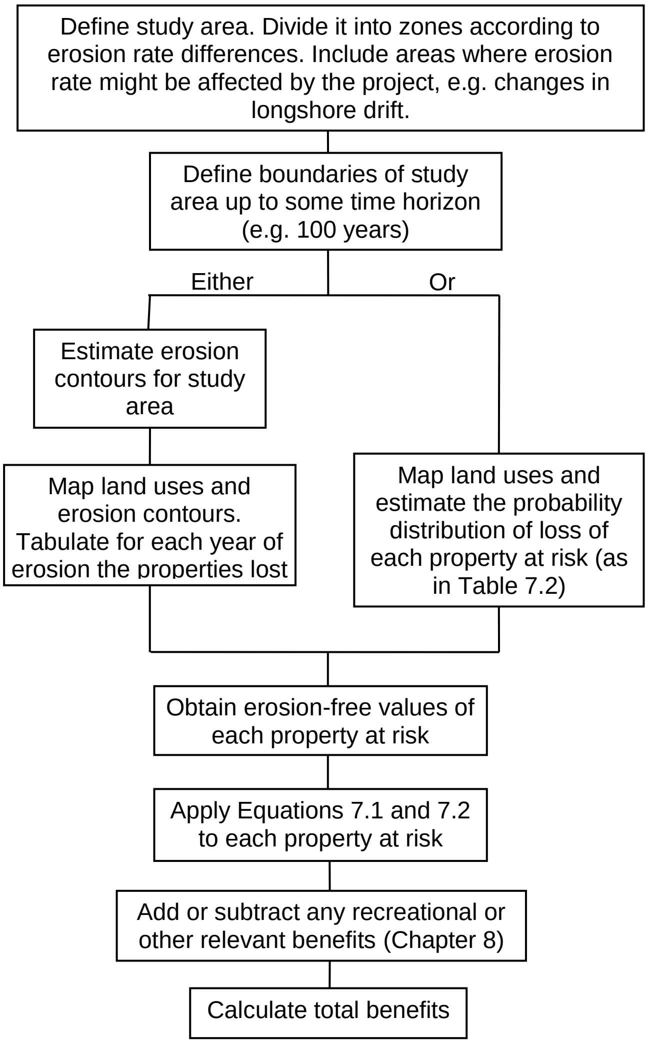

Table 7.1	Basic data for a hypothetical project to delay coastal erosion	
Property	**Value (£)**	**Mean year lost**
House A	80,000	4
House B	60,000	7
3 mobile homes	3,000	10
Public house	240,000	13
House C	120,000	16
House D	90,000	17

Table 7.2	A best estimate of the probability that house 'A' will be lost in any given year						
Year	0	1	2	3	4	5	6
Probability	0.05	0.1	0.15	0.2	0.35	0.1	0.05

Step One: Collect data on the study area's characteristics

EROSION RATES AND EROSION 'CONTOURS'

- Produce a set of predicted erosion 'contours' for the coastline in question, initially using, say, 5-year intervals, for at least the projected life of the proposed coastal protection works. Use smaller time intervals if erosion rates are particularly rapid;
- These erosion predictions will not be certain, and will need to be based on averages of the likely effects of storms of different magnitudes, and sensitivity analysis used to gauge the significance for benefit totals of the assumptions made here;
- For properties at risk from erosion there will be some minimum acceptable safety margin between the cliff top edge and the building: this is the point of erosion where the use of the property is assumed to be lost. Defra has recommended a 2-year margin.

CALCULATING BENEFITS BY ASSESSING THE PROBABILITIES OF EROSION

Since erosion is often episodic, with sudden losses of land and slides of cliffs, the use of erosion contour lines can be misleading whereby it is assumed that erosion will reach a certain point inland in a given year. Therefore, the use of a probabilistic approach should be considered, depending on the distribution of probabilities of cliff falls and hence losses over time.

Table 7.1 gives some data for a hypothetical project and Table 7.2 gives a best estimate of the probability that house "A" will be lost in any given year where the same probability function also applies to all the other properties. If it is assumed that the scheme has an engineering life of 20 years at which point it fails, then the present value of erosion benefits is £215,758.

If, instead, we assume that each property is lost in the year at which the probability of loss is the maximum (i.e. year 4 for house "A"), then the present value of erosion benefits is £205,000. So, in this case the probabilistic approach makes very little difference. However, where the distribution of probabilities (as in Table 7.2) is very asymmetric there can be much larger differences in calculated benefits.

The FCERM-AG economic appraisal spreadsheets use the probabilistic approach (see FCERM-AG supplementary guidance). If the probability of loss for a given property is set to 1.00 in a given year then the method can be used deterministically.

Step Two: Collect valuation data for properties at risk

THE IDEA OF BENEFIT AS A DELAYED LOSS

The benefit of coast protection works is an extension to the life of, or the delay in the loss of, erosion-prone property and land for a period of time equal to the life of the protection works (scheme life). This assumes that erosion after the end of the project's life would proceed at the same rate as it would have done without the project.

Thus a property that is predicted to be lost by erosion in 20 years' time without protection would, with effective coast protection works having a life of 50 years, be expected then to be lost in 70 years' time. Thus the benefits of coast protection are critically affected by the timing of the extension of the life of the property.

THE PROCEDURE FOR VALUING PROPERTY LIFE EXTENSION

The procedure recommended here for valuing erosion-prone properties, involves the following stages:

- Determine the erosion-free market value of similar properties in the local area: market-based property prices;
- Use the Equation 7.1 [see Step 3] to determine the present value of the use of that property up until the time when it is lost through erosion at current erosion rates;
- Use the Equation 7.2 [see Step 3] to determine the present value of the use of the property with the extended life provided by the coast protection scheme (i.e. the life as above plus the anticipated lifetime of the scheme).

EROSION-FREE PROPERTY PRICES

- The property and land prices required are market freehold values, not adjusted for erosion risk. Tables 7.3 and 7.4 provide data sets for values of the main types of dwelling found in this country. These values can be used in the equations below, but greater reliability may be achieved by obtaining values locally for the specific types of property to be affected by the project. Values used for residential property should reflect its location type – such as being near the sea – but it should be safe (i.e. based on properties which do not have an erosion risk);
- Defra (2004) provides guidance on distributional impacts in their interim guidance note.

LOCALLY APPROPRIATE PROPERTY PRICES CAN BE OBTAINED THROUGH:

- The Coast Protection Authority's own valuation department, if it has one;
- Local estate agents: use typical or average values for the type of property which ignore the risk of the properties being lost through erosion without a coast protection scheme also and ignore factors such as a sea view.

Table 7.3 *UK dwelling prices and average annual rental values by Region*

Region	New dwellings (Jan 22 - Dec 22) £	All dwellings price (Jan 22-Dec 22) £	Annual Average Rent (Feb 23) £
North East	242,360	156,539	7,548
North West	295,810	210,635	11,424
Yorkshire & Humberside	273,676	204,858	9,528
East Midlands	349,343	243,912	9,684
West Midlands	347,928	246,159	10,440
East	460,913	350,677	13,488
London	550,949	531,203	23,700
South East	475,519	389,589	14,796
South West	402,126	323,599	13,104
England	391,281	303,501	12,635
Northern Ireland	199,961	171,136	9,432
Scotland	279,274	187,456	10,068
Wales	298,815	214,241	9,600

Source: Gov.UK (https://www.gov.uk/government/statistical-data-sets/uk-house-price-index-data-downloads-february-2023 dwelling prices are calculated as an average over the 12 month period indicated); Homelet (Average rent: Feb 23: https://homelet.co.uk/homelet-rental-index)

Table 7.4 *Residential property prices and annual rent by dwelling type*

Average 2023 values by residential property type						
	Region	**Detached**	**Semi-detached**	**Terraced**	**Flat/ Maisonette**	**All**
Property price (£)	England	476,422	290,599	248,573	249,342	303,501
	Wales	328,364	207,697	167,380	134,881	214,241
	Scotland	337,643	199,755	159,005	128,049	187,456
Annual rent (£)	England	19,833	12,098	10,348	10,380	12,635
	Wales	14,714	9,307	7,500	6,044	9,600
	Scotland	18,134	10,729	8,540	6,877	10,068

Source: H.M. Land Registry (2023) https://homelet.co.uk/homelet-rental-index#Data
*Annual rent for each property type has been calculated as a proportion of the average annual rent (see Table 7.3)
Property prices from https://www.gov.uk/government/statistical-data-sets/uk-house-price-index-data-downloads-february-2023

Step Three: Perform the calculations

The two formulae identified in Step 2 are as follows:

Equation 7.1

PV (without scheme) = MV $(1 – 1 / (1 + r)^{p})$

Equation 7.2

PV (with scheme) = MV * $(1 – 1 / (1 + r)^{p+s})$

where:
PV is Present value
PV asset value = MV * $(1 - [1 / (1 + r)^{\text{year of loss}}])$,
where r = discount rate
PV is Asset loss = MV – PV asset value =
MV * $[1 / (1 + r)^{\text{year of loss}}]$
p = expected life of property with no coast protection project
s = expected life of the coast protection project

This amounts to:

PV benefit = PV asset value (with scheme) – PV asset value (without scheme) or PV benefit = PV asset losses (without scheme) – PV asset loses (with scheme)

Both calculations of PV benefit produce the same answer.

Step Four: Interpret the results

The benefit of carrying out the scheme is the difference between the two values of present value which represent the gain from ‘s’ years of equivalent annual benefit (‘s’ being the scheme’s effective life).

The procedure, very simply, involves the calculation of the discounted value of the property loss with coast protection less the discounted value of the same property loss without any proposed protection works.

The greater the life of the scheme the larger the benefit, but not proportionately, because losses further into the future are discounted more heavily than those incurred in the medium or short term.

The benefits calculated as above need to be compared with the costs of the scheme, both capital and maintenance. Costs in the future need to be discounted to present values.

- A ratio of benefit-cost greater than 1.0 indicates that the scheme is economically worthwhile;
- Delay in scheme implementation will increase the benefit-cost ratio, as the cliff edge gets nearer to the property, with erosion.

KEY POINTS WITHIN THE BENEFIT ASSESSMENT PROCESS

- Realistic erosion rates and probabilities are the key to accurate benefit estimation;
- Assessment of the effective life of any scheme is important to determine, with as much accuracy as possible, as this determines the delay of erosion and ‘drives’ the benefit calculations;
- The recreation benefits of coast protection (see Chapter 8) are often very large and can be a key reason for scheme implementation. They can be costly to assess (with site surveys), so caution is necessary here;
- All appraisals should be based on the existing properties at risk. No allowance should be made for new developments or possible regeneration of sea frontages.

REMAINING ISSUES

1. House value trends not covered here

Coastal risk management works are generally appraised for a long expected project life of perhaps 50 or even 100 years. Whilst general inflation over this time is ignored in benefit-cost analysis, potential changes in relative real prices are relevant (HM Treasury, 2022).

However, no conclusive reason and no reliable method for making future predictions of long-term house price or rental trends have been found. The standard approach of assuming constant relative prices is therefore recommended, for benefits and costs.

2. Other matters not covered here

The following are not covered here but are tackled in the full MCM:

- Infrastructure loss (promenades and associated structures);

- Infrastructure loss integral to properties at risk from erosion (gas; water; electricity; etc);
- Infrastructure lost that is serving areas not at risk from erosion at the same time (gas; water; electricity; etc);
- Valuing non built-up land: agricultural land and other open space.

SOME COMMON MISCONCEPTIONS

- Property and land must be protected at all cost;
- Decisions in the future about coast protection should reinforce planning decisions made in the past;
- A valuable promenade is a benefit if it is to be protected (even if it is falling down);
- There is no merit in delay;
- The sea will not win in the end.

SOME KEY LESSONS FROM EXPERIENCE

- Flooding and erosion are often inextricably interlinked; probabilities can become very complex to calculate;
- Market prices of houses situated on the tops of cliffs do not accurately reflect their risk of falling into the sea;
- Many people claim that the loss of a view from a property, if that property is lost due to erosion, is important. But the loss of one person's view is another person's gain: the view itself is not lost (so there is no economic loss);
- The environmental benefits of coast protection are mixed: some assets gain (e.g. eroding cliffs revealing important geological sites); others involve losses (e.g. the loss of habitats for birds);
- Delay is a real option that should be seriously considered.

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8 Recreational Gains and Losses

8 Recreational Gains and Losses

OVERVIEW

This chapter outlines the procedures and techniques for assessing the potential recreation and amenity benefits of – or losses from - coastal erosion or fluvial flood risk management. The term 'recreation benefits' covers benefits arising from the enjoyment of landscape, wildlife and natural amenities as well as from the enjoyment of recreational activities.

The approach to assessing these gains and losses has not altered in any way since 2010. The changes here only comprise providing up-dated data in Table 8.3: *£ gains and losses per adult visit with coastal protection scheme options at coastal sites* and Table 8.4: *£ value of losses and gains per visit for various changes at river sites* in Tables and Figures for Chapter 8 on MCM-Online. This up-dating has been done using the Office for National Statistics (ONS) Consumer Price Index (CPI).

LESSONS FROM EXPERIENCE

- Estimating the visit numbers or the number of beneficiaries deserves to be given as much attention as estimating valuations, and this has not always been the case in the past;
- The kind of visitors who visit 'natural' undeveloped coasts are different in some respects from those who go to developed sites. If coastal sites were to be changed radically to a more 'natural' condition, they might draw on a different constituency of visitors (making the new visit numbers difficult to determine);
- The public are generally supportive of measures to protect and defend the coast through major interventions such as seawalls and off-shore reefs;
- People who visit or live at the coast are reluctant to see natural erosive processes take their course at the coast and want the coast to continue to be maintained and defended as it had been in the past. This makes such options as 'managed realignment' or 'retreat' difficult to implement;
- The few river restoration studies, in contrast, show that residents are supportive of, and attach value to, works to restore rivers to a more natural condition, where the level of flood risk is not increased;
- Public responses to, and thus valuations of, options and structures at the coast, such as rock groynes vary from site to site in ways that are difficult to predict. This makes benefit transfer approaches problematic;
- The recreation benefit assessment methodology recommended here does not take into account new visits (as opposed to transferred visits) that may be generated among local residents or more widely. Nor is additional visiting by current users easily allowed for (again not transferred visits);
- Questionnaire surveys can make a valuable additional contribution to public consultation and participation on coastal and fluvial projects but early engagement is an ideal that may be difficult to achieve, not least because new options emerge within the appraisal period;

- Recreation and amenity changes are of vital public interest. There are few – if any - legal obligations in this respect on those promoting coastal and fluvial risk management, as opposed to the Water Framework Directive's strictures, but the issues still need very close attention.

ESTIMATING RECREATION BENEFITS

Recreation benefits are calculated by multiplying the £ value of a visit for recreational use (often a small number), derived using the Contingent Valuation (CV) method, by the number of visits or beneficiaries (often a large number). The crucial stage in estimating recreational benefits is usually the estimation of the number of visits or beneficiaries.

The CV method (see 'expressed preference' methods in Chapter 2) is essentially a questionnaire survey method in which respondents are asked directly in carefully designed survey questions to say what value they place on, or how much they would be willing to pay (WTP) for, a change in the availability of a resource such as beach or riverside recreation.

We have developed and tested a particular variant of the CV method, the value of enjoyment per adult visit (VOE) method. In this approach, respondents are asked to say what value they put on their enjoyment of a day's visit under varying options in £ and pence.

In the WTP approach, respondents are asked how much they would be willing to pay in entrance fees or in rates and taxes for a change in recreation opportunities/values such as provided by a coastal protection scheme. The advantages and disadvantages of the two approaches have been debated but in this Handbook and the associated MCM (Penning-Rowsell et al., 2013) the VOE approach remains the recommended method and the basis for the standard data presented here.

THE RECOMMENDED APPROACH AND TECHNIQUES

A two-stage framework for recreation benefit assessment is recommended. This involves:

- **An initial study stage** for initial examination of projects and for strategy studies. This will normally rely upon secondary source data and desktop methods. Table 8.1 presents a range of methods for estimating visit numbers. It is acceptable here to use standard values or data from existing CV studies and visit data. Data that can be used on visit numbers are presented in Table 8.2: *Examples of visit numbers used for benefit assessment purposes*. Table 8.3: *£ gains and losses per adult visit with coastal protection scheme options at coastal sites* gives data on losses and gains with various options at coastal sites, and for rivers in Table 8.4: *£ value of losses and gains per visit for various changes at river sites*. Using secondary source data on values and visit numbers in this way is, however, a very approximate approach;
- **The full detailed study** stage involving detailed site-specific information and data collection methods: site-specific counts of visit/visitor or resident numbers and a site specific CV survey to provide site-specific estimates of the value of recreation with the different scheme options. These surveys and count procedures are expensive and time-consuming activities to mount and manage.

In making the key decision as to whether or not to proceed to a feasibility study, it is recommended that a form of sensitivity analysis is undertaken using combinations of the highest and lowest appropriate estimates of visit numbers and £ value per visit (based on data in Tables 8.2-8.4) to obtain four annual recreation estimated benefit assessments.

