ECONOMICS OF COASTAL HAZARD PREVENTION

ECOSHAZ

ECONOMICS OF PREVENTION MEASURES ADRESSING COASTAL HAZARDS

GUIDELINE 1

IMPLEMENTATION OF COST BENEFIT ANALYSIS OF COASTAL RISK MANAGEMENT PREVENTION MEASURES AGAINST NATURAL HAZARDS

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Chapter 1: Introduction

These Guidelines are built on the EcosHaz **COMMON FRAMEWORK OF COASTAL HGAZARD AND RISK MANAGEMENT** (EcosHaz TASK C1) but are intended to be a stand-alone "How to do it" guide to assessing the benefits of flood risk management (FRM) at the coast.

When put together 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 cost of investment decisions. This comparison should enable the users to identify those risk management plans and schemes which maximise the economic return to their nation (not the locality nor the region in which the scheme is located) and therefore represent "best value for money" by being economically efficient.

The rationale for this approach is that most of the resources used for coastal protection schemes in most countries come from national taxation, and therefore the nation is the appropriate reference point for the appraisal calculations. Where resources are not sourced in this way, then a different approach might be taken, emphasising financial gains and losses rather than economic gains and losses.

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 hereinafter for simplicity.

These Guidelines are intended to allow appraisals of flood and coastal erosion risk management schemes to be undertaken with the minimum of appraisal effort. One important dimension of this 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 flood damage per unit floor area is generally far higher than residential flood 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. ensuring flood probability and erosion rate data is of the highest quality readily available).

1.1 The basis of flood and coastal erosion CBA: predicting the future

It should never be forgotten that the cost:benefit analysis of coastal risk reduction measures concerns the future. And it is well known that predicting the future is difficult, even with the most sophisticated scientific analysis. Therefore uncertainty is inherent in this process, and therefore we must proceed with caution.

Any cost-benefit analysis seeks to gauge the likely future direction of coastal losses, and use these as a basis for predicting how much it is worthwhile spending to alleviate or even prevent those losses in the future. This does not mean to say that there will not be political pressure to prevent the kind of damages that occurred in the last major flood or erosion event at any given location. These pressures should be resisted, because gauging expenditure for long-term investment on the basis of what has occurred in the past in single events is likely to be erroneous.

In this regard, local opinions concerning coastal hazards and their mitigation should not be dismissed, but they should be understood in relation to the above point concerning the national focus of expenditure on coastal hazard mitigation and the need to provide national taxpayers with the most efficient solutions possible.

1.2 Economic efficiency: the sole criterion

We also need to remember that cost-benefit analysis (CBA) uses economic efficiency as the sole criterion for guiding decision making. Economic efficiency is measured as the balance of outcomes versus inputs, and only when that is at maximum is economic efficiency to be found.

Thus, in the most extreme example, it is economically more efficient to “unfairly” protect those with larger assets from flooding (i.e. rich households or valuable factories) than it is to protect those who are poor and with meagre assets. We can counter this possible “unfairness” effect in two ways, and this diversity of situations and planning tools needs to be acknowledged here:

- Employing weightings within the CBA to increase the apparent benefits of protecting the poor, as is now common practice in the United Kingdom (Environment Agency, 2010).
- Employing spatial planning, outside or alongside CBA, for instance as in Spain. Here land planning has a very important role in the wealth distribution and socio-economic balance of regions.

1.3 What to do without good data

In many cases, and in many countries, good data may be lacking for the application of CBA. This should not be a reason for not proceeding to do some form of economic analysis:

- Using the best available data ahead of data quality improvements
- Using surrogates (e.g. the number of properties affected if damage/loss values cannot be found)
- Using data from other regions or countries (e.g. from the UK, where there is a data rich environment for flood and erosion CBA)
- Using educated guesses and professional judgement!

At least even the last approach listed here will begin the ‘thinking process’ that is embodied in CBA, and is actually one of its main objectives.

1.4 Some further caveats

As stated in our C1 report, it is inevitable that some factors will not be able to be included in a traditional economic analysis of flood/erosion risk management measures. The strategy to be adopted in the appraisal process here should be to describe these factors in as much detail as possible, so that those making the decision can take these into consideration. Also:

- Many so-called "intangible" effects can be taken into consideration using a multi-criteria approach (Reference FLOOD-CBA C3 report on MCA).
- Other factors are even more difficult to quantify, such as the disruption, inconvenience and noise created during construction of major engineering works.
- The loss of life floods is often an important consideration, yet there is disquiet about quantify this in monetary terms, despite this being quite normal for life insurance companies.
- Certain environmental aspects of flooding and erosion are also difficult to quantify in economic terms, and they have to be left with detailed descriptions. An example here might be a salt marsh, eroded or flooded by the sea, providing environmental benefits to the locality and indeed to the nation which are not easy to quantify in money terms.

As indicated above, the best approach here is to describe in full the potential effects of the flood/erosion risk management scheme – positive or negative – and leave it to the decision-makers to make the decision.

There is, of course, the danger that the most important considerations are those that have to be described in this way, and the economic analysis simply considers those matters which are simple to quantify.

There is no easy way round this dilemma, except to stress again that economic analysis is a guide to decision making, rather than a system that decides "by itself", and that proper stakeholder engagement will be an important mechanism whereby these considerations that are not included in the CBA are foregrounded.

Chapter 2: Frameworks, principles and data: flood risk mitigation

In this chapter we provide pointers as to how a flood risk management benefit assessment should be conducted for a flood CBA. This draws on the theory that should guide this and the sources of data that will be necessary.

2.1 Types of flood damage and flood loss[1]

The benefits of flood alleviation comprise the flood damage and loss averted in the future as a result of schemes[2] 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. This situation is summarised in Table 2.1.

In the case of "intangible" losses, where money values cannot be applied, it is important to record in a narrative form the extent of these possible losses, rather than ignore them, so that any appraiser and decision maker can take these aspects into consideration when making their decisions. The more detail that is provided about these intangible aspects of both costs and benefits the more they can be taken properly into consideration and weighed against monetary aspects which in most cases are easier to quantify.

It is important to ensure that for the purposes of cost-benefit analysis we normally assess only the national/regional 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 2.2).

Table 2.1		Direct, indirect, tangible and intangible flood losses 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

[1] "Damage" is direct damage to property touched by flooding; a "loss" is broader than this, covering loss of business activity by factories affected by flooding cutting roads, etc.

[2] Structural or non-structural (see Chapter 1).

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

Table 2.2	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	

2.2 Calculating annual average damages

The methodology for assessing the benefits of flood alleviation combines:

- An assessment of the hazard, 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.

A combination of the above two, as the annual average flood damage, is a general statistic summarising risk at any one location and can be capitalised to generate a "lump sum".

Figure 2.1 provides the classic four-part diagram summarising the inter-relation of hydrology, hydraulics and economics as the basis of calculating the benefits of flood alleviation. The annual average flood damage is the area under the graph of flood damage/loss plotted against exceedance probability (the reciprocal of the return period in years), often termed the 'loss-probability curve'.

In Figure 2.1 Part B shows that floods with low probability of occurrence tend to have high discharges (in rivers), or large volumes of flood water (at the coast). Part A shows that these rarer floods tend to be deeper (that is to say flood stage is larger). These two parts summarise the hydrology/hydrography of floods, just indicating that the rare floods are both deeper and larger, as any historical records of flood events will demonstrate. Part C shows that the larger and deeper events are associated with greater levels of damage, which in most cases will be self-evident.

In Figure 2.1, Part D brings these three elements together to graph damage against probability, showing that the low probability larger events are associated with higher levels of damage. As indicated above, this is a graph of loss against probability: the 'loss-probability curve'. The two colours here show the difference with and without some intervention scheme, whereby the loss-probability curve is pushed downwards (into the yellow area), revealing the orange area as measuring the benefits of flood risk reduction, measured as the annual average benefit, since the area under each of these curves in part D represents the annual average damage.