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Then, the difference the four estimates make to the overall benefit-cost ratio for the scheme can be considered, to aid a decision as to whether it would be worth refining visit number estimates or valuations through site-specific data collection.

At both outline and detailed study stages it will be necessary to go through the same steps (see below) but at different levels of detail.

Step One: Define the problem and objectives

This is the definition of the nature and rate of coastal erosion or degradation or of coastal or fluvial flooding, and with it the geographical area affected: its length and breadth and its characteristics and the type of changes to the physical characteristics that are likely to take place in the future with the 'do nothing' situation.

Problems such as coastal erosion may be site-specific or may affect a more extensive area. Similarly, the problems affecting a river may be present in much of the catchment or may be site specific. It is essential in this way to consider problems and the options for dealing with them in their wider context.

Step Two: Identify adult recreation and amenity users or beneficiaries

Find out whether there is current or potential recreational use of the site and identify the range of recreational activities that are, or could be, undertaken there. Although children may be important users of the coasts and riversides, the benefit assessment methods apply to adult users or beneficiaries only.

Visitors can also be classified according to their origins:

- **Local visitors.** Those living within a three-mile radius of a site;
- **Day visitors.** Anyone starting and finishing their trip from their permanent home;
- **Staying visitors**. Anyone staying away from home for one or more nights.

Recreation benefit assessments can be refined by obtaining and using separate visit number and £ value per visit estimates for these different categories of user as presented in the *Checklist of recreational uses* and *Summary of possible effects of options on coastal and riverine recreation and amenity* available in the Additional Resources section for Chapter 8.

A crucial issue in both outline and detailed studies is to establish the level of use of the site in terms of the number of visits it receives or the number of those who benefit from recreation at the site. It is recommended that two or more of the methods presented in Table 8.1 should be used and that indirect methods (items 4-8) should only be used in initial study stages.

Table 8.1		Sources and methods of information on recreation users/beneficiaries
Source/ method		**Comments**
1	Long period counts using people counters	Infra-red or other counters installed over a period (at least March to September). Counters are manually calibrated to relate passages to adult visits. Mainly applied in detailed studies: in conjunction with a CV survey – see MCM, Section 8.5.3 (Penning-Rowsell et al., 2013).
2	Short period manual count /surveys	Manual counts/surveys over a period of days normally including the August Bank holiday. At initial stage, this method might be combined with site visits and at detailed study stage, with the CV survey.
3	CV survey data	CV survey data on the frequency of visiting by local residents in conjunction with census data on the number of adult residents and staying visitors (in conjunction with managers' estimates of occupancy rates) can be used to generate visit number estimates. However, the tendency of survey respondents to overstate their visiting frequency has to be noted - see the Corton Case Study in the MCM, Section 8.7 (Penning-Rowsell et al., 2013).
4	Old survey/ count data for the project	Planning, tourism or recreation departments of local authorities or local colleges or schools may have undertaken surveys or counts at the project site in the past, which can be updated to indicate current levels of use.
5	Inferred estimate	The number of visits to a coastal or river site is inferred from counts of visits to a related site nearby such as: Car and coach parks multiplied by the average adult car or coach occupancy rate (Hengistbury Head), funfair, cafe, visitor centre, historic site or museum (Hurst Spit and Hurst Spit castle). This requires estimating the proportion of all visitors to the project site who also use the counted site and vice versa. At detailed level, this can be done in conjunction with the CV survey.
6	Visitor equations	A number of equations have been developed which predicts-distance-frequency functions so that from census data on the population in different zones a prediction can be made as to the number of visitors generated by the site.
7	Estimates from an informed persons or source	Written, telephone or personal contacts with: Car park attendants, park rangers/wardens, visitor centre staff, staff at associated visitor attractions, local authority tourism, sport and recreation or planning staff, regional or local offices of organisations such as the English Tourist Board, National Trust or English Heritage and their Welsh equivalents, the Environment Agency's recreation and fisheries staff, managers of general recreation or staying visitor facilities or tourism business organisations that may have information on bedspaces and occupancy rates - see the Corton Case Study in the MCM, Section 8.7 (Penning-Rowsell et al., 2013); both commercial and club managers of specialist facilities (e.g. sailing, boating/sailboarding, fishing, birdwatching) and specialist organisations at national regional and local level for information on the availability of alternative sites e.g. for caravans or sailing.
8	Average number of visits to equivalent sites	This benefit transfer approach is only suitable for initial and strategic studies. The number of adult visits to the project site is estimated as being of the same order as the number of visits made to an equivalent site. However, there are few sites for which good data are available and little research to enable reliable identification of an equivalent site.

Step Three: Identify options

Identify the options for dealing with the problem and their likely impacts on the physical characteristics of the site as well as the 'Do nothing' option. Thus recreation benefits may have the following two components:

1. The prevention of further deterioration - losses with the 'Do nothing' option.
2. A reinstatement of the condition of the site from the current state to a better one – gains. For example, the replacement of hard river flood defence structures reaching the end of their life with soft engineered defences may enhance the recreational value of a river site. Beach nourishment for coastal protection purposes may result in a 'better' beach in recreational terms.

Step Four: Identify the recreation and amenity benefits

Identify the impacts on recreation and amenity of the changes to the physical environment resulting from the 'Do nothing' and the 'Do something' options.

This process will benefit from the participation of the recreational stakeholders, particularly at the initial stage. They may have particular insights into how changes will impact on their recreational enjoyment.

Step Five: Determine the annual recreation and amenity benefits

Annual recreation benefits. Step 5 involves first deriving estimates of the annual recreation benefits arising from the options and comparing the benefits for the options.

There are two components that have to be estimated:

1. The value that individual adult users or beneficiaries place on the changes that would occur with the options in place. These values will be derived from an application of the CV method using either the VOE per visit or the WTP approach.
2. The annual number of adult visits to the site (for the VOE approach) or beneficiaries who have an interest in the site (for the WTP approach).

The annual recreation benefits can then be determined as:

Equation 8.1

Annual benefits =
£ value of the options (VOE gains and/or losses) or (WTP valuations) * the number of visits per annum (VOE) or number of beneficiaries/ visitors (WTP)

Where the options involve both VOE losses and gains, the annual benefits should be calculated separately for the losses and the gains because these may need to be treated differently for discounting (see Total recreation benefits below).

National economic benefits and substitute sites. If changes to a particular coastal or river site simply transfer recreation from one site to another without any overall gains or losses in the value of recreational enjoyment, once travel costs have been taken into account, then no national gain or loss will be involved. The availability of substitute sites must therefore be considered when recreation benefits are being assessed.

Total recreation benefits. The total recreation benefits of a scheme are estimated by discounting the annual benefits over the life of the project using the recommended 'Green Book' discount rates. A different approach and separate calculations are required where there are annual benefits from both VOE losses and gains with the options, since gains become available on scheme completion whereas losses are likely to be incurred only after some years of site deterioration.

Losses under the 'Do nothing' option: VOE approach[1]

The following two equations should be used for estimating possible losses (or gains) under the 'Do nothing' option: some respondents may enjoy the site under the 'Do nothing' option more than the current site and therefore might gain.

Benefit for those who continue to visit:

Equation 8.2

$$L1 = Eo - E^1$$

Benefit for those who would visit an alternative site under the 'Do nothing' option:

Equation 8.3

$$L2 = (Eo - Ea) + (Ca - Co)$$

where:
L is The benefit per person (in cases 1 and 2)
Eo is The value of enjoyment of today's visit/ a visit in current conditions
E^1 is The value of a visit under the 'Do nothing' option
Ea is The value of a visit at the alternative site under the 'Do nothing' option
Co is The cost incurred visiting the present site
Ca is The cost incurred in visiting the alternative site under the 'Do nothing' option. The difference between Co and Ca is derived from a question in the questionnaire.

[1]These equations are explained more fully in the MCM (Penning-Rowsell et al., 2013)

Gains under the 'Do something' option formulae:
VOE approach

Two similar equations should be used for estimating possible gains (or losses) under the 'Do something' options: some respondents may enjoy the site less than the current site under the 'Do something' option, for example where there is a radical change in the appearance or recreational facilities with the option. Also they might wish to visit elsewhere instead.

Benefit for those who continue to visit:

Equation 8.4

G1 = Exn - Eo

Benefit - for those who would visit an alternative site under the 'Do something' option n:

Equation 8.5

G2 = (Eo - Ean) + (Can - Co)

where:
G is The benefit per person (in cases 1 and 2)
Eo is The value of enjoyment of today's visit/ a visit in current conditions
Exn is The value of a visit under the 'Do something' option n
Ean is The value of a visit at the alternative site visited under the 'Do something' option n
Co is The cost incurred visiting the current site
Can is The cost incurred in visiting the alternative site under the 'Do something' option n. The difference between Co and Ca is given by a question in the questionnaire.

Using these equations, the losses and gains should be calculated for each person in the survey and then the mean value should be calculated.

REMAINING ISSUES

- Estimating the visit numbers or the number of beneficiaries deserves to be given as much attention as estimating the VOE or WTP valuations. Shoreline Management Plans (SMPs) should be investigated for this data, and Catchment Flood Management Plans (CFMPs) may be sources for fluvial cases;
- Coastal studies indicate that the public are often reluctant to see natural processes take their course at the coast and may want the coast to continue to be maintained and defended as it had been in the past;
- Visitors who visit 'natural' undeveloped coasts are different in some respects from those who go to developed sites;
- Public responses to, and thus valuations of, options and structures at the coast such as rock groynes, vary from site to site in ways that are difficult to predict. Therefore, there is still a need for most schemes for site-specific CV surveys at detailed studies stage for both coastal and riverine sites;
- The few river restoration studies, in contrast, show that residents are supportive of, and attach value to, works to restore rivers to a more natural condition where the level of flood risk is not increased;
- The recommended methodology does not take into account new visits (as opposed to transferred visits) that may be generated among local residents or more widely. Nor is additional visiting by current users easily allowed for (again not transferred visits). Both are impossible to gauge without substantial databases or surveys. There may, therefore, be significant underestimating of the benefits of schemes which offer substantial improvements or attractive new facilities.

REFERENCES

Penning-Rowsell, E.C, Priest, S., Parker, D., Morris, J., Tunstall, S., Viavattene, C., Chatterton, J., Owen, D. (2013) Flood and Coastal Erosion Risk Management: A Manual for Economic Appraisal, London and New York, Routledge.

9 Appraisal of Flood Risk Management for Agriculture

9 Appraisal of Flood Risk Management for Agriculture

OVERVIEW

Flood risk management for farmland is an important element of support to the agricultural sector in Britain. Many floodplain and coastal areas benefit from publicly funded flood defence[1] and land drainage schemes that reduce flood damage and provide opportunities for productive farming (Morris, 1992).

Flood risk management (FRM) for agricultural land can facilitate agricultural production where otherwise it would be impeded – for the whole or for part of the year - by either saturated soils or surface inundation. Agricultural land may be lower than high tide or fluvial flood levels and FRM for agriculture protects these areas from regular flooding, in some cases assisted by pumping schemes. Sea defences can prevent inundation by sea water that can result in complete crop loss and reduced yields in subsequent years. Coastal protection may prevent agricultural land from being lost to the sea.

There is increased use of 'natural processes' and 'non-structural measures' to reduce flood risk in urban areas by retaining water in the general farmed landscape or temporarily storing it in floodplains (Environment Agency, 2018; Morris *et al.*, 2014; SEPA, 2015; cbec, 2017). Simultaneously there has been a drive to integrate FRM in rural areas with other objectives, such as nature conservation, soil protection, water quality improvement and recreation (Yorkshire Dales, 2017), often supported by an 'ecosystems' approach to the management of land and water resources (Posthumus *et al.*, 2010; Rouquette *et al.*, 2011).

The role of appraisal is mainly to determine whether it is worthwhile to provide a given standard of FRM for agriculture (Figure 9.1). This may involve comparing some existing or proposed standard with the 'do nothing' option, recognising that tolerance of flooding and associated damage costs vary considerably amongst land uses (Table 9.1). Appraisal may require a comparison of the financial and economic performance of agricultural land use under a range of different flood risk management regimes, and how these compare with the costs of delivering those options.

Where farming is impossible in the absence of flood defence, the advice is to estimate economic loss (and therefore the benefits of flood defence) in terms of the loss of the 'adjusted' market value of agricultural land.

[1]The terms flood 'defence' and 'protection' are often used in the agricultural case, reflecting the past focus on reducing flooding on agricultural land to enhance its productivity. The term 'flood risk management', however, is now more appropriate for the appraisal of the range of flood management options on farm land, including the intentional use of farmland for the temporary storage of flood waters.

The approaches needed for appraisal are:

- At a broad catchment scale, appraisals will at least require information on categories of land use, and the extent to which these might be affected by a change in flood frequency.
- At a detailed scheme appraisal level, there will be a need to collect primary data and undertake detailed analysis of farming systems, in proportion to the significance of agriculture within the scheme as a whole.
- Such detailed scheme level analysis is usually complex and is not detailed here. The MCM (Penning-Rowsell *et al*., 2013) has the complete coverage of this topic. Recommended methods have changed since the 2005 edition.

Concerns about global food security and the possible impacts of climate change have renewed interest in improving the productivity of British agriculture. Almost 60% of Grade 1 Agricultural Land in England is dependent on flood risk management and land drainage, including coastal defences and pumping infrastructure. However, for major flood events in the UK, agricultural losses tend to be a relatively small proportion of total damage costs. Flooding occurred on between 40,000 ha and 50,000 ha of farmland in different parts of the country in the 2007 summer floods in England and also in the winter 2013/14 floods England and Wales. In both cases 'on-farm' agricultural damage costs only accounted for about 3% of the estimated total economic costs of the event (Chatterton *et al*., 2010; Chatterton *et al.*, 2016). Agricultural flood costs may however be regionally concentrated: agricultural damage costs accounted for about 8% of total estimated economic costs attributed to flooding in Somerset during the long duration winter 2013/14 event.

The assessment of agricultural damage costs here is based on Chapter 9 of the MCM (Penning-Rowsell *et al*., 2013), which draws evidence from the 2007 (Posthumus *et al*., 2009) and 2012 floods (Morris and Brewin, 2013). The estimates here are also consistent with the type and magnitude of costs incurred in the winter 2013/14 floods in England and Wales (Chatterton *et al*., 2016).

For the purpose here, the estimates of damage costs contained in MCM 2013 and MCH 2013 have been updated to 2019 values using Defra Agricultural Price Indices (Defra, 2019) to reflect changes in agricultural output and input prices between 2013 and 2019[2]. For the most part, agricultural commodity prices in the UK are influenced by world market prices, moderated by UK£ exchange rates. During the period 2017-2019 some recovery of global demand and UK£ devaluation associated with EU exit returned UK agricultural output prices to levels that prevailed in the 2011-2013 period.

Adjustment factors applied here to convert UK 2013 prices used in MCM 2013 to 2019 values are 1.00 for all crop outputs and 0.98 for all livestock outputs. UK Agricultural all input prices are adjusted by a factor of 1.00 (consumables 0.98, non consumables – e.g. buildings and machinery 1.07). As a result, estimated agricultural flood damage costs in 2019 values are very similar to those contained in the MCM for 2013.

LESSONS FROM EXPERIENCE

- There is a close connection between the management of flood risk for agriculture and the management of agricultural land drainage as this affects the productivity of farm land. Managing flooding on farm land cannot be seen in isolation of managing waterlogging.

[2] For the purpose here, price adjustments are based on the reported differences in UK agricultural price indices between the three-year periods 2011-2013 and 2017-2019 (2015=100), including projections made in March 2019 for the remaining part of the 2019 year based on Defra (2019) and AHDB (2018) forecasts.

- The main factors affecting the costs of a flood event on agricultural land are the type of land use, and the seasonality and duration of flooding. Flood costs are much higher on arable land than on grassland, especially where high value salad, potatoes and other vegetable crops are damaged. Flooding in summer results in much higher damage than flooding in winter, especially on arable crops and grassland conserved for winter feed. Generally, the longer the period of flooding, the greater is the damage. Most arable crops and grassland can sustain short period winter flooding of less than one week duration, but yields may be affected. Longer floods have much greater impact.
- Over 80% of agricultural damage costs are associated with loss of production or additional production costs incurred. The remainder is associated with damage to property and equipment. Generally, production losses are not insured.
- At the individual farm scale, the bigger the proportion of the total farm area affected by flooding, the bigger is the likely impact on the farm business as a whole and the magnitude of costs incurred.
- Methods to assess the economic impacts of flooding on agricultural land can also be used to help appraise land-based flood risk management options involving 'natural processes' such as the retention of flood water in the general landscape, floodplain storage and conveyance, and the creation of wetlands.

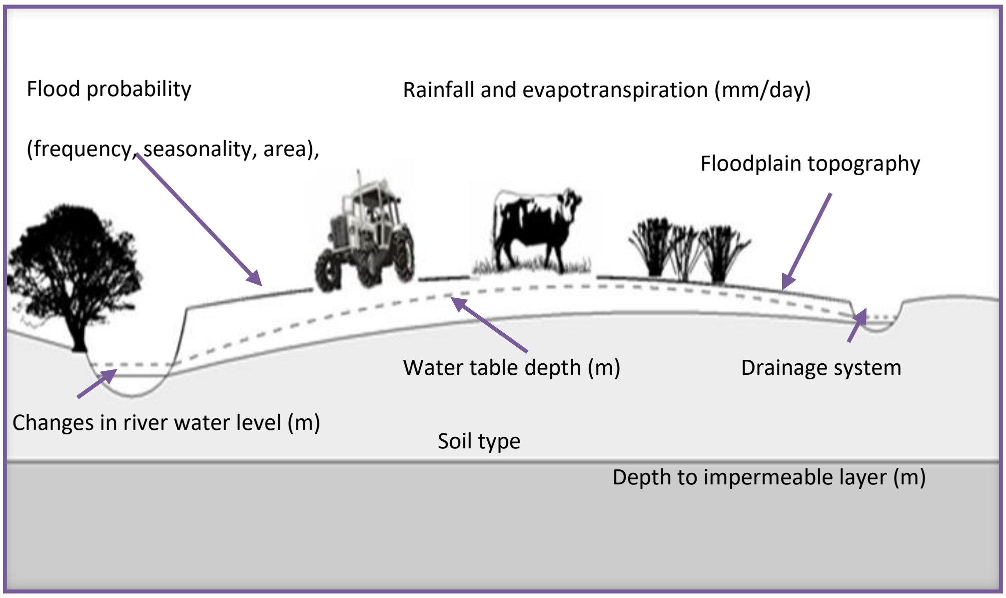

Figure 9.1 Flooding and drainage factors influencing agricultural productivity on floodplain

Table 9.1 Tolerance of flooding according to agricultural land use

Agricultural land use Type	Common minimum acceptable flood frequency: annual probability	
	Whole Year	Summer April-October
Horticulture	5%	1%
Intensive arable including sugar beet and potatoes	10%	4%
Extensive arable: cereals, beans, oil seeds	10%	10%
Intensive grass: improved grass, usually dairying	50%	20%
Extensive grass, usually cattle and sheep	≥100%	33%

METHOD FOR ASSESSING AGRICULTURAL BENEFITS

The principle behind this method is to establish the impact of flooding regimes on agriculture, and then to quantify those impacts as rigorously as possible. Three main steps are required to derive a monetary value of agricultural benefits under different flood risk management conditions. These are listed below.

The greatest detail will be required to assess changes in flood risk management standards for specific schemes on relatively intensively cropped land, including intensive grassland. Less detail is justified for broad scale or 'overview' assessments at the catchment scale.

Step One: Defining agricultural productivity

The first step identifies the total area that is liable to flooding, and hence the 'benefit area' of any flood risk management intervention. The second step determines land use classified into major crop and grassland types (Table 9.1) in order to estimate the likely consequences for the physical and financial performance of arable crops and grassland under different standards of flood risk. The third step assesses the likely soil 'drainage' conditions as determined by field water table levels during critical periods of the farming calendar and the consequences for agricultural productivity (Table 9.2). 'Bad' agricultural drainage, associated with 'sub-surface' flooding and waterlogging of soils, reduces yields and limits land use options. The cost of surface flooding on poorly drained soils is usually less than on well drained soils.

Table 9.2 Drainage conditions for agriculture and water levels in fields and ditches

Agricultural drainage condition	Agricultural productivity class	Depth to water table from surface	Spring time freeboards in water-courses (natural drainage)	Spring time freeboards in water-course (field drains)
Good: 'rarely wet'	Normal, no impediment imposed by drainage	0.5 m or more	1 m sands 1.3 m peats 2.1 m clays	1.2 m clays to 1.6 m sands (0.2 m below pipe outfall)
Bad: 'occasion-ally wet'	Low, reduced yields, reduced field access and grazing season	0.3 m to 0.49 m	0.7 m sands 1 m peats 1.9 m clays	Temporarily submerged pipe outfalls
Very bad: 'commonly or permanently wet'	Very low, severe constraints on land use, much reduced yields, field access and grazing season: mainly wet grassland	Less than 0.3 m	0.4 m sands 0.6 m peats 1 m clays	Permanently submerged pipe outfalls

- For **arable land**, estimates of crop yields can be obtained from farm surveys or from data on regional yields adjusted for local drainage conditions (See Table 9.3: *Common farming performance field drainage conditions (England and Wales)* in Tables and Figures for Chapter 9 on MCM-Online). Farmers are usually able to report the degree to which yields on poorly drained parts of their farm are lower than elsewhere;
- Assessing **grassland** productivity is more complicated, requiring information on type and age or weight of grazing livestock; livestock feeding regime; length of grazing season; liveweight gain or milk yield; and type and tonnage of conserved grass;
- Using data from secondary sources and from farm surveys in the benefit area, it is possible to estimate the productivity of grassland according to the type and number of livestock that can be carried per hectare (ha) under different drainage conditions – see Chapter 9, MCM (Penning-Rowsell *et al*., 2013).

Step Two: Defining the impacts of flooding

These can be distinguished in terms of:

- Frequency of occurrence (including the chance of multiple floods per year);
- Seasonality (especially the distinction between winter and summer floods);
- Duration (from a few days to one or more weeks);
- Depth (as this affects damage to crops and livestock).
- Water quality (including contamination, sedimentation and salinity);
- Soil damage (including compaction and erosion risk, loss of soil biota);
- Carryover effects (chance of crop recovery, impacts on yields in subsequent years).

Flood damage costs comprise damage to arable, grass and other crops, to livestock enterprises and ‘other’ impacts at the farm scale.

Flood costs for arable crops include:

- Loss of the value of output;
- Additional inputs less any savings in uncommitted costs, such as harvesting;
- Remedial work such as land restoration and re-sowing crops.

For grassland, the impact of a flood occurring in a given month is assessed in terms of the loss of animal feed. This is measured as the energy lost from grass (its calorific value) valued at substitute feed prices, less any savings in hay/silage making costs if relevant. Livestock costs include the cost of relocating and/or housing animals, increased morbidity/mortality and loss of sales. ‘Other’ costs include damage to field infrastructure (fencing, drains), utilities, machinery, buildings and contents, and the cost of clean-up (see Morris and Brewin, 2013).

The seasonal timing of flooding critically affects flood costs on farm land depending on land use. Summer floods are much more damaging than winter floods (see Table 9.4: *The Impacts of flooding on farm land vary according to type of agricultural land use and the seasonality of the flood event* in Tables and Figures for Chapter 9 on MCM-Online).

In the case of coastal saline flooding, yield losses on most crops are approximately 20% higher than losses due to freshwater flooding, except for potatoes and horticultural crops that would be completely lost. Planting a salt tolerant crop such as barley in the year following flooding may be required, with resultant loss in gross margin compared with normal cropping. Remedial application of gypsum to neutralise saline soils may be required. Coastal flooding tends to result in much higher livestock fatalities than fluvial flooding.

Step Three: Expressing any difference in monetary values

GROSS AND NET MARGINS

The monetary value of changes in flood risk management standards can be determined using the accounting conventions of gross margins, fixed costs and net margins, expressed either per hectare (ha) or for a farm as a whole.

The level of detail required depends on the purpose and context of the appraisal. Where the ‘do-nothing’ option involves write-off of agricultural assets, the appraisal can use the estimated reduction in land values as a basis for assessment (as explained below). In many other cases, it will be necessary to estimate the financial (to farmers) and economic (to the national economy) performance of agriculture under different flood management options using the conventions of gross and net margins.

Gross margins per hectare per year of crop or grassland based livestock activity (see Table 9.5 *Indicative Financial and Economic Gross Margins and Net Margins for Selected Crop and Livestock Enterprises and Systems* in Tables and Figures for Chapter 9 on MCM-Online) are used to measure the value of output less variable costs such as seeds, fertiliser and supplementary animal feed if appropriate. Variable costs are directly related to each unit of activity and can be avoided if that activity is not pursued – see Chapter 9, MCM (Penning-Rowsell *et al*., 2013). Gross margins show the monetary gain (or loss) associated with one more (or one less) unit of an activity, assuming other so-called 'fixed' resources available to the business, such as regular labour, machinery, buildings and land (and their associated costs) remain unchanged. Net margins provide an estimate of average annual profit after average fixed costs per ha are subtracted from gross margins.

Defra guidance for appraisal requires two main types of adjustment to financial estimates to derive economic values: namely, the removal of subsidies and allowance for 'displacement' effects. Adjustment to remove direct subsidies from crop and livestock gross margins is no longer required because, with a number of small exceptions, these direct subsidies no longer exist under the current EU Common Agricultural Policy (2013-2020) regime and since the UK exited the EU. Farmers receive income support in the form of annual 'Single Payments' that is not linked directly to (i.e. 'decoupled' from) crops or livestock production. Regarding displacement, Defra advise that persistent flooding of high value horticultural crops, field vegetables and potatoes, and commodities subject to quota such as sugar beet and dairy milk, would lead to the relocation of their production elsewhere, displacing wheat as the most common arable crop in the process. For this reason, areas of high value crops and dairying are treated as though they are a wheat crop in the economic analysis of permanent changes in FRM standards. This assumption may be moderated where the potential changes are large scale, of strategic importance, or where an area has a special comparative advantage that is not easily transferable.

The estimates in Table 9.5 are given in 2019 values using the adjustments explained earlier. Appraisals of FRM investments should take a long term view, allowing for possible future market and policy conditions. International forecasts (OECD/FAO, 2017) suggest that world agricultural commodity prices are likely to remain flat over the next decade or so in real terms, although there is a 'strong chance of at least one severe price swing in the next 10 years', with added uncertainty due to climate change

There is considerable agricultural policy uncertainty as a result of the UK Government's decision in 2016 to leave the European Community in 2019 (commonly referred to as Brexit), with possible consequences for the economic appraisal of FRM. The EU Common Agricultural Policy is the main mechanism for farm income support and for agri-environmental programmes that include measures supportive of natural FRM. Furthermore, withdrawal from the EU could significantly change patterns of agricultural trade and the prices received by farmers, especially due to competition from imports from outside the EU.

The UK Government has guaranteed that the current regime of agricultural support will remain within this parliament (up to 2024), changes beyond that date and the transition to a new funding framework will commence after this date. While the financial circumstances of farmers may change considerably as a result of changes in income support, the economic assessments made here are for the most part based on international prices of agricultural commodities and these may not change greatly. However, given the high level of uncertainty, it is advisable that appraisals should assess the extent to which FRM projects are likely to be vulnerable to policy changes associated with EU Exit. Estimates of financial and economic performance of farming, as well as incentives for agri-environment options, should be kept under review during the development of a FRM scheme (usefully reviewed in current editions of The John Nix Pocketbook (Redman, 2018).

The estimates contained in Tables 9.5 and 9.7 should be regarded as central estimates. They should be changed by plus and minus 25% to provide a range of low and high estimates respectively for use in sensitivity analysis.

SCENARIOS AND THEIR TREATMENT

Defra (2008) appraisal guidance identifies three scenarios which reflect the nature of changes in flood risk, namely:

- Scenario I: Permanent loss of agricultural land;
- Scenario II: One-off damages arising from infrequent flood events;
- Scenario III: A permanent change in flood risk management standards.

These scenarios justify different approaches and methods for the assessment of flood risk management benefits (see Table 9.6 *Defra advise that different assumptions are made for alternative agricultural flood defence scenarios* in Tables and Figures for Chapter 9 on MCM-Online). Regarding Scenario I, Defra advise that land permanently lost to agriculture should in most cases be valued at its market value (£11,000/ha - £14,000/ha for grazing land and £18,000/ha - £22,000/ha for arable land according to quality and region (Savills, 2018)) less £600/ha to reflect the subsidy effect of farm income support. After a period of firm prices, agricultural land prices are expected to fall slightly over the next 5 years (Savills, 2018).

Regarding Scenario II, estimates of flood costs will reflect the likely impacts on output loss, gross margins and other costs for a given land use. Table 9.7 (in Tables and Figures for Chapter 9 on MCM-Online) contains indicative estimates in 2019 values of the seasonally weighted cost of a single flood occurring in a year by land use and drainage condition.

Regarding Scenario III, the analysis is more complicated because there may be a change in land use and net margins (e.g. from arable cropping to grassland), a change in the costs of a given flood event (e.g. from flooding on arable to flooding on grassland), as well as a change in flood frequency (e.g. from 1 in 10 to 1 in 2 years). More details are given in Chapter 9 of MCM-Online.

Throughout the appraisal process, it is important to identify major sources of risk and uncertainty and the possible effect on benefit and cost estimates. It is advisable to derive a range of low, central and high estimates, with some assessment of relative likelihood, rather than any one single value estimate.

While this guidance generally applies, specific advice should, however, be sought from Defra for:

- High level strategic assessments;
- Large scale schemes of more than 10,000ha; and
- Agriculturally less-favoured areas where there could be significant impacts on vulnerable farming communities and local economies.

DATA NEEDS, SOURCES AND COLLECTION METHODS

It is advisable to start with an exploratory survey of the study area to define the geographical boundary of influence, that is the benefit area, and to determine current flood risk management standards and issues arising.

This ‘overview’ survey will also identify broad categories of land use, dominant farm types and systems, possible flood risk management options, the likely impact of these and the likely attitudes of key stakeholders, especially farmers.

Key informants will include:

- Staff with flood risk management interests in regional offices of the Environment Agency and Defra;
- Local Internal Drainage Boards if relevant;
- Representatives of farmer organisations (such as the National Farmers' Union);
- Local advisors and land agents;
- Environmental and conservation groups such as the local Wildlife Trusts, Farming and Wildlife Advisory Groups (FWAGs), River Trusts and National Parks;
- University Agricultural Economics and Agriculture Departments.

In most cases some form of farm survey will be needed, usually involving a sample of representative farmers that covers the major variations in farm circumstance (e.g. size, tenure, land type, flood risk), farm practices (e.g. enterprise mix, drainage improvements), and farmer characteristics (e.g. age, skills, preferences and motivation).

Those embarking on such a survey should refer to Chapter 9 of the MCM (Penning-Rowsell *et al*., 2013).

For agricultural enhancement schemes, the extent to which flooding and drainage currently constrain farming will be a focus of enquiry, together with the factors that are likely to encourage farmer take-up of potential benefits. Conversely, the scope for, and attitudes towards, reconciling flood storage, wildlife and farming interests will be a focus for wetland and washland development schemes, especially in the context of catchment flood management and shoreline management plans.

REMAINING ISSUES

- Leaving the European Union will impact on UK Agriculture and may affect the economic analysis considered here. However, as of April 2020, the Agriculture Bill is still with Parliament and the detail of the proposed Environmental Land Management Scheme (ELMS) is still being discussed;
- In line with government policy, appraisals in future will seek to integrate flood risk management with other rural land use objectives such as agriculture, nature conservation and other environmental objectives, including adaption to climate change;
- Farm surveys should be carried out by competent and experienced interviewers with knowledge of farm management systems;
- Flooding from estuarine and coastal sources results in greater impact and higher losses than freshwater flooding, and the land is likely to take longer for full production to be restored.

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10 Assessing Environmental Benefits and Costs

10 Assessing Environmental Benefits and Costs

OVERVIEW

This chapter discusses how to take account, in the appraisal of FCERM schemes, of their impact on the environment (both positive/benefits or negative/costs). This is an essential component of project appraisal (HM Treasury, 2022).

This appraisal should be:

- Approached positively to explore the case for flood and coastal erosion risk management schemes contributing to environmental improvement;
- Part of mainstream appraisal, both from the outset and throughout.

An appraisal should aim to assess all the costs and benefits, including those environmental costs and benefits which are not straightforward to value in monetary terms. The costs and benefits of goods and services that are not traded in markets must not be ignored just because they are more difficult to assess (e.g. nutrient capture or a breeding site for birds).

The approach to assessing these benefits and costs has not altered fundamentally since 2010. However, the Environment Agency's FCERM-AG guidance (Environment Agency, 2022) has more detail than was available previously from Defra on the use of Multi-Criteria Analysis (MCA) to derive inferred values for environmental goods and services, along with guidance on the use of Appraisal Summary Tables. A full-scale application of this use of MCA is given in the TE2100 Plan (Environment Agency, 2011a). Appraisers in England should also consult the supplementary guidance (Environment Agency, 2021) last update in November 2021 relating to environmental improvements (Outcome Measure 4).