Once the annual averages have been determined in this way, the values need to be cumulated over the anticipated lifetime of any intervention (i.e. annual average times the number of years of scheme life, such as 50 or 100 years for most major engineering works but less long for other measures). These sums in the future need to be discounted to give the present values of damages (PVD).

Discounting is a complex subject which would require a lengthy explanation here, and therefore the reader is referred to Penning-Rowsell et al. (2013), pages 44-46 and the literature cited there. Suffice it to say that the process of discounting makes all costs and benefits comparable, whenever they occur in time, and this is an essential part of the appraisal process.

Figure 2.1 The classic 4-part diagram summarizing the calculation of annual average flood losses

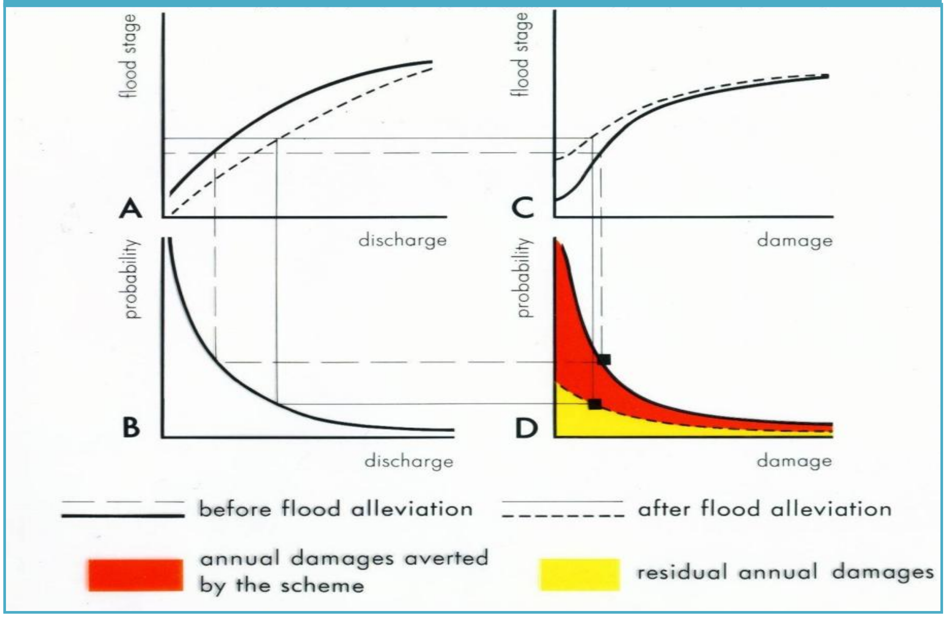
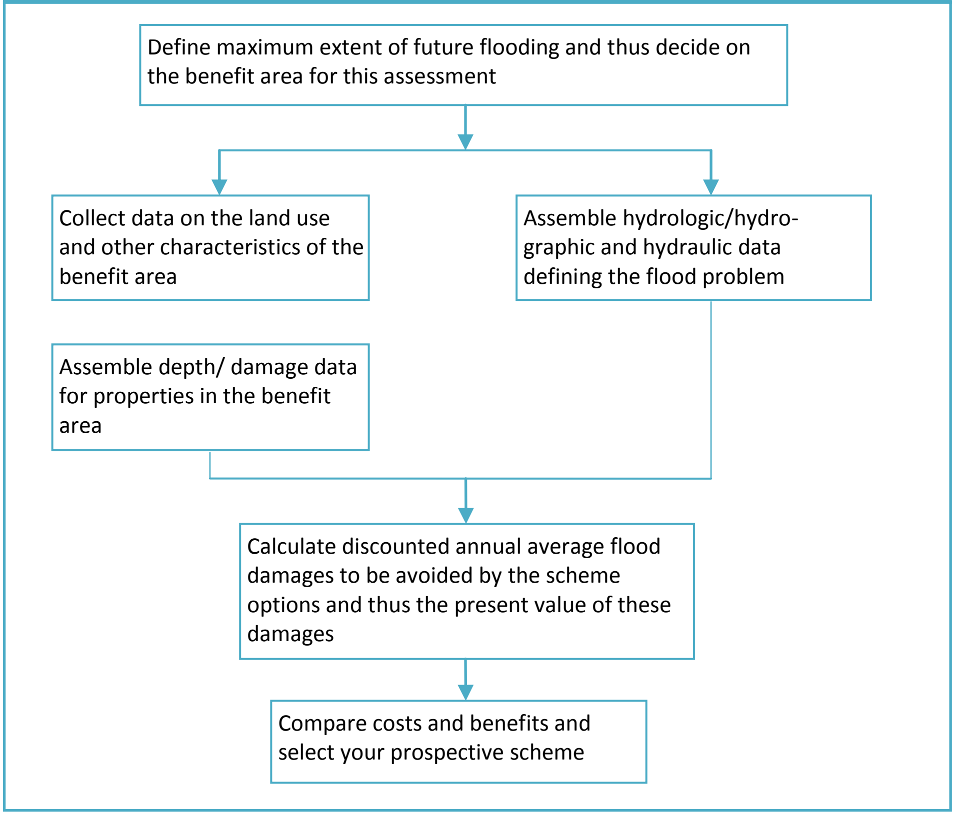


Figure 2.2 gives a simplified flow chart of the stages that need to be followed in order to calculate the benefits of flood alleviation (or, put another way, the stages for calculating the Present Value of flood Damages/losses (i.e. 'PVD') that will occur in the future if a "do nothing" option is adopted).

Figure 2.2 The stages that need to be followed in order to calculate the benefits of flood alleviation to compare with scheme costs



2.3 Data inputs

2.3.1 Defining 'the benefit area'

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

Usually the benefit area will be the maximum known or modelled extent of flooding in the area involved. However, it may also be necessary to extend the benefit area beyond the flood plain as conventionally defined by, say, the 1 per cent probability event. The indirect effects of flooding can also extend well beyond the flood plain. Telecommunications, road and rail traffic disruption can occur many kilometres from the flood plain, 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, gas, telecoms and electricity supplies.

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

2.3.2 Data inputs: Assessing vulnerability to flooding for the land uses in the benefit area

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

It is customary within cost-benefit analysis of flood alleviation 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 benefits it will be necessary to determine:

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

Field surveys can identify land uses in the benefit area. Otherwise, national databases are the first source of data that should be consulted (e.g. in the UK the Environment Agency's 'National Property Dataset'; the Cadastre and SIOSE databases in Spain), but field surveys may also be necessary to determine the type of non-residential property in the area and its floor area.

2.3.3 Data inputs: Flood damage data – the general approach

The general approach here to assessing the benefits of protecting properties from flooding encapsulates the following principles:

1. Data in the Middlesex University Flood Hazard Research Centre's (FHRC) datasets (i.e. 'MCM-Online'[3]) and Manuals 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.
2. Much of the flood damage data available from the literature is "synthetic" (i.e. from a synthesis of many data items). It is therefore not directly derived from an analysis of properties which

[3] http://www.mcm-online.co.uk/public/ This is a free-of-charge dataset.

have been flooded in the recent past, not least because evidence suggests that post-flood surveys can be very inaccurate.

3. 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.
4. Any taxation element within potential flood losses is subtracted, because these are transfer payments within the economy rather than real resource costs. Therefore the Value Added Tax (VAT) element in UK repair costs is not counted. The same principle should apply in other countries, deducting any taxation from flood damages or erosion losses in order to get to national economic efficiency values. As indicated above this is necessary in order to compare them with the costs of any interventions, which generally come from national taxation.

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 that is not flooded.