LESSONS FROM EXPERIENCE

- A more comprehensive approach to decisions affecting the environment over a longer time-scale, which fulfil criteria for sustainable management of the environment, needs to take a more holistic, as opposed to a piecemeal, approach;
- It is not always possible to predict the impacts of a specific course of action on the environment;
- Stakeholder engagement can save time and resources spent on consideration of scheme designs which would have an unacceptable environmental impact;
- The 'acid test' question is now not one of how much of the environment to sacrifice in order to save money but how much we can afford to spend to enhance the environment;

- Some wildlife sites are now designated at a European level, and at these sites which are of international importance, environmental considerations can be given precedence over usual economic criteria in the initial appraisal;
- Only those criteria for which an internationally important site has been designated can be taken into account in the appropriate assessment;
- Environmental considerations may not be the same and there may be conflicts between the interests of different components of the environment or between maintaining current assets and processes;
- Existing environmental assets and current conditions may be highly significant but, in some circumstances, some loss may have to be accepted (for which a pass under the WFD Article 4.7 is required);
- European, National and local criteria for site importance should not necessarily be judged in the same way;
- A scheme design which is preferred on technical and economic grounds can often be modified to minimise adverse impacts on the environment without compromising its performance;
- Small schemes can be just as contentious as large ones and allowances for time in consultation exercises will not necessarily relate to the size of a scheme;
- Difficult choices cannot be made into simple ones by some technical sleight of hand; look for increased understanding through project appraisal rather than hoping that economic evaluation can of itself remove the difficulties.

WHAT TO VALUE, AND EXCEPTIONS

In principle, all environmental costs and benefits that can be valued in monetary terms should be included in the benefit-cost analysis. The only exceptions are:

1. When environmental valuation is likely to be very difficult (or disproportionately expensive), and when a sensitivity test has clearly shown that it would make no difference to the decision about what scheme/option to develop;

2. Where no meaningful monetary valuation is possible. In this case the environmental costs and benefits should still be fully described and taken account of outside the benefit-cost analysis, so as still to have a bearing on the overall appraisal. Multi-Criteria Analysis (MCA) provides a framework for this. Even if it is not feasible or practical to value all costs and benefits of a proposal, it is important to consider:

- How the scheme options differ in environmental terms; and
- How only these differences might be best described and possibly valued in money terms.

THE WATER FRAMEWORK DIRECTIVE (WFD): A VITAL AND OVER-RIDING CONSIDERATION

1. INTRODUCTION

The WFD is a European Directive which introduces a new strategic planning process designed to manage, protect and improve the water environment (Environment Agency, 2011b). The purpose of the WFD is to establish a framework for the protection of water bodies (including terrestrial ecosystems and wetlands directly dependent on them) which aims to:

- Prevent further deterioration;
- Enhance their status;
- Promote sustainable water use;
- Reduce pollution; and
- Mitigate the effects of floods and droughts.

In this context river basin management plans (RBMPs) are statutory plans for protecting and improving the water environment. They describe the main issues for the water environment within each river basin district. They tell us, at a local level, which measures the competent authority (the Environment Agency in England and Wales) and others need to implement to achieve the objectives of the WFD.

The WFD requires organisations such as the Environment Agency to aim to achieve good status or potential in all water bodies. For surface waters, this means:

- Good Ecological Status (GES) in water bodies; or
- Good Ecological Potential (GEP) in water bodies designated as Artificial or Heavily Modified Water Bodies (AWB/HMWB). And
- Good Chemical status.

2. GOOD ECOLOGICAL STATUS (GES)

Good Ecological Status is the WFD default objective for all water bodies and is defined as a slight variation from undisturbed natural conditions. This term includes both the hydrological and geomorphological characteristics that can support a healthy functioning aquatic ecosystem.

3. GOOD ECOLOGICAL POTENTIAL

Good Ecological Potential is the WFD objective for AWB/HMWBs and which are designated for a specific use, such as recreation, flood risk management, or urbanisation. Water bodies are designated as AWB/HMWBs when:

- The level of modification in these water bodies means the biological status is not able to achieve GES; and
- The use(s) for which the water body has been modified are still needed and cannot be achieved through “other means”.

The AWB/HMWB designation accepts that the biological status of the water body has been impacted by its modification and so the alternative objective of GEP is set: GEP is the best ecological status a AWB/HMWB can achieve without compromising the use for which it was designated. No WFD action can be taken on these water bodies which will have a significant adverse impact on its use. So a water body which has been designated as having a flood risk management use should maintain that use. Only when all the relevant mitigation measures have been put in place can a AWB/HMWB be said to have reached GEP.

4. ‘NO DETERIORATION’

The WFD includes an obligation to prevent deterioration in the overall status of water bodies, referred to as ‘no deterioration’. New activities such as flood risk management schemes could lead to deterioration. This may lead to a water body failing to meet its ecological objectives.

For new FCERM schemes any hydromorphological impacts need to be fully assessed to establish if they will:

- Cause deterioration; or
- Prevent the achievement of ecological objectives.

To do this a WFD assessment needs to be made, for which an eight-step process has been developed by the Environment Agency to help assess the compliance of new modifications with the WFD (Table 10.1).

5. ARTICLE 4.7 OF THE WFD5

Exceptionally, there may be situations where it is not possible for a scheme to be designed to prevent deterioration in ecological status/potential. Under these circumstances the project needs to satisfy the exemptions criteria set out in Article 4.7 of the Directive. These criteria are summarised below:

- All practicable steps or measures are taken to minimise the impact.
- The reasons for the modification are explained in the RBMP.
- The reasons for the modification are of overriding public interest and/or the benefits to human health, safety or sustainable development outweigh the benefits of achieving WFD objectives.
- The benefits of the modifications cannot be achieved by (an)other means (i.e. they are not technically feasible or are disproportionately costly).

Table 10.1 *An eight-step process to inform the compliance of new modification with the Water Framework Directive (Source: Environment Agency, 2011b)*

Step	Action
1	Collect up to date water body baseline data
2	Collect proposed scheme baseline data
3	Preliminary assessment
4	Design and options appraisal
5	Detailed impact assessment
6	Apply Article 4.7 tests
7	Reporting
8	Follow-up post-project appraisal work

THE ASSESSMENT OF IMPACTS

Proper assessment of environmental impacts (and meeting WFD requirements) depends on a structured and rigorous approach to appraisal, which should include the steps described in the Environment Agency’s project appraisal guidance: define; develop; compare; select and confirm. These are discussed below. For assessment at strategy, initial, and detailed study levels, see “Remaining Issues”; 6.

Step One: Define: problem definition and objectives

This stage should define the full range of FCERM options.

In all cases, the environmental consequences and objectives should be brought into the appraisal at the start. The most important aspect at this stage is an acknowledgement that avoiding environmental damage and achieving environmental gains are material considerations for scheme definition and objectives. They are just like any other category of benefit which may justify a flood or coastal erosion risk management scheme. In all cases, the relevant stakeholders (e.g. Natural England and English Heritage, or Natural Resources Wales and Cadw in Wales) should be contacted for their advice at this stage.

When considering environmental objectives, appraisers should identify:

- Any critical environmental criteria, such as meeting legal requirements and WFD imperatives;
- Any highly desirable objectives, such as meeting high level targets (e.g. the PSA target for SSSIs); and
- Any more general environmental outcomes that may be desired.

Step Two: Develop: preliminary appraisal

Having defined the FCERM options, a preliminary assessment should describe all the costs and benefits, including the positive and negative environmental impacts of all the alternatives.

When considering strategies and high level plans, a scheme's Strategic Environmental Assessment should help this task. The purpose here is not to attempt a monetary valuation or consider the balance of the costs and benefits (that comes later). But it is important here that descriptions of the effects are as clear and as quantified as practicable.

What needs describing (and later valued) is the change (positive or negative) brought about by the options being considered, not an overall valuation of all aspects of the environment. Both the costs (damages) and the benefits of the "Do nothing" option should always be fully appraised. One approach here is to use Total Economic Valuation (Turner, 2005) (see "Remaining Issues" section below; 1). This comprises both 'use' and 'non-use' values (e.g. carbon sequestration (a use value) and knowing that a wetland will be available for future generations (a non-use value). See also Table 10.2 for costs of environmental enhancement and mitigation.

The next task is a preliminary appraisal and eliminating those options that are definitely not feasible, while ensuring that options with environmental benefits are not ruled out. Only options clearly not meeting the critical criteria such as complying with legal requirements should be eliminated here. For example, a scheme having an adverse impact on a site designated under European Directives might be ruled out if there were an alternative solution not adversely affecting the site (see "Remaining Issues" section below; 2).

Care should be taken not to let appraisers' views or prejudices eliminate options that further analysis might justify. For example, until a realistic assessment is made of total benefits it might not be possible to say that the costs of a scheme with substantial environmental benefits, such as habitat creation, are disproportionate. Any grounds for ruling out options should be clearly reported. Appraisal Summary Tables may help structure this initial assessment to ensure that all environmental effects are captured (see the Environment Agency's FCERM-AG).

Step Three: Compare: identifying the preferred option

A more detailed appraisal should be made of the options that have not been eliminated in Step 2.

This should include a statement describing the environmental costs and benefits of options together with a monetary valuation of those impacts where possible, subject to the principles described above. Care and rigour in the appraisal process will be needed to ensure that all relevant effects are captured and double counting is avoided (see “Remaining Issues” section below; 3).

A sequential approach should be used to decide on the method for:

- Calculating a monetary value for an environmental cost or benefit, and
- Ensuring that any impacts which cannot be included in the benefit-cost analysis are taken into account.

Following the principles outlined above, impacts on the environment should be valued in the following way:

1. MARKET PRICES

Market prices, where available, should be used to establish a value for environmental benefits/costs. Establishing monetary valuations should be relatively straightforward where there is a market price. For example, if a managed re-alignment increases fish stocks this will have benefits to the local fishery, which can be valued.

However, many environmental goods and services do not have readily available market prices. In which case, alternative means of establishing values will need to be considered (see below).

2. VALUE TRANSFERS

In some cases, values from previous studies may be transferable. Care must be taken to allow for the fact that in differing circumstances values may vary, which may limit the validity of this approach. Where available, benefits functions should be used rather than unit benefits, as benefits functions can take into account important variables, which may differ from site to site (Brouwer et al., 1999).

As the number of valuation studies increases, the opportunity for drawing on their results should expand. If credible applicable values from previous studies are not available, plausible upper and lower bounds on values may be possible, helping to consider whether it is worth commissioning further work to establish more robust values.

Where there is no market price, or acceptable proxy or robust transfer value available, a scheme–specific study to establish values should be considered. Before undertaking this, an assessment should be made:

- To clarify whether the results are likely to affect the preferred option;
- To clarify whether a meaningful monetary valuation is likely from that study.

3. REPLACEMENT COSTS

This method is only to be used where a prior decision has been made to maintain or replace a feature, for either policy reasons, or to meet a statutory requirement. Then the cost of maintaining it in situ, relocating it or recreating it, whichever is the lower, can be used as a minimum value for the appraisal. However, this technique has limited applicability (see "Remaining Issues" section below).

4. WILLINGNESS TO PAY

Where none of the above methods is applicable, a new study should be considered to establish values by calculating people's willingness to pay for the proposed environmental enhancement. At this stage, appraisers with experience and competence in environmental valuation need to:

- Make a realistic assessment of the feasibility of such studies;
- Ensure that the values derived are credible.

The preferred method is to calculate the relevant population's willingness to pay as inferred by observing consumer behaviour (i.e. revealed preference using hedonic pricing). Where this is not feasible the alternatives are to ask people what they would be willing to pay for a particular benefit (stated preference) or identifying the compensation that they would require in order to accept a cost (willingness to accept) - see Chapter 10 of the MCM (Penning-Rowsell et al., 2013).

5. TAKING ACCOUNT OF ENVIRONMENTAL COSTS AND BENEFITS THAT HAVE NOT BEEN VALUED IN MONEY TERMS

At this stage of appraisal all the environmental costs and benefits of all the options should be described and those that can be valued should have been valued.

If all the effects were included (through monetary valuation) the preferred option should be revealed by the scheme meeting the Environment Agency's guidance on decision rules (FCERM-AG): see Chapter 3, both in the MCM Handbook and in the MCM (Penning-Rowsell et al., 2013). Any environmental costs and benefits that it has not been feasible to include will need to be clearly identified, because they may still influence the decision about which option to choose. Again, Appraisal Summary Tables can help here.

Where there are significant non-monetised costs and benefits, judgement will be needed as to whether they are sufficient to influence the preferred option. The most common framework for comparing unvalued costs and benefits is weighting and scoring (such as Multi-Criteria Analysis). This technique can help rank options taking account of both monetised and non-monetised costs and benefits.

Even if all the costs and benefits of an option cannot be valued, it is important to consider how the options differ and whether the difference can be valued. Switching analysis is one way of valuing the difference between options (see "Remaining Issues").

Step Four: Select and confirm: a rigorous appraisal of the preferred option

The final Step is a rigorous appraisal to determine whether the preferred option is justified in terms of the funding criteria. Much of the work for this should already have been done in Steps 2 and 3.

However, if a scheme has been chosen on the basis of benefits that have not been valued in money terms, extra consideration may need to be given to ensure that the non-monetised benefits justify the expenditure.

Table 10.2 The costs of environmental enhancement and mitigation
In the case of the protection of environmental assets, costs include:
Increased time for negotiation in the planning and design stages
Increased land-take for the project
Increased construction costs due to on-site mitigation measures during the operational stage
Management after construction
Monitoring and management adjustments
In the case of the replacement of environmental assets, costs should cover:
Land acquisition
Initial site survey/feasibility study
Background research including species and population studies
Removal and maintenance of plant species (ex-site conservation)
Seed bank creation from sources at site to be lost or damaged
Reintroduction
Habitat creation including physical factors (e.g. Hydrological and sediment regimes)
Habitat management/site wardening
Control of competitors
Monitoring: short, medium and long-term
Site safeguards
On-going advice to land managers
Publicity and public relations
With the creation of substitute sites as a replacement for what is being lost, the main costs should cover:
Land acquisition
Set-up costs
On-going management during the establishment stage
On-going monitoring
Subsequent adjustment of management regimes over several years, depending on habitat type

REMAINING ISSUES

1: Total economic value. The most comprehensive method of assessing the value of environmental impacts is to take a functional systems approach to establishing a total economic value for the effect that each option will have on the environment (i.e. the 'ecosystems services' it provides). In theory this should capture most (but not all) values and avoid double counting. However, there are a number of practical difficulties and some of these - but by no means all - are rooted in quantifying environmental risks and uncertainties.

2: Legal requirements. Schemes that are necessary to meet legal requirements may be assessed using cost effectiveness analysis. The benefits of meeting the legal requirements are assumed to outweigh the costs and hence the focus can be shifted to achieving these objectives at least cost. However, often other types of benefits will differ between options which aim to meet the objective, in which case it may still be necessary to identify, describe, quantify and monetise the benefits, to the extent that they materially affect the choice.

3: Avoiding double counting. Double counting is best avoided by recognising the impact pathway, the final impact on human welfare and the means of measuring this impact. For example, an environmental improvement that benefits anglers by improving fish nursery conditions and increasing fish stocks leading to higher catch rates should be evaluated via the change in the anglers' willingness to pay for these improvements. Other impacts such as increased fish size, increased bait sales, consequential tourism impacts etc. should already be reflected in this value, and separate estimations of these impacts would lead to double counting.

4: Replacement cost and its limitations. The replacement cost method as an appraisal valuation technique is contingent on there being a prior decision to maintain, replace or relocate the feature being valued (many of which would not be WFD compliant). What is then being assessed is the cost of complying with a policy/requirement and not the value of the feature (so these values cannot be used in benefit transfers). This is therefore not an acceptable measure of value where one is considering the merits of going beyond compliance with policy/statute or assessing the acceptability of an option that would lead to the loss of a feature, whether or not it is protected by statute. Where the preferred option is to relocate or replace a feature, this method of valuation may not capture some potentially significant costs (dis-benefits), such as loss of local amenity or historical significance: these effects will need to be considered separately.

5: Switching analysis. Consider two alternative schemes A and B. The whole-life cost of A is £10m compared to £8m for B, but A has significant additional environmental benefits. These environmental benefits would need to be at least £2m for B to be preferable to A. Some 5,000 people live in the affected area, who might benefit from these environmental improvements. Each beneficiary would need to be willing to pay £400 for these benefits to be sufficient to alter the choice based on the whole life costs.

6. Levels of assessment: strategy, initial, and detailed studies. To avoid disproportionate time and resources being spent on environmental benefit assessments, such as inappropriate use of willingness-to-pay surveys, questions need to be asked at strategy and initial stages:

- Is there an environmental concern significant enough to warrant such time and resources in assessment?; And
- Is option choice likely to hinge on the environment issues to be tackled?

If appraisers have evidence that impacts are significant, then more consideration of them should take place at the initial and detailed study stages, exploring any concerns confirmed at strategy or overview stages. There will normally be a pressing need for assessment at initial stages, although at detailed study levels the need may vary on a case-by-case basis, depending again on the size of environmental impacts identified at the relevant location.