2.3.4 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 flood plain and the accuracy of the hydraulic profiles that intersect this surface.

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 new GPS
- 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 causing damage. In coastal locations this will obviously relate to the failure of existing raised defences such as sea walls or dikes (by overtopping or breaching), and the probability of such failure is likely to be difficult to establish. Nevertheless without this data no appraisal is possible.

Whilst the quality of all data as inputs to this kind of analysis is important, 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 and in each country.

2.4 Loss-probability curve and related issues

2.4.1. Residual risk

In the UK, the Environment Agency's project appraisal guidance (FCERM-AG (EA, 2010)) decision rules seek the lowest acceptable standard of protection commensurate with maximising the difference between costs and benefits. Schemes therefore may not protect wholly or even significantly against the more major floods4.

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 'dis-benefits' requires the assessment of the impact and damage of the major floods not avoided. Such assessments will often be time-consuming, particularly for the very low probability floods which may cover large areas.

2.4.2 Decision rules and options

In the UK the Environment Agency appraisal guidance (EA, 2010) provides a logical decision making approach with regard to the standards of flood protection to be implemented.

This approach requires:

1. First, identifying the scheme with the highest benefit:cost ratio.
2. Secondly, assessing the incremental benefit:cost ratios for alternative schemes which allow higher standards of coastal protection to be considered.
3. Choose the scheme with the largest difference between benefits and costs and where an increase in the standard of protection would lead to a negative incremental benefit:cost ratio.

Flood risk management options should be appraised against these rules, so as to seek the best value for public money. When a mix or 'portfolio' of option elements is being appraised, this can be a complex operation.

[4] There may well be similar guidance in other countries, and this should be sought out to ensure that procedures undertaken there are relevant to local circumstances. However, this reference here is to one of the most comprehensive sets of guidelines we have found, as developed over many years in the UK. In each case, however, the user should look to investigate the marginal increase in benefits with the marginal increase in costs, to determine which scheme is most economically efficient at a given location.

Chapter 3: Flood damage to residential properties, and related social impacts

Residential flood damage is significant in almost all cases of serious flooding, and remains an area of public and governmental 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. In addition, and as an example only, information is provided for incorporating UK government guidance on the appraisal of the indirect and intangible impacts of flooding.

The assessment of direct residential property flood damage potential in the UK utilizes the standard data available from Middlesex University (at "MCM-Online")[5]. The most detailed standard flood damage data provided there is for:

- Five house types;
- Seven building ages; and
- Four different social grade/grouping of the dwellings' occupants

Each of these variables is known to affect flood damage, and flood damage is the basis of the cost-benefit analysis (CBA) of flood risk reduction measures (see Chapter 2). Other EU countries will have their own depth/damage data, and this should be used wherever it is appropriate to do so.

3.1 Underlying assumptions

Damage data. The UK's residential potential flood damage data for household inventory and building fabric items is based on damage per property (not per unit of floor area such as /m^2) and uses economic values not financial values (see Table 2.2). The assumption behind this is that many houses are very similar to each other, and can be treated as such within the appraisal of flood risk management schemes: a house is a house is a house. Other EU countries will have their own depth/damage data and it will be necessary when using this data to have a good understanding of the assumptions behind its compilation.

The 'intangible' effects of flooding. The 'intangible' effects of flooding are now recognised to be significant. UK research has begun to establish an economic valuation of the intangible health impacts

[5] Some of this data is available free of charge at: http://www.mcm-online.co.uk/public/

of flooding. This research confirmed the significance of the health impacts of flooding and led to the publication of interim guidance (Defra, 2004). The 'Floodsite' project continued this work, looking at a European scale[6].

3.2 Strategy-level project appraisals

A flood CBA can be undertaken at several levels of detail, depending on what data is available and the stage of decision-making involved (i.e. preliminary 'outline' ideas, or detailed investment appraisal) (see Table 3.1). In many situations it would be wise to start with a strategic level assessment, fundamentally to investigate whether more detailed analysis is worthwhile, driven by the significance of the problem being analysed. Significant resources will be saved if analysts do not embark upon detailed investigations before taking an overview of the situation and thereby determining where to maximise effort in the appraisal process by examining "hotspots" revealed by the overview/strategic analysis.

Table 3.1 Strategic, outline and full feasibility methods

Scale of analysis:	Strategy	Outline	Feasibility
Guidance	For rapid '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 benefit area	▪ Number of properties at risk	▪ Number, type and age of house at risk ▪ Standard of protection (pre and post scheme for intangible values)	▪ Number, type, age and social class of houses and householders at risk ▪ 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	▪ Detailed standard data for type, age and social class of houses and householders ▪ Vulnerability analysis where feasible
Indirect/intangible method of assessment	▪ Surrogate vales for average indirect losses ▪ Health: £200 per property per year for intangibles	▪ Surrogate values for indirect losses and ▪ Vulnerability analysis where feasible (see MCM 2013) ▪ Health: £200 per property per year for intangibles	▪ Surrogate values for indirect losses and ▪ Vulnerability analysis where feasible (see MCM 2013) ▪ Health: £200 per property per year for intangibles

And the most basic level of analysis, where only the number of properties in the benefit area is known, and therefore there is no flood probability data available, approximate flood alleviation benefits can be derived by making some assumptions about the depth of flooding expected from floods with different

[6] *www.floodsite.net/*

return periods. In the UK it is then customary to use Weighted Annual Average Damage (WAAD) figures as initial estimates of potential direct damages (Table 3.2).

Table 3.2	Weighted Annual Average Damages (WAAD) assuming variable threshold Standards of Protection (SoP) (UK example)
Existing SoP	**No warning (£)**
No protection	5393
2 years	4824
5 years	3116
10 years	1582
25 years	743
50 years	316
100 years	79
200 years	39

To employ both these two methods, above, 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 in the UK from the National Property Dataset (NPD3), from the Environment Agency; other countries will have their own sources of data on properties at risk, including from the flood extent maps required under the Floods Directive. The depth of flooding is determined from the ground level data and the results of hydraulic modeling or, more likely at this exploratory 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 their return periods, use the weighted annual average damage (WAAD) approach, if this is available, broken down by warning lead time and the standard of protection (Table 3.2). Table 3.2 gives the reduced values provided by different standards of protection and different levels of flood warning (to which householders are assumed to respond effectively).

However, where this WAAD value is used in outline studies, as the weighted annual average damage per residential property within a defined benefit area (say, the 1 in 200 year flood plain), the number of properties affected by successively more frequent return period floods should be reduced (for the UK, as in Table 3.3). This is a very “rough and ready” exploratory method, to be used with caution.

Table 3.3	Estimate of the number of properties affected by different floods (UK example)
Return Period	**Number of properties as % of 200 year number**
100	93
50	80
25	25
10	10
5	5

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 here 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.

Using less than three floods will give grossly exaggerated and misleading results, and using five events is much to be preferred.

3.3 Outline project 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 or some other source (‘Google maps/Street View’ can be useful here; cadaster in Spain).

With this information, the appraisers should then use the depth/damage data available in their countries. Identifying the variables used to classify dwellings should be a routine procedure in the field. Firstly, identifying the type of dwelling can be done from maps (e.g. in the UK, with the OS MasterMap) and from direct observation. Secondly, by contrast, assessing the age of any dwelling may involve a small degree of subjectivity unless City/Town Halls and their spatial planning departments can provide mapped information

3.4 Full feasibility project appraisals

In full scale (detailed) appraisals, it is appropriate to differentiate houses in the benefit area by their type, age and the social grade/group of the occupants (for the UK, as in Table 3.1). This means that the most detailed direct damage data available in each country (and for the UK provided at MCM-Online) can be used.

Detailed standard residential depth/damage data. Social grade/group affects flood damages (the more affluent people suffer greater monetary loss, on average). In the UK, the social grade/group of the occupants of the houses in the benefit area should be established. Because the social grade or household income variable derived from census data in many countries relates to the census output area (OA) as a whole, and not to the individual dwelling's occupants, the social grade/group of individual occupants is calculated on the basis of weighted averages.

3.5 "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: it is not worth spending more than the property is worth in the marketplace to protect it from flooding. This "capping" is ideally done for all levels of project appraisal but certainly at the most detailed level.

3.6 'Health warnings'

Cost:benefit analysis (BCA/CBA) is not an exact science. So we need to be cautious in its application, and use the relevant data with a good understanding of its limitations. For example:

1. Applying nationally based data to small areas locally may lead to errors.
2. The figures given at MCM-Online for the UK do not include damage from saltwater. Where saltwater flood damage is expected, flood damage repair costs to building fabric are estimated to increase by 10% (Penning-Rowsell et al., 2013).
3. The "intangible" losses from flooding at the coast may be very considerable, including injury and loss of life. The guidance in Chapter 2 herein should be consulted in this respect (2.1).

Chapter 4: Flood damage to non-residential properties (NRPs)

4.1 Introduction

Flood damage to Non-Residential Properties (NRPs) can be a significant factor when considering major expenditure on flood risk management measures at the coast. The NRP flood damage data are available at MCM-Online[7] as depth/damage and depth/damage/duration data in which short, long and extra-long flood durations are considered.

These data were generated employing a new method of data acquisition during 2012 and replace the data contained in the MCM (2005) and MCH (2010). The data have been selected and compiled to represent 95% of NRPs located in flood risk areas of England and Wales and it is likely that the same is broadly true in other EU countries.

The data are broken down into six components of damage:

- building structure and fabric;
- building services;
- moveable equipment;
- fixtures and fittings;
- stock;
- clean-up costs.

In addition, the 2013/14 data includes damages from saltwater and wave impact for coastal flood risk management (FRM) schemes, and the damage-reducing effects of flood warnings.

4.2 How to use the data

The potential flood damage data needs to be related to flood probability in order to calculate annual average flood damages, which is the key appraisal objective (see Chapter 2).

A property-by-property database is required which identifies the type of property (e.g. see Chapter 4, Annex 4.1, below), and the ground floor threshold height above which flooding will start to enter the property and cause damage. 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 flood model or other data system which allows flood depths for a range of floods of different probability to be assigned to each property.

[7] Repeat footnote from Ch 3

4.3 Overview studies

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

The number of properties in the flood affected area 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 electricity substations. These are the NRP sub-sectors and categories for which discrete weighted mean depth/damage/duration data are provided (see Annex 4).

A very low resolution preliminary 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 or €/m^2 therefore the area of the ground floor area/space of each NRP also needs to be entered into the property-by-property database. In the UK the National Receptor Dataset (NRD) is used to determine each property's footprint. If unavailable, the following sources of information may be used depending on the resources available:

- Determine floor area by field measurement; or
- Use GIS tools to measure the area from OS 'Mastermap' or the national equivalent ; or
- Use the indicative floor sizes provided in Table 4.1 within the Standard Data for Chapter 5 on MCM-Online.

Table 4.1 Indicative floor sizes for Non-Residential Properties (UK data)

New MCM Code	Property Type	Floor Area (m^2)
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	Multi-Storey Car park	2,700
960	Electricity SubStation	48

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

This information will need to come from river, water, flood or the equivalent national/regional agencies, and is important because to assume there is no current protection is likely to be erroneous and will exaggerate calculated benefits.

***Step Four**: Apply the Weighted Annual Average Damages (WAAD)*

The WAAD values (see Chapter 3) are then taken from the Table 4.2 herein 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 Table 4.2 represents the different subsector/category levels. Annual benefits can be converted to capital sums using discounting (see Chapter 3).

Table 4.2 2013-2014 Price base Weighted Annual Average Damages [£] (see text)

		Standard Of Protection						
New MCM Code	**Sector Type**	**None**	**5**	**10**	**25**	**50**	**100**	**200**
2	Retail	69.87	34.47	25.10	12.92	5.77	1.44	0.72
3	Offices	66.43	31.11	23.31	11.77	5.19	1.30	0.65
4	Warehouses	81.72	43.33	31.32	15.89	7.20	1.80	0.90
5	Leisure and sports	NOT APPLICABLE - CONSTITUENT CATEGORIES TOO DIVERSE						
51	Leisure	127.38	44.82	35.50	16.30	7.00	1.75	0.88
52	Sports	NOT APPLICABLE - CONSTITUENT CATEGORIES TOO DIVERSE						
521	Playing Field	0.89	0.40	0.30	0.15	0.07	0.02	0.01
523	Sports Centre	24.88	11.40	8.56	4.22	1.87	0.47	0.23
526	Marina	9.08	4.40	3.18	1.65	0.73	0.18	0.09
525	Sports Stadium	9.44	4.24	3.18	1.60	0.70	0.18	0.09
6	Public Buildings	32.92	15.85	11.78	5.95	2.64	0.66	0.33
8	Industry	13.24	6.75	4.91	2.52	1.13	0.28	0.14
9	Miscellaneous	NOT APPLICABLE - CONSTITUENT CATEGORIES TOO DIVERSE						
910	Car park	2.19	1.16	0.82	0.44	0.20	0.05	0.02
960	SubStation	181.24	112.05	79.95	43.91	19.90	4.97	2.49
NRP sector average		65.26	34.52	25.25	13.41	6.14	1.63	0.81

4.4 Initial and full-scale studies

A step-wise approach to data assembly is also suggested here:

***Step One**: List the NRPs in the benefit area*

- Determine the number by sub-sector or category of NRPs in the benefit area.
- 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, using one of the following sources. Selection will depend upon available budget and timescale. For example:

- Determine area by field measurement; or
- Use GIS tools to measure the area; or
- Use the indicative floor sizes provided on MCM-Online.

  And:
- Determine the property ground floor threshold level through the use of a site survey.

***Step Three**: Linking land uses to the new MCM-Online depth/damage data*

- Link the land use types to the weighted sub-sector or category mean depth/damage data on MCM-Online.
- Use the NRP sector weighted mean data for any miscellaneous sub-sector 9 'unknown' properties.

***Step Four**: Allocate depth/damage/duration data*

- Within MCM-Online UK database, the preferred depth/damage/duration data for each NRP (MCM) code with appropriate data quality are available.
- At the coast, 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*

- Calculate the estimated present value of NRP damages (PVd – discounted annual values over the life of any prospective scheme), using proprietary software, as indicated in Chapter 3.

4.5 Site surveys

The variety of NRPs is considerable, and average/standard depth/damage data given in MCM-Online 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 flood damage data by damage data collected locally 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 the appraisal. These 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 high or very high average annual damage.

A simplified approach will focus on the following questions making sure that flood damage or cost estimates exclude taxes such as 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.

4.7 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 damage data sets than other flood loss data.
- The type and function of an NRP is not necessarily the most important determinant of potential NRP flood damage. Flood depth, property size and precautionary measures all tend to 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.
- Error is present in any flood damage data set and therefore it is wisest in any appraisal (at any scale) to subject these data and the results they give to sensitivity testing.

Chapter 4: Annex 4.1

Matching the UK's National Receptor Dataset (Multi-Coloured Manual) codes to the new 2013 Multi-Coloured Manual codes

NRD MCM code	Description	New 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)**	
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

Chapter 5: Business disrupted by flooding: potential losses and benefits

5.1 Introduction

Disruptive impacts of floods arise from direct damage to business properties and their contents and to infrastructure that they depend upon. These disruptive impacts are sometimes called 'indirect' or 'consequential' losses and avoiding them generates benefits.