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TABLES AND FIGURES

4 Residential Properties

Tables and figures

Table 4.1 Categories of flood water

Category of Water	Description
Major clean/grey (IICRC Category 2)	Water contains significant contamination and can contain potentially unsafe levels of microorganisms or nutrients for microorganisms, as well as other organic or inorganic matter: commonly discharge from washing machines, dishwashers or toilet overflows (not including faeces).
Minor black (IICRC category 3)	Water is grossly contaminated: As 'Major clean/grey', but includes sewage backflow scenarios from an internal source where water may contain faeces, urine and other waste through toilet discharge system.
Major flood/storm (IICRC category 3)	Water is grossly contaminated: This is the most common category for a typical fluvial, surface water or coastal flood scenario. Water may contain: organic matter, pesticides, heavy metals or toxic organic substances.
Major Flood including sewage (IICRC category 3)	Water is grossly contaminated: As 'Major flood/storm', but with the inclusion of animal and human waste materials.
Major Flood 'Contaminated' (IICRC Special situations)	Water may contain regulated hazardous waste (as per Technical Guidance WM2, see: https://www.gov.uk/how-to-classify-different-types-of-waste), including (but not limited to): asbestos, heavy metals, pesticides, solvents, caustic chemicals etc.

Adapted from: Institute of Inspection, Cleaning and Restoration Certification (IICRC) (2006) S500: Standard and Reference Guide for Professional Water Damage Restoration. 3rd edn, IICRC: Washington DC.

Table 4.2 The range of possible flood impacts on households (not exhaustive or necessarily mutually exclusive)

Direct Tangible Losses For Flooded Households	Intangible Losses On Flooded Households	Indirect Losses On Flooded Households	Indirect Losses For Non-Flooded Households
➢ Damage to building fabric	➢ Worry about future flooding	➢ Permanent evacuation from area	➢ Increased travel costs
➢ Damage to household inventory items	➢ Loss of memorabilia and irreplaceable items and pets	➢ Disruption to household due to flood damage	➢ Loss of income/earnings
➢ Clean-up costs	➢ Damage to physical and/or mental health, death or injury	➢ Temporary evacuation costs	➢ Loss of utility services
	➢ Loss of community	➢ Disruption due to flood warnings or alarms	➢ Loss of other services
	➢ Loss of confidence in authorities and services	➢ Loss of utility services	➢ Loss of leisure and recreational opportunities
		➢ Loss of income/earnings	➢ Increased cost of shopping and recreational opportunities
		➢ Loss of leisure and recreational opportunities	
		➢ Additional communication costs	
		➢ Loss of services	
		➢ Increased travel costs	
		➢ Increased cost of shopping and recreational opportunities	

Tables 4.3 Social grade categorisation and weighted factor by occupation

Social Group	Description	Weighted Factor
AB	Upper middle and middle class: higher and intermediate managerial, administrative or professional	0.74
C1	Lower middle class: supervisory or clerical and junior managerial, administrative or professional	1.12
C2	Skilled working class: skilled manual workers	1.22
DE	Working class and those at the lowest level of subsistence: semi-skilled and unskilled manual workers. Unemployed and those with no other earnings (e.g. state pensioners)	1.64

Table 4.4 Types of project appraisals (2023 values)

Overview, Initial and Full-Scale methods			
Scale of analysis	**Overview**	**Initial**	**Full-Scale**
Guidance	For rapid MDSF and similar desktop type appraisals: first approximations to identify areas where more detailed work is required	For more detailed appraisals where further assessment of household loss potential is warranted	For the detailed study of potential benefits using the most detailed of the standard data sets
Data requirements for the benefitting area	Number of properties at risk	Number, type and age of house at risk	Number, type, age and social class of houses and householders at risk
		Standard of protection (pre and post scheme for intangible values)	Standard of protection (pre and post scheme for intangible values)
			Government Weighting Factors for distributional impact analysis
Direct/tangible method of assessment	Annual average direct damages: sector average	Generalised standard residential depth/damage data for type and age of houses	Additional data for type, age and social grade of houses and householders
	Vehicle Damages: 42% of total properties damaged x £5,600 (2021 value)	Vehicle Damages: number of properties at risk above 0.39m x £6,944 (2022 value)	Vehicle Damages: number of vehicles at risk above 0.39m x £5,600 (2021 value)
Intangible method of assessment	Health: £279 per property per year for intangibles	Health: Defra's intangibles matrix	Health: Defra's intangibles matrix
Indirect method of assessment	Evacuation per household: temporary accommodation costs (£1,370) plus alternative accommodation costs (£3,921)	Evacuation per household: evacuation costs per property type and flood depth	Evacuation per household: survey on percentage of households evacuated and duration of evacuation. Evacuation costs per property type and flood depth
Vulnerability Analysis	Not required	Where feasible	Where feasible

Table 4.5 Weighted Annual Average Damages (WAAD) (2023 values) assuming variable threshold Standards of Protection (SoP)

Existing SoP	No warning (£)	<8 hour warning (£)	>8 hour warning (£)
No protection	5,269	5,227	5,215
2 years	5,269	5,227	5,215
5 years	3,163	3,136	3,129
10 years	1,615	1,602	1,597
25 years	772	766	764
50 years	326	324	323
100 years	82	81	81
200 years	41	40	40

Table 4.6 Estimate of the number of properties affected by different floods

Return Period	No. Of properties as % of 200 year No.
100	93
50	80
25	25
10	10
5	5

Table 4.7 Intangible benefits associated with flood risk management improvements (2023 values)

Standard of Protection After – AFP (RP in years)										
Standard of protection before – AFP (RP in years)			**0.007**	**0.008**	**0.01**	**0.013**	**0.02**	**0.033**	**0.05**	**0.1**
			-150	**-125**	**-100**	**-75**	**-50**	**-30**	**-20**	**-10**
	1	**-1**	£348	£343	£319	£244	£117	£40	£19	£8
	0.1	**-10**	£342	£336	£312	£236	£108	£34	£13	£0
	0.05	**-20**	£328	£322	£301	£225	£96	£21	£0	-
	0.033	**-30**	£308	£302	£279	£204	£75	£0	-	-
	0.02	**-50**	£231	£226	£202	£128	£0	-	-	-
	0.013	**-75**	£104	£99	£75	£0	-	-	-	-
	0.01	**-100**	£29	£24	£0	-	-	-	-	-
	0.008	**-125**	£6	£0	-	-	-	-	-	-

AFP = Annual Flood Probability
RP = Return Period
Annual Benefits = Damages (before) - Damages (after)

Source: Department for Environment, Food and Rural Affairs (Defra) (2004) Flood and Coastal Defence Project Appraisal Guidance. FCDPAG3 Revisions to Economic Appraisal on Reflecting Socio-economic Equity in Appraisal and Appraisal of Human Related Intangible Impacts of Flooding. Supplementary Note to Operating Authorities. July 2004. Defra: London.

Table 4.8 The probability of evacuation and duration in relation to flood depth

Maximum depth in house (cm)	% who evacuated	Mean duration of evacuation in weeks
0	23	11
1-10	41	12
10-20	55	18
20-30	59	18
30-60	69	21
60-100	76	23
100+	87	33

Table 4.9 Regional Residential House Prices (2023)

Region/Country	All residential	Detached	Semi detached	Terrace	Flat
England	£306,342	£481,808	£293,476	£250,990	£250,389
Scotland	£187,598	£338,051	£200,118	£159,369	£127,903
Wales	£216,132	£331,598	£209,566	£168,820	£135,457
Northern Ireland	£173,029	£265,704	£166,999	£120,552	£127,697
North East	£158,478	£274,032	£161,714	£128,171	£100,819
North West	£212,796	£371,243	£227,696	£164,421	£144,007
Yorkshire & Humberside	£206,592	£340,102	£207,109	£163,447	£134,167
West Midlands	£249,329	£416,008	£244,947	£197,608	£146,421
East Midlands	£246,949	£365,853	£228,082	£185,934	£133,664
East of England	£353,609	£549,474	£364,658	£297,209	£211,661
South West	£326,572	£521,200	£336,849	£274,487	£193,596
South East	£392,999	£699,874	£427,207	£332,516	£226,265
London	£533,816	£1,092,820	£693,136	£586,323	£441,474

Source: https://landregistry.data.gov.uk/app/ukhpi/ (March 2022 - February 2023 average value)

5 Non-Residential properties

Tables and figures

Table 5.1 Matching NRD (MCM) codes to the latest MCM code

NRD MCM code	Description	MCM Code	Property type
2	**Retail**	**2**	**Retail**
21	Shop/Store (Weighted mean)		
211	(High Street) Shop		
213	Superstore/Hypermarket		
214	Retail Warehouse		
215	Showroom		
216	Kiosk		
217	Outdoor market		
218	Indoor Market		
22	Vehicle Services (Weighted mean)		
221	Vehicle Repair Garage		
222	Petrol Filling Station		
223	Car Showroom		
224	Plant Hire		
23	Retail Services (Weighted mean)		
231	Hairdressing Salon		
232	Betting Shop		
233	Laundrette		
234	Pub/Social club/wine bar		
235	Restaurant		
236	Café/Food Court		
237	Post Office		
238	Garden Centre		
3	**Offices**	**3**	**Offices**
310	Offices (non specific)		
311	Computer Centres (Hi-Tech)		
320	Bank		
4	**Distribution/logistics**	**4**	**Warehouses**
410	Warehouse		
411	Electrical w/h		
412	Ambient goods w/h		
413	Frozen goods w/h		
420	Land Used for Storage		
430	Road Haulage		
5	**Leisure and Sport**	**NOT APPLICABLE - CONSTITUENT CATEGORIES TOO DIVERSE**	
51	**Leisure (Weighted mean)**	51	Leisure
511	Hotel		
512	Boarding House		

513	Caravan Mobile	Due to a change in Environment Agency guidance, readers should no longer apply the MCM damage value for caravan sites. Please see the following document for further information: **Environment Agency (2008) Economic evaluation of damages for Flood Risk Management projects, Environment Agency, Bristol**	
514	Caravan Static		
515	Self catering Unit	51	Leisure
516	Hostel (including prisons)		
517	Bingo hall		
518	Theatre/Cinema		
519	Beach Hut		
52	**Sport (Weighted mean)**	**NOT APPLICABLE - CONSTITUENT CATEGORIES TOO DIVERSE**	
521	Sports Grounds and Playing Fields	521	Playing Field
522	Golf Courses	521	Playing Field
523	Sports and Leisure centres	523	Sports Centre
524	Amusement Arcade/Park	523	Sports Centre
525	Football Ground and Stadia	525	Sports Stadium
526	Mooring/Wharf/Marina	526	Marina
527	Swimming Pool	523	Sports Centre
6	**Public Buildings**	**6**	**Public Buildings**
610	School/College/University/Nursery		
620	Surgery/Health Centre		
625	Residential Home		
630	Community Centres/Halls		
640	Library		
650	Fire/Ambulance station		
651	Police Station		
660	Hospital		
670	Museum		
680	Law court		
690	Church		
8	**Industry**	**8**	**Industry**
810	Workshop		
820	Factory/Works/Mill		
830	Extractive/heavy Industry		
840	Sewage treatment works		
850	Laboratory		
9	**Miscellaneous**	**NOT APPLICABLE - CONSTITUENT CATEGORIES TOO DIVERSE**	
910	Car Park	910	Car park
920	Public Convenience	NOT CURRENTLY AVAILABLE	
930	Cemetery/Crematorium	NOT CURRENTLY AVAILABLE	
940	Bus Station	NOT CURRENTLY AVAILABLE	
950	Dock Hereditament	526	Marina
960	Electricity Hereditament	960	Electricity sub-station

Table 5.2 Indicative floor sizes for NRPs

New MCM Code	Property Type	Floor Area (m²)
2	Retail	340
3	Offices	360
4	Warehouses	3,270
5	Leisure and sports	NA
51	Leisure	1,020
52	Sports	NA
521	Playing Field	21,850
523	Sports Centre	5,400
526	Marina	1,860
525	Sports Stadium	25,600
6	Public Buildings	1,300
8	Industry	2,480
9	Miscellaneous	NA
910	Car park	3,500
910	MS Car park	2,700
960	Sub Station	48

Table 5.3 NRP Weighted Annual Average Damages (WAAD) (2023 values)

		Standard Of Protection						
MCM Code	**Sector Type**	**None**	**5**	**10**	**25**	**50**	**100**	**200**
2	Retail	86.69	42.84	31.22	16.05	7.16	1.79	0.89
3	Offices	84.90	39.06	29.46	14.74	6.48	1.63	0.81
4	Warehouses	97.37	51.33	37.15	18.84	8.53	2.13	1.07
5	Leisure and sport	NOT APPLICABLE - CONSTITUENT CATEGORIES TOO DIVERSE						
51	Leisure	196.48	67.64	53.85	24.45	10.49	2.62	1.31
52	Sport	NOT APPLICABLE - CONSTITUENT CATEGORIES TOO DIVERSE						
521	Playing Field	3.66	1.47	1.17	0.56	0.24	0.06	0.03
523	Sports Centre	45.20	19.56	14.97	7.28	3.18	0.80	0.40
526	Marina	16.34	7.49	5.49	2.79	1.23	0.30	0.16
525	Sports Stadium	11.45	5.58	4.11	2.10	0.93	0.23	0.12
6	Public Buildings	52.35	23.68	17.86	8.85	3.90	0.98	0.48
8	Industry	18.39	9.09	6.62	3.38	1.51	0.38	0.19
9	Miscellaneous	NOT APPLICABLE - CONSTITUENT CATEGORIES TOO DIVERSE						
910	Car park	5.64	2.52	1.87	0.94	0.41	0.10	0.05
960	SubStation	273.27	165.76	118.61	64.85	29.34	7.33	3.67
NRP sector average		90.37	47.28	34.64	18.29	8.32	2.18	1.09

Table 5.4 Business floor space: rateable value per m2 of floor space (2023 values)

Area	Main Category	Mean	Median	Upper quartile	Lower quartile
ENGLAND	Total	104.36	96.73	57.27	166.72
ENGLAND	Retail	190.91	140.00	87.82	227.81
ENGLAND	Offices	197.27	134.91	94.18	194.72
ENGLAND	Industrial	47.09	53.45	38.18	73.82
ENGLAND	Other	86.54	72.54	33.09	136.18
NORTH EAST	Total	71.27	66.18	39.45	114.54
NORTH EAST	Retail	162.91	98.00	61.09	165.45
NORTH EAST	Offices	108.18	89.09	63.64	126.00
NORTH EAST	Industrial	31.82	38.18	26.73	52.18
NORTH EAST	Other	54.73	43.27	19.09	90.36
NORTH WEST	Total	77.64	77.64	48.36	134.91
NORTH WEST	Retail	169.27	114.54	73.82	187.09
NORTH WEST	Offices	124.73	112.00	80.18	155.27
NORTH WEST	Industrial	38.18	44.54	31.82	59.82
NORTH WEST	Other	72.54	59.82	30.55	90.36
YORKSHIRE AND THE HUMBER	Total	71.3	76.4	45.8	131.1
YORKSHIRE AND THE HUMBER	Retail	162.91	115.82	75.09	187.09
YORKSHIRE AND THE HUMBER	Offices	124.73	104.36	76.36	146.36
YORKSHIRE AND THE HUMBER	Industrial	36.91	44.54	31.82	59.82
YORKSHIRE AND THE HUMBER	Other	70.00	66.18	29.27	119.63
EAST MIDLANDS	Total	62.4	66.2	43.3	105.6
EAST MIDLANDS	Retail	137.45	98.00	63.64	156.54
EAST MIDLANDS	Offices	89.09	87.82	68.73	114.54
EAST MIDLANDS	Industrial	40.73	44.54	33.09	57.27

EAST MIDLANDS	Other	67.45	64.91	28.00	113.27
WEST MIDLANDS	Total	73.8	76.4	48.4	124.7
WEST MIDLANDS	Retail	156.54	108.18	72.54	169.27
WEST MIDLANDS	Offices	129.82	110.73	82.73	150.18
WEST MIDLANDS	Industrial	42.00	48.36	35.64	62.36
WEST MIDLANDS	Other	78.91	73.82	36.91	115.82
EAST	Total	95.5	100.5	61.1	162.9
EAST	Retail	184.54	150.18	98.00	231.63
EAST	Offices	143.82	136.18	101.82	180.72
EAST	Industrial	53.45	59.82	42.00	81.45
EAST	Other	89.09	80.18	36.91	145.09
LONDON	Total	246.9	194.7	118.4	336.0
LONDON	Retail	299.09	220.18	148.91	353.81
LONDON	Offices	356.36	267.27	164.18	437.81
LONDON	Industrial	86.54	94.18	71.27	123.45
LONDON	Other	166.72	146.36	71.27	227.81
SOUTH EAST	Total	112.0	114.5	71.3	171.8
SOUTH EAST	Retail	198.54	156.54	106.91	234.18
SOUTH EAST	Offices	145.09	143.82	112.00	180.72
SOUTH EAST	Industrial	63.64	68.73	49.64	90.36
SOUTH EAST	Other	86.54	75.09	31.82	143.82
SOUTH WEST	Total	90.4	89.1	56.0	146.4
SOUTH WEST	Retail	175.63	140.00	92.91	213.82
SOUTH WEST	Offices	127.27	113.27	86.54	148.91
SOUTH WEST	Industrial	47.09	54.73	40.73	72.54
SOUTH WEST	Other	73.82	73.82	30.55	134.91

6 *Other flood losses:* Utility, schools, hospitals, transportation networks and emergency costs

Tables and figures

Introduction: Prioritisation of losses for inclusion in project appraisal

Figure 6.1 Prioritisation process for selecting those assets to quantify potential losses

STEP 1

Identify those assets at risk of flooding

This first step is simply to identify those assets at risk of flooding and thereby the scale of the issue.

There are a number of ways in which to enumerate assets depending on the type of asset (e.g. km of network, or numbers of assets) but mapping of these is preferable.

Use GIS tools

STEP 2

Determine the likelihood of flooding of assets

Utilise flood threshold information to identify on a simple scale (e.g. low, moderate, significant) the likelihood of flooding and include the probability of a particular asset being affected.

STEP 3

Determine the criticality of the assets to flooding

Categorise the affected asset using a criticality scale (e.g. such as a Risk Matrix or a variant)

This should take into account the scale of the loss or disruption and the joint and the joint effect of *susceptibility*, *dependency* and *transferability* within the system.

Utility and transport organisations have been developing risk registers since 2007.

These should be accessed where possible as for many assets Steps 1 to 3 may have already been undertaken

STEP 4

Utilise total risk matrix for prioritisation

A risk matrix approach should be adopted obtain an estimation of the total risk of assets to induced losses. This combines the scales in Steps 2 and 3 to identify the significant assets.

FIRST DEGREE OF PRIORITISATION

At this stage those assets which will have a significant impact upon induced losses to flooding will be identified.

STEP 5

Assess the impact of resistance and resilience

Identify those assets where resistance and resilience measures are implemented and/or planned and where the impact of flooding is mitigated.

These should be excluded from the assessment and quantification of induced losses.

SECOND DEGREE OF PRIORITISATION

Update the likelihood and/or impact categories to account for resistance and resilience measures.

STEP 6

Quantify losses for 'high' and 'very high risk' assets

Judgement is required about which risk categories should be quantified. However, it is suggested that only those high or very high risk assets should be considered.

Assets which are in lower risk categories should be included but described qualitatively in the project appraisal.

Table 6.1 Enumeration, descriptors and valuation measures to gauge the scale of the infrastructural risk

Infrastructure type	Enumerator/ Descriptor	Valuation Measures
Roads	Length (in km) of motorways, A, B, minor within the floodplain; flood thresholds	User numbers (cars, HGV, LGV, PSV) Flood free alternatives
Railways	Length (in km) of intercity, regional, local, commuters tracks; flood thresholds	No. of passengers of different types (commuter, business, other), trains per day,
Electricity transmission	KV, lengths, thresholds of flooding of plinth	Supply catchment, population served
Electricity distribution	Size of substations; threshold of flooding	Supply catchment, population served
Gas pressure, pumping stations [1]	Type and number	Supply catchment, population served
Water treatment works	Type and number (pumping station, booster station etc); thresholds of flooding	Supply catchment, population served
Sewage treatment works	Type and number (biological filter, activated sludge, pumping station etc); thresholds of flooding	Drainage catchment, population served
Telecommunications [2]	Exchanges, cabinets, pillars, threshold of flooding	Population served
[1] Water distribution and supply mains, trunk sewers and gas lines can all but be ignored unless likelihood of fracture is high (e.g. on exposed river crossing or where it might be threatened by the ground around it becoming saturated so that it floats and threatened the pipe work joints).		
[2] Redundancy is now high with universal application of mobile telephony. Telecommunication losses and disruption can all but be ignored unless physical damage is likely with high probability within an exchange.		

Table 6.2 Risk Matrix

IMPACT**	*Significant*	Medium Risk	**High Risk**	**Very High Risk**
	Moderate	Low Risk	Medium Risk	**High Risk**
	Low	Negligible Risk	Low Risk	Medium Risk
		Very Low	*Low*	*Medium/High*
			LIKELIHOOD*	

* These follow the Environment Agency's Risk of Flooding from Rivers and Sea likelihood bands.
** The significant, moderate and low impact categories are defined for each receptor type.

Table 6.3 Summary of impacts for utility and infrastructure assets assuming that there are no flood resilience measures or actions taken to increase **redundancy**

Utility/ infrastructure	Susceptibility	Dependency	Redundancy/ Transferability	Scale 1 = few 2 = many 3 = very many	Total likely impact
Electricity transmission and distribution					
> 132 kV (fluvial)	Low	High	Low	3	Low
>132 kV (tidal) [1]	High	High	Low	3	High
<132 kV (fluvial)	Low	High	Low	2	Low
<132 kV (tidal)	High	High	Low	2	Medium
Grid (Super grid) substation	High	High	High	3	Medium [2]
Grid (Bulk Supply Point) substation	High	High	Medium	3	Medium [2]
Primary substation	High	High	Medium	2	Medium[2]
Distribution substation	High	High	Low	1	Medium/ Low [3]
Gas transmission					
Gas pressure stations	Medium	Medium	Low	1	Low
Gas pressure stations	Medium	Medium	Low	2	Medium
Water and waste water treatment					
Sewage treatment	Medium	High [4]	Low [5]	1	Medium
Sewage treatment	Medium	High [4]	Low	2	Medium
Water treatment	High	High	Medium [6]	1	Medium
Water treatment	High	High	Medium [6]	2	High
Water pump stations	High	High	Low	1 and 2	Medium
Telecommunication systems					
Connection points – cabinet	Low	Medium	High	2	Low
Telecoms connection points – pillars	Low	Medium	High	1	Low [7]

[1] Transmission lines across a coastal floodplain are likely to collapse during a severe tidal inundation. Also if a transmission line is within an area flooded for any considerable period of time, then maintenance of that structure will be difficult and the integrity of the asset threatened.

[2] The absolute impact will depend upon the specific site plan and the location of equipment within it; in particular the positioning and height of the switching gear and transformers.

[3] This is 'low' in the situations whereby the properties the substation is servicing are also flooded as the substation will be repaired before the houses. It is 'medium' in situations where the substation is servicing properties which remain dry (i.e. ‘unflooded’ properties).

[4] Environmental damage through treatment bypass might be as important as physical damage.

[5] A reminder that in this circumstance the redundancy remains low – unless measures have been taken as a consequence of the Pitt Review to increase the transferability of the service.

[6] Depends upon locality.

[7] Redundancy of landline facilities is extremely high with saturation coverage of mobile telephones.

NB. This is Table 6.14 in the MCM 2013

Infrastructure

Table 6.4 Types of electricity substations (ENA, 2009)

Substation type	Typical Voltage transformation levels	Approximate number in UK	Typical size	Typical numbers of customers supplied
Grid (Super grid)	400kV to 132kV	377	250m x 250m	200,000 to 500,000
Grid (Bulk Supply Point)	132kV to 33kV	1,000	75m x 75m	50,000 to 125,000
Primary	33kV to 11kV	4,800	25m x 25m	5,000 to 30,000
Distribution	11/kV to 400/230V	230,000	4m x 5m	1 to 500

NB. This is Table 6.6 in the MCM 2013

Energy Networks Association (ENA) (2009) 'Resilience to flooding of grid and primary substations', Engineering Technical Report (ETR 138), issue 1, Energy Networks Association, London.

Table 6.5 Risk matrix for electricity substations

IMPACT	Sig: Grid substations with serving a population of > 125 000	Medium Risk	**High Risk**	**Very High Risk**
	High: Primary substations those with > 10000 *population supplied*	Medium Risk	**High Risk**	**High Risk**
	Mod: Primary substations with 5,000 to 10,000 population supplied	Low Risk	Medium Risk	**High Risk**
	Low: Distribution substations with fewer than 500 people supplied.	Negligible Risk	Low Risk	Medium Risk
		Very Low	*Low*	*Medium/High*
		LIKELIHOOD		

NB. This is a revised version of Table 6.7 in the MCM 2013

Figure 6.2 List of Approved Designated Services which are able to be considered to be added to the Protected Site List*

- Gas reception terminals; storage installations including boosting and compression equipment; gas compressor stations and principal development and control sites for the control of gas supply systems and emergency procedures;
- Licensed electricity generators, and licensed network operators;
- Oil refineries and vital oil pumping stations;
- Sites with a continuous manufacturing process, not sustainable through standby generation, where regular shutdown for 3-hour periods is not possible and would cause significant financial damage;
- Major airports and associated control facilities;
- Significant railway operations;
- Ports and docks which have a national infrastructure significance;
- Essential water and sewerage installations;
- A major location for essential food manufacture, processing or storing;
- Hospitals as agreed with NHS Foundation Trusts, Primary Care Trusts, Acute Trusts, Local Health Boards (in Wales), Welsh NHS Trusts and NHS Health Scotland;
- Digital and telecommunication services where there is a national need for continued operation
- Emergency services of regional significance;
- Armed forces sites that provide civil protection support;
- Financial services where there is a national need for continued operation.

Source: Department for Business, Energy and Industrial Strategy (2019; Table 1).

Department for Business, Energy and Industrial Strategy (2019) Electricity Supply Emergency Code (ESEC), Revised November 2019, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/845221/electricity-supply-emergency-code-nov-2019-rev.pdf, accessed 12 April 2023.

* PSL has replaced 'V' list customers.

Table 6.6 Estimations of population served based on the perimeter fence length (after Energy Networks Association, 2018b)

Sub station type	Average Perimeter Fence	Ratio customers to metres of perimeter
Grid (Super grid)	1000m	225:1
Grid (Bulk Supply Point)	300m	183:1
Primary	100m	150:1

NB. This is Table 6.8 in the MCM 2013

Energy Networks Association (ENA) (2018b) 'Resilience to flooding of grid and primary substations: Annex', Engineering Technical Report (ETR 138 Annex), Issue 1, 2018, Energy Networks Association (ENA): London.

Table 6.7 Resilience levels for electricity substations*

Flood type	Protection level			Allowance for climate change rises	Freeboard
	Grid Substation	Primary Substations† > 10,000 unrecoverable connections	Primary Substation† < 10,000 unrecoverable connections		
Fluvial	1:1000 Flood level	1:1000 Flood level	1:100 Flood level	Flood Depth x 20% or use of EA CC factored levels	300mm
Tidal	1:1000 Flood level	1:1000 Flood level	1:200 Flood level	105 mm or use of EA CC factored levels	300mm
Surface	1:1000 Flood level	1:1000 Flood level	1:100 Flood level	Flood Depth x20%	300mm

Source: UK Power Networks (2019, 10); ENA (2018a, 20).

* Please note that critical infrastructure resilience is a priority area following recent floods and storms and the *National Flood Resilience Review* (HM Government, 2016) and so the resilience levels may be subject to change. Furthermore, some DNOs have issued guidance recommending additional safety factors are applied (e.g. Electricity North West, 2017). In particular, the updated ENA (2018a) suggests that Network Operators should ensure that they utilise the most recent guidance available. It is recommended that appraisers also check for updated information. The third round of Climate Change Adaptation Reporting accordance with the Climate Change Act 2008, provides the updated information on climate resilience for each supplier (Defra, 2022).

† ENA (2018a) suggests that network operators should focus on the resilience of service provision to sites supplying significant local communities (SLCs) (which are defined as those comprising at least 10,000 customers/connections) and to the level of the EA's Extreme Flood Outline (i.e. 1/1,000 flood risk). Therefore, those primary substations which are likely to serve a customer population of over 10,000 should have the same protection level (1:1000) as grid substations.

Department for Environment, Food and Rural Affairs (2022) Climate change adaptation reporting: third round reports, Reports from organisations invited to report under the third round of the climate change Adaptation Reporting Power, Latest update 24th March 2022, https://www.gov.uk/government/collections/climate-change-adaptation-reporting-third-round-reports#energy-companies, accessed 05 April 2023.

Electricity North West (2017) Substation Flood Protection, Electricity Policy Document 355, Issue 3, April 2017, https://www.enwl.co.uk/globalassets/get-connected/cic/icpsidnos/g81-policy/policy-library-documents/substation/epd355---substation-flood-protection.pdf, accessed 05 April 2023.

Energy Networks Association (ENA) (2018) 'Resilience to flooding of grid and primary substations', *Engineering Technical Report (ETR 138),* Issue 3, June 2018, Energy Networks Association, London.

HM Government (2016) *National Flood Resilience Review*, September 2016, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/551137/national-flood-resilience-review.pdf, accessed 05 April 2023.

UK Power Networks (2019) Substation Flood Protection, Engineering Design Standard EDS, https://g81.ukpowernetworks.co.uk/library/design-and-planning/substations-major/general/eds-07-0106-substation-flood-protection, accessed 05 April 2023.

Table 6.8 ***Potential intervention measures for electricity infrastructure with their advantages and disadvantages***

Intervention Measure		Advantages	Disadvantages
Permanent	EA intervention measure (wall or embankment)	Removes flood risk to design flood level	High cost solution and long ‘solution’ lead time
Permanent	Buildings and Critical assets protected 365 days per year	Access maintained and all apertures sealed with site not requiring to be manned during flood	Protection generally only effective to a height of 1 metre above ground level. Medium cost solution
Permanent	Barriers and gates at critical openings in perimeter	Access to critical pant maintained	Site needs to be manned during flood incident. Medium cost solution
Permanent	Substation critical assets raised	Removes risk of flooding to new design threshold	High cost solution with long construction lead time
Permanent	Substation relocation outside floodplain	Wholly removes flood risk	Very high cost solution and disruptive to customers during construction
Demountable	Buildings and critical assets where supports are permanent and panels etc stored on site	Removes flood risk to design flood level	Medium to high cost solution and resource intensive during flooding with potential for operational failure.
Demountable	Site protection where supports are permanent and panels etc stored on site	Removes flood risk to design flood level	Medium to high cost solution and resource intensive during flooding with potential for operational failure.
Temporary	Site protection measures installed following flood warning	Low cost solution	High deployment and training costs for erection etc.

Source: Adapted from Energy Networks Association (2009)

NB. This is Table 6.10 in the MCM 2013

Energy Networks Association (ENA) (2009) ‘Resilience to flooding of grid and primary substations’, Engineering Technical Report (ETR 138), Issue 1, October 2009. Energy Networks Association, London.

Figure 6.3 Indicative figures for average energy and gas consumption and willingness to pay to avoid a power outage

Average electricity consumption† – 2020 estimates

Annual Energy Consumption per household (Ofgem, 2020)	Daily Energy Consumption per household
2,900 kWh	7.9 kWh

Average gas consumption – 2020 estimates

Annual Gas Consumption per household (Ofgem, 2020)	Daily Gas Consumption per household
12,000 kWh	33 kWh

Willingness-to-pay* to avoid disconnection of supply for electricity (2023 values)

Willingness to pay to avoid disconnection – Domestic users (BERR, 2007)	Willingness to pay to avoid disconnection – Business users** (BERR, 2007)
£15.16 per kWh	£53.06 per kWh

The annual consumption per household figure is the medium Typical Domestic Consumption Value calculated by Ofgem (2020) – the higher or lower values might be used to provide a more conservative or maximum estimate. TDCVs are industry standard values and are those still recommended by the industry in April 2020. These figures are still those adopted as per the update of 1st May 2023. However, Ofgem report that they are undertaking their regular (but postponed due to Covid-19 impacts) update of these values which will be released in Spring 2023 so users are advised to check to see if there have been any updated consumption values (https://www.ofgem.gov.uk/information-consumers/energy-advice-households/average-gas-and-electricity-use-explained).
††TDCV Electricity Profile Class 1 has been used (i.e. those not on an Economy 7 tariff) the assumption being that households are not only reliant on electricity for power and this will provide a more conservative estimate. For a maximum estimate, TDCV Profile Class 2 can be used and accessed from Ofgem (2020).
*These values have been generated in relation to electricity supply. However, this might also be used in the case of the disruption to a gas supply in the absence of other appropriate estimates.
**This is an average value and there is likely to be significant variation amongst business owners depending upon the type of business and its dependency upon water.

Department of Business, Enterprise and Regulatory Reform (BERR) (2007) Electricity Priority Users Arrangements, Department for Business, Enterprise and Regulatory Reform, https://webarchive.nationalarchives.gov.uk/ukgwa/20090609003228/http://www.berr.gov.uk/files/file40466.pdf, accessed 05 April 2023.

Ofgem (2020) 'Typical Domestic Energy Consumption Values', https://www.ofgem.gov.uk/information-consumers/energy-advice-households/average-gas-and-electricity-use-explained revised Jan 2020, accessed 21 April 2023.