Business disruption can be substantial especially when impacts on supply chains and reputational values are taken into account. On occasions even small events can have major disruptive impacts whereas, sometimes, large events have fewer impacts,

However, generally, the larger and the more severe the flood, the larger will be business disruption. Much depends on the characteristics of flooding and the number, density and type of businesses which are flooded and how they are linked. Unlike direct damages which are largely invariate over time, consequential impacts are time-variate and often evolve in the days, months and even years after the relevant flood event.

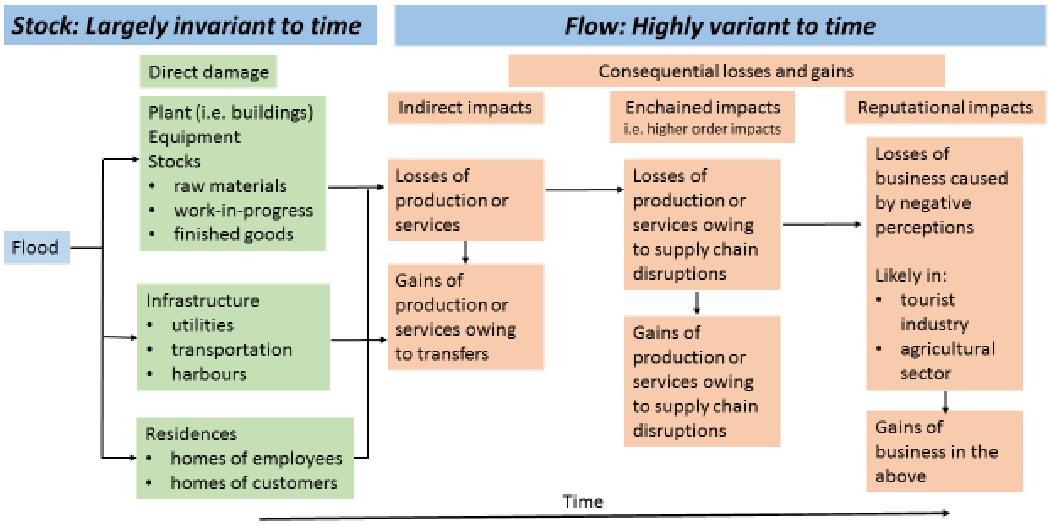
5.2 How businesses are disrupted

One of the fundamental distinctions in economics is between stocks and flows (Figure 5.1). Stocks refer to a quantity at a single point in time, while flows refer to the services or outputs of stocks over time.

Direct property damage represents a decline in stock value at the time of the flood and usually leads to a decrease in service flows. Business disruption losses are a flow measure and include a time dimension (i.e. they occur over time in the period following the flood). However, business disruption losses emanate only in part from a company's own property damage. All businesses are forward-linked (i.e. they rely on regional customers to purchase their output) or backward-linked (they rely on regional suppliers to provide their inputs) and are thus potentially vulnerable to interruptions. So a business may be disrupted by a supplier's property damage or, say, because of the disruption of a vital transport link.

Figure 5.1 portrays the linkage between business stock (i.e. direct) and flow (i.e. consequential, including indirect) losses. In effect business disruption losses start with initial indirect impacts upon a business (if it is flooded) and then ripple forwards in time through enchained (or higher order) impacts caused by supply chains inter-dependencies.

Figure 5.1 Stock and flow flood impacts on the business sector



A business that is not flooded may still suffer disruption if a company in its supply chain is flooded. Some business sectors are particularly susceptible to a particular type of consequential loss caused by reputational impacts.

The tourist sector is especially susceptible to reputational damage following natural disasters such as floods and this may extend consequential losses over a number of years after a flood. Figure 5.1 also shows that although some businesses lose as a result of flooding disruption, others are likely to gain because purchases will be transferred from disrupted to non-disrupted businesses. Although it is often difficult to identify and estimate business gains, the net loss is therefore the correct measure of business disruption loss.

5.3 Effects and scale of business disruption

The effects of business disruption can be short- or long-lasting and they may spread well beyond the flooded area: much depends on the scale and severity of the flood, its direct impacts and whether business continuity plans exist and reduce disruptive impacts. Apart from large businesses and business sites which are part of larger corporations, business continuity planning for coastal flooding is not particularly well developed in Europe (see Parker et al., 2012). The extent of indirect losses also depends upon such factors as the availability of alternative sources of supply and markets for products, the length of the production disturbance and the 'deferability' of production.

In floods which are not particularly severe and/or damaging and where the number of businesses flooded is relatively low (e.g. <30), the value of consequential losses is unlikely to exceed the value of direct losses and is usually, but not always, considerably less. An exception is where the operations of an important, unique business are badly disrupted and the businesses which depend on it for supplies or services have no alternative supplier (the classic example here is the hard drive manufacturer in Bangkok, Thailand, which was badly disrupted by flooding affecting both its suppliers and the supply of hard drives into electronic equipment worldwide for weeks if not months after the flood event).

On the other hand, local coastal business economies may recover relatively rapidly from flooding disruption where direct damage is limited, customers are able to defer purchases in time and where the local economies' backward and forward supply chain linkages are unaffected because they are located inland and away from the flooded area.

In contrast, where business activity is heavily 'localised' (i.e. businesses have taken steps to buy and sell to others locally to try to strengthen their local economy), the flooding of one or more key businesses may have more widespread, serious local impacts. An example here would be high quality restaurants which specialise in purchasing locally may find their business disrupted if greengrocers shops selling fruit and vegetables are affected by flooding and cannot trade.

The scale of business disruption losses in large-scale flood disasters such as the Hurricane Katrina flooding of New Orleans, Louisiana in 2005 is a different matter. Such flood disasters affect businesses across the globe (as also with the Bangkok example, above) as well as their local, regional and national economies. Producer and consumer demand for goods and services may be significantly reduced and so businesses may be forced to scale back operations causing increasing unemployment or trading losses. In turn, this may well reduce personal incomes and erode household demand.

In these events disaster assistance is likely to flow and there will be an increased demand for the reconstruction sector and goods which acts as stimulus to economies. It has been calculated that when direct flood losses exceed US $100 billion in Louisiana, the scale of net consequential losses reaches 39% of direct losses and when direct losses exceeded US $200 billion, additional net consequential losses attain an amount equal to direct losses (Hallegatte, 2008).

5.4 What is the best measure of business disruption loss?

The best measurement unit is Gross Value Added (or GVA). It measures the value added to the economy of each additional hour worked by a worker (measured by the projected earnings for that hour), or the value-added by a business when it puts together different inputs to create a product or service that is worth more than the inputs used (i.e. the profit).

Sales (revenues) losses are often the most important consideration for businesses but a more appropriate measure of loss of business is lost GVA. Avoidance of potential GVA losses is the benefit of flood risk management measures taken specifically to reduce this loss potential. Average annual earnings data for different business types are usually available from secondary sources [8].

5.5 How can we measure business disruption losses and benefits?

Economic models, such as input-output models which measure the relationships between producers and consumers in an economic system, are commonly employed by economists to estimate the economic consequences of large-scale disasters. However, these models are too complex and too costly to employ on most cases of coastal flood loss assessment which are not large-scale disasters. Given this, a number of approaches may be employed depending upon the data and resource available. The method in 5.5.3 below is considerably more resource intensive than the other two methods (5.5.1 and 5.5.2).

5.5.1 Qualitative assessment

A succinct written narrative describing the likely business disruption consequences of an event or range of events, categorizing these consequences on a simple scale such as (i) minor (ii) significant and (iii) major. The results of CBAs may be presented with quantitative and these qualitative components.