Table 6.9 Risk matrix for sewage treatment works

IMPACT	*Sig: > 30,000 cumecs effluent dry weather flow*	Medium Risk	**High Risk**	**Very High Risk**
	Mod: 5,000 to 30,000 cumecs effluent dry weather flow	Low Risk	Medium Risk	**High Risk**
	Low: < 5,000 cumecs effluent dry weather flow	Negligible Risk	Low Risk	Medium Risk
		Very Low	*Low*	*Medium/High*
		LIKELIHOOD		

NB. This is Table 6.12 in the MCM 2013

Table 6.10 Risk matrix for water supply

IMPACT	*Sig: > 20,000 population supplied or PSL customers*	Medium Risk	**High Risk**	**Very High Risk**
	Mod: 5,000 to 20,000 population supplied	Low Risk	Medium Risk	**High Risk**
	Low: < 5,000 population supplied	Negligible Risk	Low Risk	Medium Risk
		Very Low	*Low*	*Medium/High*
		LIKELIHOOD		

NB. This is Table 6.13 in the MCM 2013

Transport

Table 6.11 Total resource costs of travel as a function of speed (pence/km) (updated to 2022 prices)

Total resource costs (pence per km)								
Speed (km/hr)	**5**	**10**	**20**	**40**	**50**	**80**	**100**	**120**
Car average p/km	323	163	86	48	41	27	25	22
LGV average p/km	378	196	104	59	50	38	36	33
OGV1 p/km	416	221	120	69	59	45	-	-
OGV2 p/km	531	288	162	98	85	68	-	-
PSV p/km	2391	1225	642	347	288	-	-	-

Data supplied by the Department for Transport (2012)

This is Table 6.15 in the MCM 2013

Department for Transport (2012) 'UNIT 3.5.6: Values of Time and Vehicle Operating Costs', Transport Analysis Guidance (TAG), October 2012, Department for Transport, London. This is now restructured into the following TAG guidance, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1102785/tag-unit-a1.3-user-and-provider-impacts.pdf, accessed 05 April 2023.

Table 6.12 Indicative delay durations at different return periods

Likelihood of flooding	Delay duration (Hours)
Up to and including the 5 year return period (0.2%)	6
Up to and including the 10 year return period (0.1%)	6
Up to and including the 25 year return period (0.04%)	12
Up to and including the 50 year return period (0.02%)	24
Up to and including the 100 year return period (0.01%)	48
Up to and including the 200 year return period (0.005%)	96

This is Table 6.17 in the MCM 2013

Table 6.13 Speed-flow relations

Road type	Free Flow speed (kph)	Free Flow limit (pcu/h/lane)	Limiting capacity (pcu/h/lane)	Speed at Limiting Capacity (kph)
	VC	QC	QM	VM
	Free flow speed	Speed falls linearly over this range		
Rural motorway	90	1800	2600	76
Rural dual carriageway	79	1600	2400	70
Rural all purpose road	70	400	1800	57
Rural all purpose road – poorly aligned	50		600	50
Urban motorway	80	1700	1400	66
Urban dual carriageway				
With limited access and 80 kph limit	65	1400	2200	56
65 kph speed limit	50	600	1100	30
Urban single carriageway road				
outer area	45	500	1000	25
intermediate area	35	350	600	25
central business area	25	250	500	15
Suburban – major radial or outer ring roads				
No major intersections	Speed limit		2000	47
< 1 major intersection per km			1700	27
1-2 major intersection per km			1200	20

Source: Department for Transport (1981)

Department for Transport has confirmed that these 1981 values are still applicable.

NB. This is revised Table 6.16 in the MCM 2013

Department for Transport (DfT) (1981) Traffic Appraisal Manual, Department for Transport, London

NB: This has been corrected for the 2019 MCH. A formatting error was present for the final three rows and additionally the limiting capacity of a 80 kph limited urban dual carriageway was corrected to read 2200pcu/h/lane.

Table 6.14 Passenger numbers and statistics by Train Operating Company (Franchised companies only)

Train Operating Company	Passenger Journeys per year 2018-2019 (millions)	Passenger Journeys per 24 hours 2018-2019 (averaged by dividing by 365)	Passenger kilometres 2018-2019 (millions)	Passenger train kilometres 2018-2019 (millions)	Route Kilometres operated 2018-2019
c2c	49.1	134,521	1237.8	7.3	125.5
Caledonian Sleeper	0.3	822	201.0	1.4	1470.9
Chiltern Railways	29.3	80,274	1652.4	12.2	354.1
CrossCountry	40.7	111,507	3715.8	32.7	2710.1
East Midlands Railway	26.7	73,151	2415.0	22.8	1549.8
Grand Central	1.5	4,110	418.4	2.5	762.8
Great Western Railway	100.1	274,247	6001.6	41.7	1997.2
Greater Anglia	84.9	232,603	3925.2	28.5	1591.6
Hull Trains	1.0	2,740	244.6	1.4	342.8
London North Eastern Railway	22.3	61,096	5807.3	23.4	1480.6
London Overground	188.1	515,342	1287.6	8.7	167.4
Merseyrail	42.1	115,342	666.9	6.4	120.7
Northern	101.3	277,534	2584.6	48.5	2800.3
ScotRail	97.8	267,945	2978.8	47.6	3120.5
South Western Railway	216.0	591,781	6039.6	39.0	997.8
Southeastern	183.2	501,918	4693.1	31.9	748.3
TfL Rail	51.3	140,548	642.8	3.8	59.5
Thameslink	341.5	935,616	9206.8	63.3	1287.5
TransPennine Express	29.2	80,000	2081.7	20.6	1039.6
Transport for Wales	34.1	93,425	1257.3	23.8	1784.8
Virgin Trains	39.5	108,219	7673.2	36.0	1310.0
West Midland Trains	78.7	215,616	2919.4	25.6	899.6

Source: Data downloaded from the ORR National Rail Trends Portal (2020)

NB: Train operating companies change as franchises generally operate over a fixed period.

The data provided here are the latest available in an entirely pre-COVID period. These data have not been updated to more recent figures due to the observable impacts of COVID-19 and local and national lockdowns on travel. ORR (2023) suggests that passenger rail usage continues to be affected and that passenger journeys are only 80% of those at pre-pandemic levels, but the differences vary considerably between areas. Until work and travel patterns stabilise we recommend using pre-pandemic figures. Furthermore, strike action across the networks in the last quarter of 2022/23 would impact on the figures provided. These data were collected for the 2018-2019 period and operators may have changed, it is suggested that users access the Rail Trends Portal at time of use and where necessary consider current and past operators of the route of interest.

* These data have changed since the original version in the MCM as the ORR National Rail Trends Portal no longer provide data on 'timetabled train kms', but rather on 'passenger train kms.'

Office of Rail Regulation (ORR) (2023) 'The National Rail Trends (NRT) Portal', http://dataportal.orr.gov.uk/, accessed 21 April 2023.

Table 6.15 Percentage delay/cancellation due to flooding (Posford Duvivier et al., 2002)

Rail Service	Delay %	Cancellation %
Passenger service	40	60
Freight service	45	55

NB. This is Table 6.19 in the MCM 2013

Table 6.16 ***Indicative compensation values for performance delays and cancelled services (data from Network Rail)***

Actual compensation values for each of the Train Operating Companies (TOCs) and Freight Operating Companies (FOCs), as agreed in the Track Access Agreements, are restricted information. Therefore, these indicative values are based on data of the actual delay costs and cancelled services between 2011 and 2013.

	Delay compensation value £s per minute per service *			**Cancellation compensation value £s per service cancelled****		
	Low value (£)	Medium value (£)	High value (£)	Low value (£)	Medium value (£)	High value (£)
Passenger services	40	71	97	673	2034	2591
Freight services	-	18	-	-	1900	0

NB. This is Table 6.20 in the MCM 2013

* Including a delay multiplier of 3
** Including a cancellation multiplier of 3

These delay multipliers have been applied according to the Department for Transport (2009) which Burr (2008, 46) argues is "used by the rail industry to recognise that unexpected delays are more costly to passengers".

Burr, T. (2008) *Reducing passenger rail delays by better management of incidents*, report by the comptroller and auditor general, HC 308, Session 2007-2008, 14 March 2008, National Audit Office, The Stationary Office, London, http://www.nao.org.uk/wp-content/uploads/2008/03/0708308.pdf, accessed 05 April 2023.

Department for Transport (2009) 'Unit 3.5.7: The Reliability Sub-Objective', *Transport Analysis Guidance (TAG),* April 2009, Department for Transport, London. This is now restructured into the following TAG guidance https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1102785/tag-unit-a1.3-user-and-provider-impacts.pdf, accessed 05 April 2023.

Table 6.17 Values of Time - based on the willingness to pay of each type of passenger per hour (2023 values)

	Value of time* (VoT) £ per hour		
	Business passenger	Commuter	Other passenger
Original values per hour	£49.34	£6.79	£5.98
Uplifted to account for an unexpected delay**	£148.01	£20.38	£17.93

NB. This is Table 6.21 in the MCM 2013

*The resource cost estimate has been utilised in this instance as these values net of indirect taxation. Department for Transport (2012) have been updated utilising HM Treasury (2023) GDP Deflator (March 2023).

** The values have been uplifted by applying the 'delay multiplier' factor of 3.0 (Department for Transport, 2009) which Burr (2008, 46) argues is "used by the rail industry to recognise that unexpected delays are more costly to passengers".

References

Burr, T. (2008) Reducing passenger rail delays by better management of incidents, report by the comptroller and auditor general, HC 308, Session 2007-2008, 14 March 2008, National Audit Office, The Stationary Office, London, http://www.nao.org.uk/wp-content/uploads/2008/03/0708308.pdf, accessed 05 April 2023.

Department for Transport (2009) 'Unit 3.5.7: The Reliability Sub-Objective', Transport Analysis Guidance (TAG), April 2009, Department for Transport, London, This is now restructured into the following TAG guidance https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1102785/tag-unit-a1.3-user-and-provider-impacts.pdf, accessed 05 April 2023.

Department for Transport (2012) 'UNIT 3.5.6: Values of Time and Vehicle Operating Costs', Transport Analysis Guidance (TAG), October 2012, Department for Transport, London. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1102785/tag-unit-a1.3-user-and-provider-impacts.pdf, accessed 05 April 2023.

HM Treasury (2023) 'Latest figures, GDP deflators at market prices, and money GDP', https://www.gov.uk/government/statistics/gdp-deflators-at-market-prices-and-money-gdp-march-2023-quarterly-national-accounts, accessed 05 April 2023.

Table 6.18 ***Percentage breakdown of the journey purpose of rail travellers by Train Operating Company[*] and grouped train operators in 2019****

Train Company	Commute	Business	Leisure
c2c	67	6	27
Chiltern Railways	38	25	37
CrossCountry	15	28	57
East Midlands Railway	23	28	49
Gatwick Express	15	44	40
Great Northern	53	10	37
Great Western Railway	28	20	52
Greater Anglia	44	25	31
London North Eastern Railway	9	31	60
London Overground	61	3	37
Merseyrail	43	1	56
Northern	38	9	53
ScotRail	39	13	47
South Western Railway	53	15	32
Southeastern	48	21	31
Southern	52	9	39
TfL Rail	61	4	35
Thameslink	53	10	37
TransPennine Express	26	13	61
Transport for Wales	31	10	59
Virgin Trains	9	22	69
West Midland Trains	40	13	46
Grouped train operators	**Commute**	**Business**	**Leisure**
London and South East operators	50	13	37
Long distance operators	16	24	60
Regional operators	38	9	52

Source: Passenger Focus (2019a; 2019b)

NB. This is Table 6.22 in the MCM 2013

* Please note that where operating franchise companies have changed between the surveys conducted, the data from the old and new operators have been merged to create this annual percentage. Weighted sample data have been utilised. Data on journey purpose is also available for some specific routes and can be accessed in the datasets presented in the links below.
** These data have not been updated to more recent figures due to the continued change in travel patterns in comparison to pre-pandemic levels. Additionally, travel in 2022/23 has been impacted by strike action. Until work and travel patterns stabilise we recommend using pre-pandemic figures.

Transport Focus (2019a) 'National Passenger Survey data Spring 2019' https://transportfocusdatahub.org.uk/ accessed 21 April 2023.

Transport Focus (2019b) 'National Passenger Survey data Autumn 2019' https://transportfocusdatahub.org.uk/, accessed 21 April 2023.

Table 6.19 Percentage breakdown of the journey purpose of rail travellers by region (2010 data)

Region	Commuting	Business	Leisure
Scotland	59	11	30
Wales	50	12	38
North East	40	21	39
North West	53	12	35
Yorkshire and Humberside	54	14	32
East Midlands	49	17	33
West Midlands	55	14	31
East of England	67	12	21
London	69	12	19
South East	63	13	24
South West	46	19	34
Great Britain	63	13	24

NB: the percentages do not equal 100 due to rounding
Source: Department of Transport (2010)

Department for Transport (2010) 'National Rail Travel Survey Overview Report, Updated December 2010 Results from a survey of rail travel across Great Britain' https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/73094/national-rail-travel-survey-overview-report.pdf accessed 21 April 2023.

Education and Health

Table 6.20 Estimates of the value of a lost day's work – 2023 estimates

Minimum estimate*	Average estimate
£69.33	£91.55

*The minimum estimate is calculated using the £10.42 per hour National Living Wage (April 2023) for an adult and a 7.6 hour working day.

The average estimate is calculated using a median hourly wage for a full-time adult (excluding overtime) in April 2022 of £14.72 and a 7.6 hour working day (ONS, 2022).

The minimum estimate has been adjusted from gross pay values using HMRC (2023) to provide economic values net of Income Tax and National Insurance Contributions.

HMRC (2023) 'HMRC Tax Calculator', https://www.gov.uk/estimate-income-tax, accessed 05 April 2023.

Office for National Statistics (ONS) (2022) 'Annual Survey of Hours and Earnings, 2022 Provisional Results' ASHE: Table 6.6a 26 October 2022, https://www.ons.gov.uk/employmentandlabourmarket/peopleinwork/earningsandworkinghours/datasets/agegroupashetable6, accessed 05 April 2023.

Table 6.21 Average costs of hospital bed

	Average bed cost in the NHS [1]	Average bed day cost for elective and non-elective admissions [2, 3] (surgery and general medicine)	Average bed day cost for critical care
Average cost of a bed per day	£346	£530	£983

[1] This value is for 2017/18 and includes only the cost of NHS beds and excludes contracted out services.

Source: NHS Improvement (2018) Reference costs 2017/18: highlights, analysis and introduction to the data, November 2017, London. https://webarchive.nationalarchives.gov.uk/ukgwa/20200501111106/https://improvement.nhs.uk/resources/reference-costs/, accessed 05 April 2023.

[2] These values are for 2011-2012 and were provided directly from the Department of Health, however although older they might be more appropriate than the average (if it is known) of those types of treatment will be affected.

[3] The figures for critical care and general and surgery beds include the cost of treatment.

NB: These data provide the most updated values for average bed cost provided by the NHS reference cost data. The latest updated National Schedule of NHS Costs data (2021/22) and previous datasets did not provide values for average bed costs.

Table 6.22 Indicative costs per patient transfer – 2012/2013 estimates

Ambulance costs vary depending upon whether a journey is made as part of a contract or as a private journey, a cost per hour, the distance travelled and includes a minimum cost. Additionally, there are additional charges for long journeys (over 300 miles return) and on public holidays.

Appraisers will need to identify alternative sites for healthcare provision and the distance (in miles) to that location. It appears that this should also include the return journey as the ambulance will be required to return to its base. This distance should be multiplied by the costs per mile (which is approximately £0.30) to calculate the total mileage costs.

These can then be added to either of the fixed and time costs in the table below. There is a minimum charge for any ambulance transfer which might be used as a minimum indicative cost. However this would only be applicable for journeys which are undertaken in less than one hour.

Above this minimum, the costs rise according to the circumstances of the transfer, how long it takes and the day on which it occurs. Therefore a second higher indicative value is presented in the table below which is based on the following assumptions:

- Only NHS patients transferred
- The distance to the alternative supplier is less than 150 miles (and therefore does not incur the additional charge)
- That the transfer does not occur on Statutory Bank holidays
- That the transfer takes a total of 1.5 hours (including waiting time)

Cost type	Minimum value	Higher indicative value
Fixed costs and time costs	£140	£250
Mileage costs	Number of miles x 0.30 per mile	Number of miles x 0.30 per mile

Data provided by the London Ambulance Service NHS Trust (2012/2013 values)

Local Authority and Emergency Services

Table 6.23 ***Overall emergency costs as applicable to project appraisals (Summer 2007 Floods)***

Emergency costs applicable to project appraisals (based on Summer 2007 Floods - England)			
Cost item	**Amount**	**Allowed* amount (%)**	**Allowed amount**
Total Bellwin and roads:			
Bellwin	£30.20	42.5	£12.84
Roads infrastructure	£175.00	50	£87.50
Environment Agency costs+:			
Emergency repairs**	£14.80	50	£7.40
Emergency response	£2.20	100	£2.20
TOTAL	**£222.20**		**£109.94**
As % of economic property losses of £1,942m = 5.57%			

8 Recreational gains and losses

Tables and figures

Table 8.1: Sources and methods of information on recreation users/beneficiaries

Table 8.2: Examples of visit numbers used for benefit assessment purposes

Table 8.3: £ gains and losses per adult visit with coastal protection scheme options at coastal sites

Table 8.4: £ value of losses and gains per visit for various changes at river sites

Table 8.1 Sources and methods of information on recreation users/beneficiaries

	Source/ method	**Comments**
1	Long period counts using people counters	Infra-red or other counters installed over a period (at least March to September). Counters are manually calibrated to relate passages to adult visits. Mainly applied in detailed studies: in conjunction with a CV survey – see MCM, Section 8.5.3 (Penning-Rowsell et al., 2013).
2	Short period manual counts/ surveys	Manual counts/surveys over a period of days normally including the August Bank holiday. At initial stage, this method might be combined with site visits and at detailed study stage, with the CV survey.
3	CV survey data	CV survey data on the frequency of visiting by local residents in conjunction with census data on the number of adult residents and staying visitors (in conjunction with managers' estimates of occupancy rates) can be used to generate visit number estimates. However, the tendency of survey respondents to overstate their visiting frequency has to be noted - see the Corton Case Study in the MCM, Section 8.7 (Penning-Rowsell et al., 2013).
4	Old survey/ count data for the project	Planning, tourism or recreation departments of local authorities or local colleges or schools may have undertaken surveys or counts at the project site in the past, which can be updated to indicate current levels of use.
5	Inferred estimate	The number of visits to a coastal or river site is inferred from counts of visits to a related site nearby such as: Car and coach parks multiplied by the average adult car or coach occupancy rate (Hengistbury Head), funfair, cafe, visitor centre, historic site or museum (Hurst Spit and Hurst Spit castle). This requires estimating the proportion of all visitors to the project site who also use the counted site and vice versa. At detailed level, this can be done in conjunction with the CV survey.
6	Visitor equations	A number of equations have been developed which predicts-distance-frequency functions so that from census data on the population in different zones a prediction can be made as to the number of visitors generated by the site.
7	Estimates from an informed persons or source	Written, telephone or personal contacts with: Car park attendants, park rangers/wardens, visitor centre staff, staff at associated visitor attractions, local authority tourism, sport and recreation or planning staff, regional or local offices of organisations such as the English Tourist Board, National Trust or English Heritage and their Welsh equivalents, the Environment Agency's recreation and fisheries staff, managers of general recreation or staying visitor facilities or tourism business organisations that may have information on bedspaces and occupancy rates - see the Corton Case Study in the MCM, Section 8.7 (Penning-Rowsell et al., 2013); both commercial and club managers of specialist facilities (e.g. sailing, boating/sailboarding, fishing, birdwatching) and specialist organisations at national regional and local level for information on the availability of alternative sites e.g. for caravans or sailing.
8	Average number of visits to equivalent sites	This benefit transfer approach is only suitable for initial and strategic studies. The number of adult visits to the project site is estimated as being of the same order as the number of visits made to an equivalent site. However, there are few sites for which good data are available and little research to enable reliable identification of an equivalent site.

Table 8.2 Examples of visit numbers used for benefit assessment purposes

Site*		Annual visit numbers	
Name	**Characteristics**	**High estimate**	**Low estimate**
Undeveloped coastal sites			
Hengistbury Head, Christchurch, Dorset	Natural headland, a SSSI, with nature, geology and archaeology sites	609,000	584,000
Hurst Spit, Hampshire	Undeveloped shingle spit with heritage site, Hurst Castle	107,000	880,000
Developed coastal sites			
St Mildred's Bay, Westgate, Kent	Small resort with promenade and sandy beach	212,000	-
Cliftonville, near Margate Kent	Small resort with clifftops and a mainly sandy beach	146,000	136,000
Corton, near Lowestoft, Suffolk	Small village resort with cliffs and partly sandy beach	97,000	75,000
River sites			
Local park	Park drawing visitors from 800m radius with no special attractions	30,000	60,000
'Honey pot' site, country park	Site drawing visitors from a 3 km radius	60,000	250,000

* At all these sites, both coastal and riverine, almost all the visits involved informal use of the site for activities such as sitting, sunbathing and picnicking, strolling, dog walking, and, at coasts, playing informal games, playing in the sand and swimming or paddling. Very few visits involved specialist uses such as angling or boating or sailboarding.

Table 8.3 £ gains and losses per adult visit with coastal protection scheme options at coastal sites

		£ per adult visit updated to 2023	
		Mean gain with options	Mean loss with 'Do nothing'
Beach and promenade erosion			
Yellow Manual Standard data: 4 sites	Nourished beach and promenade	3.83	9.22
Lee-on-Solent	(a) Shingle beach renourishment	2.20	4.75
	(b) Rock groynes with shingle beach renourishment	2.15	
Herne Bay Visitors Centre	(a) Reef or jetty with no boat facilities	6.46	8.87
	(b) Reef or jetty with boat facilities	3.35	
	(c) Higher seawall, and promenade, rock groynes	-4.14	
Cliftonville	(a) Concrete lower promenade	5.76	8.87
	(b) Rock lower promenade	3.40	
Corton	(a) Hold the line for a limited period. Short term protection to cliff, limited access to beach and along seawall	3.30	3.33
	(b) Hold the line for a longer period >50 years. Full access along renewed seawall and onto all the beach from village	14.78	
	(c) Managed retreat. Sea defences and seawall removed to leave a 'natural' seafront', direct access from village to beach	2.31	
St Mildred's Bay	Improved beach and promenade	3.61	13.29
Hastings	Beach improvement	0.00	9.40
Breach Scenarios			
Hengistbury Head	(a) 5 rock groynes full cliff protection	0.05	5.54
	(b) 3 rock groynes partial protection	-3.11	
	(c) Beach nourishment Annual disruption	-4.66	
Hurst Spit	Slightly enlarged shingle spit	0.86	8.35

NB. This is Table 8.7 in the MCM 2013

Table 8.4 £ value of losses and gains per visit for various changes at river sites

Site	£ mean value of loss: updated to 2023	£ mean value of gain: updated to 2023
River Misbourne: Low flows		
Visitors	5.87	3.42
Residents	5.85	2.91
River Wey: Low flows		
Residents		3.33
River Ravensbourne: Full River restoration		
Visitors and residents		3.07
River Skerne: River restoration		
Residents		3.89

NB. This is Table 8.8 in the MCM 2013

9 Appraisal of flood risk management for agriculture

Figures and tables

Figure 9.1 Flooding and drainage factors influencing agricultural productivity on floodplain

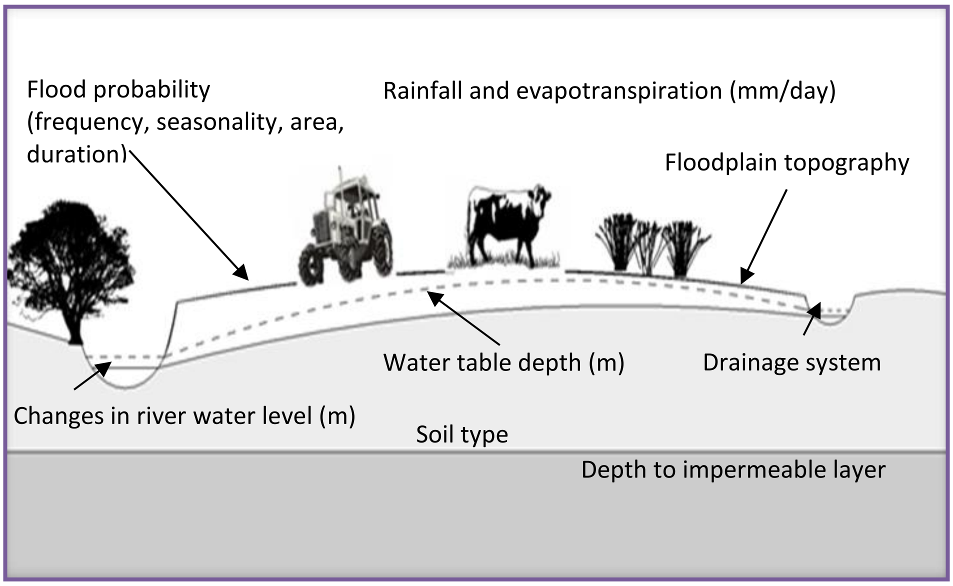

Table 9.1 Tolerance of flooding according to agricultural land use

Agricultural land use Type	**Common minimum acceptable flood frequency: annual probability**	
	Whole Year	Summer April-October
Horticulture	5%	1%
Intensive arable including sugar beet and potatoes	10%	4%
Extensive arable: cereals, beans, oil seeds	10%	10%
Intensive grass: improved grass, usually dairying	50%	20%
Extensive grass, usually cattle and sheep	≥100%	33%

Table 9.2 Drainage conditions for agriculture and water levels in fields and ditches

Agricultural drainage condition	Agricultural productivity class	Depth to water table from surface	Spring time freeboards in water-courses (natural drainage)	Spring time freeboards in water-course (field drains)
Good: 'rarely wet'	Normal, no impediment imposed by drainage	0.5 m or more	1 m sands,	1.2m clays to 1.6m sands (0.2m below pipe outfall)
			1.3 m peats	
			2.1 m clays	
Bad: 'occasionally wet'	Low, reduced yields, reduced field access and grazing season	0.3 m to 0.49 m	0.7 m sands	Temporarily submerged pipe outfalls
			1 m peats	
			1.9 m clays	
Very bad: 'commonly or permanently wet'	Very low, severe constraints on land use, much reduced yields, field access and grazing season: mainly wet grassland	Less than 0.3 m	0.4 m sands	Permanently submerged pipe outfalls
			0.6 m peats	
			1 m clays	

Table 9.3 Common farming performance field drainage conditions (England and Wales)

£ 2019 Values	Field Drainage Conditions		
	Good	**Bad**	**Very Bad**
Arable			
Yield as % of 'good' category			
Winter wheat and barley	100	80	50
Spring wheat and barley	100	90	80
Oil seed rape	100	90	80
Potatoes, Peas, Sugar Beet	100	60	40*
Typical wheat financial gross margin £/ha	£800-£900	£380-£480	£200-£300
Grassland			
Typical nitrogen use on grass kgN/ha	150 - 200	50 – 75	0 - 25
Grass conservation	2 cut silage	1 cut silage or graze	1 cut hay or graze
Typical stocking rates; Live-stock units/ha	1.7 - 2.0	1.2 - 1.4	0.7 - 1.0
Typical livestock type	Dairy, intensive beef and sheep	Beef cows, 24 month beef, sheep	Fattening of 'store' cattle, and sheep
Typical financial gross margins £/ha (after forage costs)	£1770-£1,970 (dairy) £500-£900 (intensive beef/sheep)	£390-£590	£190-£390
Days reduction in grazing season compared to 'good' category	none	Spring: 14 to 21 Autumn: 14 to 21	Spring: 28 to 42 Autumn: 28 , no stock out in winter

Notes:
Livestock units: dairy cow, 1 Lu; beef cow, 0.8 Lu; 24 month beef, 0.7 Lu; sheep plus lamb, 0.14 Lu.
A grazing day is worth about £2.2/Lu in spring, £1.6 /Lu in autumn, and £0.40/Lu in winter in terms of savings in housing costs and feed conservation costs. *not grown if persistently 'very bad'.

Table 9.4 *The Impacts of flooding on farm land vary according to type of agricultural land use and the seasonality of the flood event*

	Spring	**Summer**	**Autumn**	**Winter**
	March – May	**June- August**	**September – November**	**December – February**
Horticulture (soft fruits, salad crops)	Complete loss of soft fruits and winter /spring salads	Complete loss of annual production, possible loss of perennial stock	Loss of late season harvest, possible loss of perennial stock: replanting/reseeding	Damage to standing crops, annuals /perennials
Intensive Agriculture (including field vegetables & roots)	Delay in planting or loss of established crops	Likely complete loss of standing root crops eg potatoes/onions/carrots	Loss of unharvested autumn crops, notably potatoes. Delayed planting or loss of winter crops, substituted by spring sown crops	Possible loss of winter harvest crops (sprouts, and sugar beet). Yield loss on autumn sown crops
Extensive arable (cereals and oil seeds)	Loss or delay of spring sown cereals, yield loss on winter sown cereals, delayed spring treatments	Complete or partial loss of unharvested crops	Loss of unharvested autumn crops. Delayed planting or loss of winter crops, substituted by spring sown crops	Yield loss on autumn sown crops, reseeding with spring sown crops if severe damage
Grassland: intensive (mainly dairy)	Loss of grass yields, delayed stock turnout, delay fertiliser applications. Grass reseeding if long duration flooding	Loss of grass yields, partial or complete loss of hay/silage crop, loss of grazing, stock morbidity/mortality. Grass reseeding if long duration flooding	Loss of autumn grazing, stock relocation /housing. Possible reseeding if long duration.	Loss of winter 'accommodation' pasture.
Extensive (mainly beef and sheep)	Loss of grass yields, delayed stock turnout, delayed fertiliser applications.	Loss of grass yields, partial or complete loss of hay/silage crop, loss of grazing, stock morbidity/mortality.	Loss of autumn grazing, stock relocation /housing.	Limited impact on flood tolerant grass swards

NB. This is based on Table 9.4 in the MCM 2013

Table 9.5 Indicative Financial and Economic Gross Margins and Net Margins for Selected Crop and Livestock Enterprises and Systems

	£ 2019 values		**Winter wheat[1]**	**Extensive arable[2]**	**Intensive arable[3]**	**Dairy cows[4]**	**Beef & Sheep[5]**
	Financial assessment						
a	*Gross Output*	*£/ha*	1355	1301	2581	3512	1343
b	*Variable Costs*	*£/ha*	481	449	996	1453	580
c	*Gross Margin (a -b)*	*£/ha*	874	852	1584	2059	763
	Fixed Costs [6]						
e	*Semi-fixed Costs*	*£/ha*	251	245	371	533	276
f	*Total Fixed Costs*	*£/ha*	687	687	897	1403	747
	Net Margin						
	After semi fixed costs (c -e)	*£/ha*	622	607	1214	1526	488
	After full fixed costs (c -f)	£/ha	187	166	687	656	17
	Economic Assessment						
	Economic adjustment [7]		None	Minor subsidy removal	High value crops treated as wheat	Dairy area treated as wheat[6]	None
g	*Adjusted Gross Margin*	*£/ha*	874	852	874	874	763
	Adjusted Net Margin						
	After semi fixed costs (g -e)	*£/ha*	622	607	622	622	488
	After full fixed costs (g- f)	*£/ha*	187	166	187	187	17

Notes:
Some minor rounding errors
1 Assumes 9 t/ha
2 Assumes wheat 70%, oil seed rape, 20%, beans 10% by area.
3 Assumes wheat 66%, sugar beet 17%, potatoes and vegetables 17% y by area
4 Assumes dairy at 2 cows/ha stocking rate representing intensive grassland
5 Assumes beef suckler cows, beef fatstock and sheep in equal proportions by area, representative of extensive grassland
6 Land rent or land purchase costs are omitted from economic analysis
7 Dairy grassland area and high value crops are treated equivalent to a wheat crop

This is based on Table 9.9 in the MCM 2013, updated to 2019 prices (Defra, 2019)
2013 prices weighted by ratio of average of 2011-13 to average of 2017-2019 (2015=100)
Defra (2019) Agricultural Price Index. (published March 2019), https://www.gov.uk/government/statistics/agricultural-price-indices
Regional and local estimates vary according to circumstances and practices
Refer to Tables 9.8 and 9.9 in MCM 2013 (Penning-Rowsell *et al.*, 2013) for more detail.

Table 9.6 Defra advise that different assumptions are made for alternative agricultural flood defence scenarios*

	Scenario I	**Scenario II**	**Scenario III**
	Land lost to agriculture	Temporary, one-off loss of agricultural output	Permanent change in the value of agricultural output
All agricultural land use	Loss equivalent to market value of land less £600/ha to reflect 'single payment' subsidies where received (no adjustment on land for fruit and vegetables)		
Crops: Cereals; oilseeds; beans/ peas. **Grassland:** Beef and sheep		Loss of Gross Margins per ha (adjusted for possible savings in costs), plus clean-up costs	Change in Net Margins associated with change in flood and land drainage conditions
Other: Dairy; sugar beet; potatoes; high value fruit/ vegetables		As above, treated as though area occupied by wheat	As above, treated as though area occupied by wheat

* Following Defra Guidance, 2008 (See also Tables 9.4 and 9.5 above)

NB. This is Table 9.16 in the MCM 2013

Table 9.7 Estimated seasonally weighted cost of a single annual flood and indicative average annual damage flood costs by land use and drainage condition, all England and Wales monthly distribution of flooding (2019 prices)

	Drainage condition	Cost of a single annual flood £/ha	Indicative flood return period by land use, years	Average annual cost of flood damage according to indicative return period, £/ha
1. Extensive grass	Good	98	1	98
	Bad	79	0.75	105
	Very Bad	49	0.5	98
2. Intensive Grass	Good	177	3	59
	Bad	49	2	25
3. Grass/Cereal Rotation	Good	402	8	50
	Bad	311	5	62
4. All Cereal	Good	632	8	79
	Bad	451	5	90
5. Extensive Arable	Good	652	8	82
	Bad	480	5	96
6. Intensive Arable	Good	1154	10	115

Notes:
Some minor rounding errors
This is Table 9.20 in the MCM 2013