5.5.2 Uplift factors

An uplift factor is defined as the amount by which the best estimate of total direct loss is increased to take into account likely consequential losses. The costs of business disruption have been researched in depth in the UK for two widespread flood events in 2000 and 2007. In these floods the consequential loss uplift factor was 31% and 27.6% respectively. These estimates reflect the reported financial losses to the businesses which were flooded (see Table 2.2).

The economic loss uplift factor is significantly less and lies between 2%-6% because of transfers of business between losers and gainers.

Transferring these uplift factors to different floods and different settings and countries is questionable and likely to lead to estimation error but these uplift factors may be used where no other estimate is available as long as the necessary caveats are explained. Thus if the direct damages to relevant non-residential properties were estimated at €300,000, then to assess the total direct and indirect (consequential) economic losses could add an additional €6,000 to €18,000 as a measure of the indirect losses within that total (then the total rises to €306,000 to €318,000).

[8] In the UK the Office of National Statistics publishes on-line the Annual Survey of Hours and Earnings. In Spain, Instituto Nacional de Estadística (INE, www.ine.es) regularly publishes on-line surveys. There are likely to be similar data sources in other countries.

5.5.3 Supply chain identification and GVA loss estimation

Analysts need to proceed as below:

1. Identify the principal businesses in the flood risk zone which are likely to be flooded or affected by disruption of infrastructure on which they are likely to depend.
2. Through interview with owners or managers of these companies, identify the principal forward and backward linkages in their supply chains and how these linkages are likely to be affected by the companies being flooded (the supply chain may extend beyond the flood risk zone).
3. Calculate the value of working hours potentially lost through business disruption, per business for each business type. Use the following formula – (*Average annual earnings per employee (business type 1) X Average number of employees per business (business type 1) X (Average expected length of disruption (weeks)/52).*
4. Calculate the total expected value of working hours lost across all businesses in each business type. This is calculated by multiplying the value in iii) by the number of businesses in each particular business type.
5. Calculate the total expected value of working hours lost across all businesses. This is done by summing up the total expected value across all business types (see formula below):*Sum[total expected annual value (business type i)] over all i*

It should be noted that this approach only provides an estimate of financial rather than economic loss.

5.6 Cautionary issues

The state-of-the-art of consequential business loss and benefit assessment is not yet as well developed as that for direct losses and benefits and therefore it presents considerable uncertainties. It is essential that uncertainty is recognised within all calculations and approaches used. The ways in which impacts on the economy are realised over time are uncertain.

Therefore it is important to:

- Present results using ranges where at all possible to reflect the extent to which results differ under alternative assumptions.
- Be transparent about key assumptions and the evidence used. In particular, be sure to highlight limitations in the analysis so that your results can be interpreted appropriately.

Chapter 6: Coastal erosion risk management: potential losses and benefits

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.

Coastal 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 (i.e. continue as before the works were implemented).
It is important to note here that coastal protection works involve a range of structural and non-structural measures, both designed to prevent the erosion of land by the sea or to minimise its effects.

- Engineering measures can involve seawalls, groynes, beach nourishment, dune restoration, off-shore structures and other devices designed to lessen the power of the sea or to stop it invading the land. In all cases these measures seek to prevent the loss of valuable assets on that land, including houses, infrastructure, recreation facilities and indeed ecologically important habitats.
- Non-structural measures such as spatial planning, warning systems, and insurance arrangements are designed to prevent the buildup of risk at the coast, provide advance warning of hazard events or compensate for damage.

This chapter is designed primarily with the first of these categories in mind (engineering measures and similar interventions) but a cost:benefit analysis approach is equally applicable to loss of recreation facilities as it is to houses falling into the sea, and equally applicable to beach nourishment as to the construction of seawalls, since both have the same aim (i.e. halting the erosion of valuable assets).

We emphasise houses falling into the sea here, because it is the simplest situation in terms of measuring losses whereas, for example, the loss of recreation facilities may *imply* economic losses, but these losses could be recouped if recreation facilities elsewhere take up the demand from the facility that has been eroded and therefore lost: the recreation activity/value is transferred.

It should also be emphasised that in order to undertake a rigourous analysis all coastal protection projects are first compared with a 'do-nothing' option. This 'do-nothing' option may involve 'walk-away' and hence the prospect of substantial erosion of coastal land.

6.1 The recommended approach

In Figures 6.1 and 6.2 the key points 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 here 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.

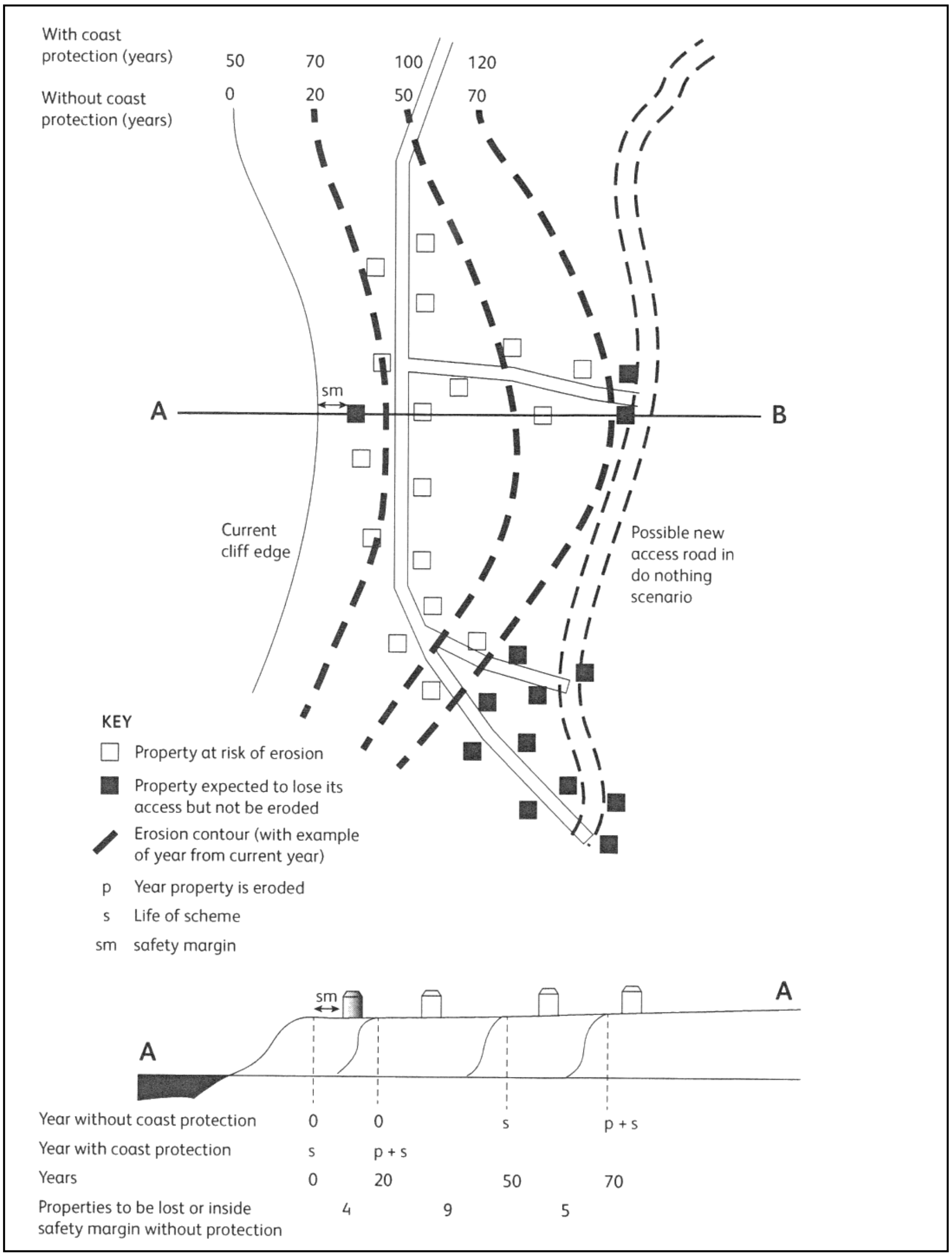


Figure 6.1 *An example of erosion contours at the coast (from Penning-Rowsell et al. (2013) p. 266*

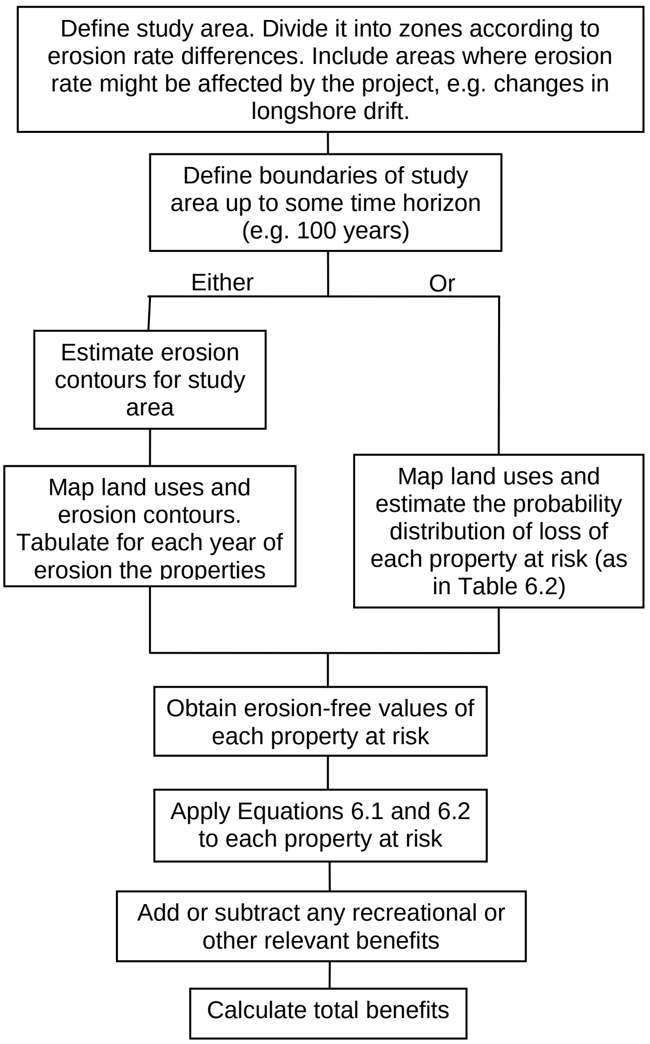


Figure 6.2 *Flow chart of the assessment process*

Table 6.1	Basic property value data for a hypothetical project to delay coastal erosion [see section 6.3]	
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 6.2	A best estimate of the probability that house 'A' (in Table 6.1) will be lost in any given year [see section 6.3]						
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

6.2 Erosion rates and "contours": recommended procedure(s)

- 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 (see Figures 6.1 and 6.2). See also Annex 6.1.
- 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. See also Annex 6.1.
- For properties at risk from erosion there will be some minimum acceptable safety margin between the cliff top edge (i.e. the erosion line) and the building: this is the point of erosion where the use of the property is assumed to be lost because it is unsafe. We recommend at least a 2-year margin.

6.3 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.

A hypothetical example

- Table 6.1 gives some property value data for a hypothetical project. These could be properties at risk of falling into the sea owing to erosion at the coast. The values are not untypical of those found in the United Kingdom.
- Table 6.2 gives a best estimate of the probability that house "A" (in Table 6.1) will be lost in any given year where the same probability function also applies to all the other properties. Please note that this is a hypothetical example, for illustrative purposes only.

- 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 6.2) is very asymmetric there can be much larger differences in calculated benefits.

Step Two: Collect value data for properties at risk

6.4 The idea of benefit as delayed loss

At its simplest, the benefit of coastal 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 "s" in Figure 6.1). 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 (or land) 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 useful life of the property.

Of course in reality the matter is never so simple: there are feedback processes induced by coastal protection structures (groynes, seawalls, etc.) that in fact can accelerate the erosion rates locally when installed. However we suggest that analysts begin with a simple approach, as outlined above, and proceed to add complexity if the analysis appears to warrant significant expenditure on coastal protection works, which in turn warrant a more complicated analytical process.

6.5 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 (MV) of similar properties in the local area: market-based property prices;
- Use the Equation 6.1 [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 6.2 [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).

6.6 Erosion free property/land prices

- The property and land prices required are market freehold values, not adjusted for erosion risk. Tables 6.3 and 6.4 provide data sets for values of the main types of dwelling found in the UK.
- We use of the value of houses at risk from erosion as an example, but it would be equally appropriate to look at the value of land, commercial property, recreational facilities, beaches, and all other "goods" found at the coast.
- These values can be used in the equations below, but greater reliability will be achieved by obtaining values locally in different countries 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).

6.7 Locally appropriate property prices: where they can be found

- The Coast Protection Authority's own valuation department, if it has one;
- The local authority; local newspaper advertisements, etc
- 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 6.3 *House prices and average annual rental values in the UK by Region*

Region	New dwellings price (£)	All dwellings price (£)	Average rent for March 2013 (£)
North East	171,684	142,240	7,080
North West	177,750	160,760	7,524
Yorks & Humber	181,427	162,841	6,948
East Midlands	191,053	171,689	6,792
West Midlands	195,398	180,808	7,200
East Anglia	255,538	249,032	8,388
Greater London	328,023	397,963	14,724
South East	290,749	292,459	9,528
South West	230,264	224,919	8,808

England (all)	232,131	242,138	8,555
Wales (all)	173,636	158,143	6,528
Scotland (all)	223,611	179,275	6,804
N. Ireland (all)	148,896	129,610	6,876

Source: (ONS, 2012) ONS House Price Index, December 2012: http://www.ons.gov.uk/ons/rel/hpi/house-price-index/december-2012/stb-december-2012.html#tab-Data-tables Published 12 Feb 2013
Source: Homelet - March 2013 Rental Index UK Regional Map https://homelet.co.uk/rentalindex/regional-map Original rental figure have been annualised by multiplying by 12 months. Please note some variation to government regions - see Horsfield (2012)

Table 6.4 *Residential property prices and annual rent by dwelling type (England and Wales)*

Average prices by property type type (England and Wales)		
	Property price (£)*	**Annual rent (£)****
Detached	253,352	13,372
Semi-detached	154,072	8,132
Terraced	122,939	6,489
Flat/maisonette	152,971	8,074
All	162,080	8,555

Notes: *December Market Trend Data from Land Registry, December 2012: http://www.landregistry.gov.uk/media/all-releases/press-releases/2013/market-trend-data-december-2012
**Annual rent for each property type has been calculated as a proportion of the average annual rent in England (see Table 6.3)

Step Three: Perform the calculations

The two formulae identified in Step 2 are as follows (see also Figure 6.1):

Equation 6.1
PV (without scheme) = $MV (1 – 1 / (1 + r)^{p})$

Equation 6.2
PV (with scheme) = $MV * (1 – 1 / (1 + r)^{p+s})$

where:

MV is the market value of the property
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 use/benefit ('s' being the scheme's effective life (see Figure 6.1)).

The procedure, very simply, involves the calculation of the discounted (market) value of the property loss with coast protection less the discounted (market) 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. In this respect all costs and benefits occurring in the future need to be discounted back to present values in order to compare these appropriately (irrespective of future inflation). This is a complex subject which would require a lengthy explanation here, and therefore the reader is referred to Penning-Rowsell et al. (2013), pages 44-46 and the literature cited there.

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 or erosion line gets nearer to the property, with erosion.

6.8 Remaining issues

1. House value trends into the future are 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 price inflation over this time is ignored in benefit-cost analysis, potential changes in relative real prices are relevant (HM Treasury, 1991) but can seriously distort the analysis by including the assumption that real property values will increase in the future, as they perhaps have in the past.
2. Other matters not covered here owing to their complexity but are tackled in the full MCM (Penning-Rowsell et al, 2013) are:
   - 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.

In relation to the first three of these, the complexity is caused by the fact that loss of infrastructure can have economic consequences far away from the coast, for example if water supply pipes are severed or gas mains are disrupted which supply property which itself is not at risk of erosion by the sea.

The complexity with regard to agricultural land is caused by the fact that many agricultural activities are subsidised or protected by national governments, or are subject to other controls, and therefore the market price for their produce and the land on which it is grown is distorted. Such distortion has to be corrected in any proper economic appraisal of protecting the coast which involves these uses of the land at risk.

6.9 Some key lessons from experience

- Flooding and erosion are often inextricably interlinked; probabilities of property loss 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: it is clear that there is market failure here, which we cannot ignore.
- 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, because as always there is other use of public money that may be more efficient or effective.
- Whatever we think, and however much we invest, it is likely that in the end the sea will win! Money should not be 'thrown' unthinkingly at an erosion problem, if the problem is fundamentally insoluble.

Chapter 6. Annex 6.1

One of the common tools to analyze coastal change is the Digital Shoreline Analysis System (DSAS henceforth). DSAS is a GIS tool that can be used to examine past or present shoreline positions or geometry. Different transects can be created with the use of airborne photography in order to estimate the coastal erosion effects and rates on the shoreline.

One of the main benefits of using DSAS in coastal change analysis is its ability to compute the rate of change statistics for a time series of shoreline positions. The statistics allow the nature of shoreline dynamics and trends in change to be evaluated and addressed.

DSAS has been developed as a freely available extension to Environmental System Research Institute (ESRI)'s ArcGIS (Thieler et al., 2009). See Spencer et al. (2015) for the implementation of DSAS in a real study case.

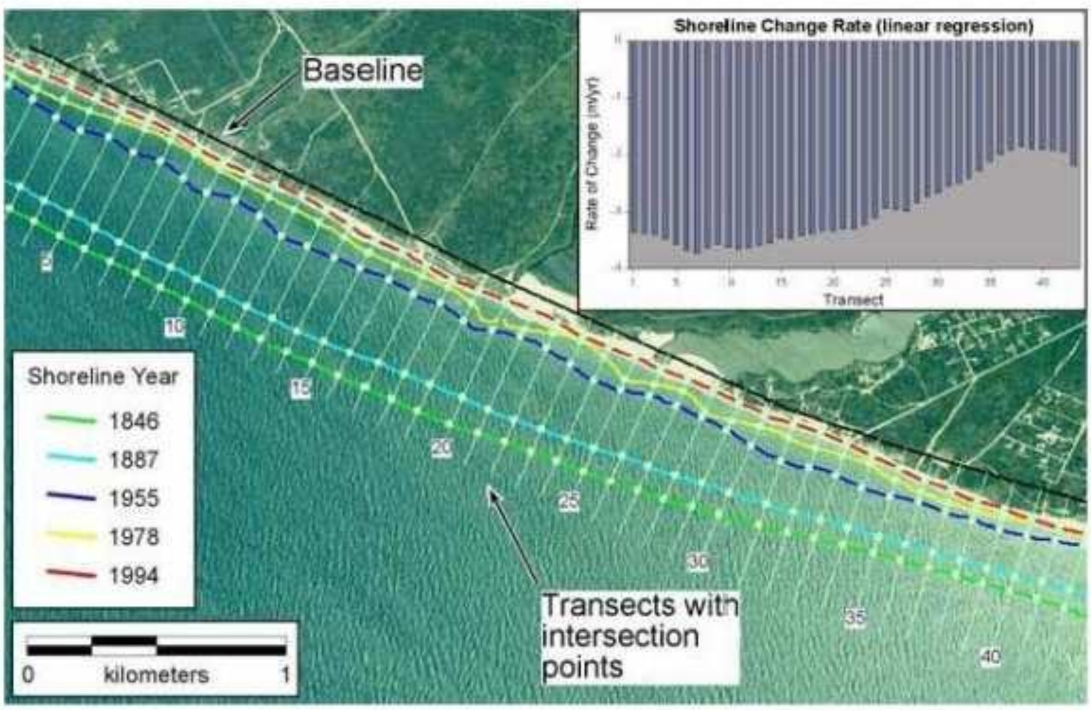


Figure A6.1
Historic shorelines and DSAS-generated transects at 100-metre spacing with histogram showing rates of shoreline change computed using simple linear regression
(source Thieler et al., 2009).

Annex 6.1 References

Spencer T, Brooks SM, Evans BR, Tempest JA, Möller I. 2015 Southern North Sea storm surge event of 5 December 2013: Water levels, waves and coastal impacts. Earth Science Reviews, 146, 120-145: http://www.sciencedirect.com/science/article/pii/S0012825215000628

Thieler ER, Himmelstoss EA, Zichichi JL, Ergul A. 2009. The Digital Shoreline Analysis System (DSAS) Version 4.0 - An ArcGIS Extension for Calculating Shoreline Change. Open-File Report. US Geological Survey Report No. 2008-1278: http://woodshole.er.usgs.gov/projectpages/dsas/version4/

References

Defra (2004) Flood and Coastal Defence Project Appraisal Guidance FCDPAG3 Economic Appraisal Supplementary Note to Operating Authorities, July 2004. Defra: London

Environment Agency (2008) Economic evaluation of damages for Flood Risk Management projects, Environment Agency, Bristol.

Environment Agency (2010) *Flood and coastal erosion risk management appraisal guidance (FCERM-AG)*, March 2010, Environment Agency, Bristol.

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.

Hallegatte, S. (2008) An adaptive input-output model and its application to the assessment of the economic cost of Hurricane Katrina, *Risk Analysis, Vol. 28, No. 3, 779-799*

H.M. Treasury (1991) Appraisal and evaluation in central government: a technical guide for government departments, HMSO, London

Homelet (2013) March 2013 Rental Index UK Regional Map, https://homelet.co.uk/rentalindex/regional-map, accessed 29 April 2013

Horsfield, G. (2012) Survey Methodology: Appendix B, Office for National Statistics, http://www.ons.gov.uk/ons/dcp171766_288107.pdf, 4 December 2012, accessed 25 April 2013

Land Registry (2013) December Market Trend Data from Land Registry 2012, http://www.landregistry.gov.uk/media/allreleases/press-releases/2013/market-trend-data-december-2012, 29 January 2013, accessed 16 April 2013

Office for National Statistics (ONS) (2012) House Price Index, http://www.ons.gov.uk/ons/rel/hpi/houseprice-index/december-2012/stb-december-2012.html#tab-Data-tables, December 2012, accessed 20 April 2013

Parker, D.J., Penning-Rowsell, E.C. and L. McFadden (2012) Business disruption and recovery planning in relation to coastal flood and erosion risks: theoretical dimensions and field survey evidence, Project Deliverable Report IDWT4.3, THESEUS research project (Innovative technologies for safer European coasts in a changing climate), FHRC, London

Acronyms

FHRC	Middlesex University Flood Hazard Research Centre
FRM	Flood Risk Management
GVA	Gross Value Added
MCH	Multi-Coloured Handbook: a cut down version of the full MCM
MCM	Multi-Coloured Manual (i.e. Penning-Rowsell et al. (2013)).
NRD	The UK's National Receptor Dataset
NRP	Non-Residential Properties
PVD	Present Value of Damages/Losses
WAAD	Weighted Annual Average Damages