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Guidelines

for Standards for Flood Protection and Safety

Flood-CBA 2

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CONTENTS

Chapter 1: Introduction

1.1 THE NATURE OF THESE GUIDELINES

These Guidelines are intended to be a step-by-step "How to do it" guide to assessing the economics of flood risk management (FRM) in relation to deciding the standard of protection to be required of any intervention to reduce flood risk and the standards of safety against flooding thereby provided.

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 and therefore represent "best value for money" by being economically efficient. At the same time they can decide the standard of protection (SOP) to be provided by that intervention, which in turn determines the degree of safety against flood risk that is provided.

These Guidelines are designed to complement the guidelines produced in the previous FLOOD CBA project and report (see Appendix 3[1]). There is no intention to repeat that material here (see Appendix 1) but concentrate on the relationship between benefit cost analysis (and the design standards of flood risk management schemes), and the safety considerations inherent in choosing a particular design standard over another. Thus whilst these guidelines offer a step-by-step guide, they are not a stand-alone document but should be consulted in conjunction with the FLOOD CBA guidelines referenced above.

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 the standard of flood 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 three ways:

- Concentrating on those components of total benefits which are the largest compared with the effort expended on assessing them (e.g. focusing on 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);

[1] http://www.floodcba.eu/main/wp-content/uploads/Cost-Benefit-Analysis-Guidelines1.pdf

- 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 data is of the highest quality readily available).
- Ensuring that the different standards of protection provided by different types of intervention are compared on a like-for-like basis, so that a genuine choice can be made as to which standard can be afforded and what standard of protection and safety is thus provided.

1.2 THE PRINCIPAL REASONS FOR UNDERTAKING COST BENEFIT ANALYSIS

There are several important reasons why flood risk management schemes should be appraised rigorously including as systematic as possible a comparison between the costs of interventions to reduce risk and the benefits they provide. The main reasons, we consider, are as follows:

1. **To facilitate thinking and learning.** Being required to set out the full lifetime costs of investment is important, because some costs can inadvertently be ignored or omitted if this is not undertaken properly. Also a requirement to assess benefits gives us information about the gains to society, communities and indeed individuals from reducing the risk of flooding that they face, and this requires a systematic approach and as much quantification as possible. Both these processes, concerning costs and benefits, require a great deal of effort and involve some important learning tasks, but this requires us to think carefully about what our objectives are, not an unimportant role for the decision-makers.
2. **To maximise the efficiency of public investment.** Most flood risk reduction schemes are funded by government or quasi-government organisations, and the funding largely comes from the public purse. This public purse is contributed to in a major way by people not at risk of flooding, who tend to be in the majority in any one country or region, and therefore we owe it to these taxpayers to ensure that the expenditure on risk reduction for those who are at risk is as efficient as possible.One of the main conclusions of the FLOOD CBA project was, other things being equal, that the optimum standard of protection is one where there is the greatest difference between benefits and costs, and therefore the return on investment is at a maximum.
3. **To decide how much to spend on risk reduction**. There are many approaches to appraising public-sector investment, including cost benefit analysis (CBA) and multi-criteria analysis (MCA). While the latter has merits in terms of being more comprehensive, incorporating as it does non-quantifiable aspects, it does not tell the decision maker how much money to spend on the investments they are designing. A great merit of CBA is that the answer is a quantified sum that should be invested to maximise the return to the relevant taxpayers or other funders.

4. **To maximise the transparency of the appraisal process.** In undertaking a CBA the analyst has to sets down unambiguously the quantified aspects of their assessment, preferably giving all details about the assumptions made. Thus the process is inherently transparent, and third parties can evaluate (and indeed repeat) the processes and calculations involved, in order to verify for themselves the merits of the conclusions that result.

This, of course, does not mean that CBA is perfect. Indeed, there are many deficiencies, principally concerning the quantifying of the so-called “intangible” elements of both benefits and costs. If such intangible elements dominate a potential decision, then the benefit cost analysis may be redundant or indeed seen to be flawed. The only way to circumvent such a situation is when the analyst sets down, in narrative form and in parallel to the calculations they have undertaken, those aspects which cannot be quantified easily or cannot be quantified at all. Such a narrative should be as detailed as necessary to convey the importance of consideration being described. This means that the decision maker has access to all that the relevant information, but some of it will be quantified and some not quantified. They are perfectly at liberty to weight the unquantified aspects as heavily as they wish, thereby setting the quantified aspects in context. Such process is one requiring judgment, rather than simply mathematics.

1.3 THE BASIS OF FLOOD CBA: PREDICTING THE FUTURE

It should never be forgotten that the cost-benefit analysis of flood 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.

The reason that we are concerned with the future is that any cost-benefit analysis seeks to gauge the likely future direction of flood damages, and use these as a basis for predicting how much it is worthwhile spending to alleviate or even prevent those flood damages occurring in the future. It is not a question of simply gauging this level of investment on the basis of damages caused by previous floods, because these will have different probabilities of recurring in the future. What we need to do is to establish the likely annual flood damages in the future, and compare that with the annual cost of preventing those damages from occurring (both converted to capital € or £ sums). Any other analysis is fraught with difficulty, and can be extremely misleading.

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 at a given location. These pressures should be resisted, because gauging expenditure on the basis of what has occurred in the past in single events is likely to be erroneous.

1.4 ECONOMIC EFFICIENCY: THE SOLE CRITERION

We also need to remember that cost-benefit analysis 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 maximum economic efficiency to be found.

Thus, in the most extreme example, it is economically more efficient to 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 meager assets. This can lead to decisions that are not seen as "fair", but fairness is not part of cost-benefit analysis. Indeed the distribution of outputs, as benefits of flood protection, is not a matter for economics generally, which simply looks at the aggregate return from particular decisions rather than their distribution across society.

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 (Defra, 2005; EA 2010). Thus the cost-benefit analysis is skewed in favour of certain outcomes, as determined politically. Also since most flood defence expenditure is raised as general taxation, it could be argued that the public should decide how public money is spent, rather than economists with their benefit-cost ratios!
- Employing spatial planning considerations, outside FRM CBA, for instance as in Spain. Here land planning has a very important role in the wealth distribution and socio-economic balance of regions. CBA and wealth distribution.

1.5 WHAT TO DO WITHOUT GOOD DATA

It is important to repeat here a significant conclusion from the Flood CBA report (Appendix 3) (FHRC, 2014). In many cases, and in many countries, good data may be lacking for the application of CBA. This should not be the reason for not proceeding to do some form of economic analysis. Strategies should involve one or more of the following:

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

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.

1.6 SOME FURTHER CAVEATS

As in our Flood CBA Guidelines report (Appendix 3 here) (FHRC, 2014), it is inevitable that some factors will not be able to be included in a traditional economic analysis of flood risk management measures. The strategy to be adopted in the appraisal process here, as advocated above, should be describe these factors in as much detail as possible, so that those making the decision can take these into consideration.

- Many so-called "intangible" effects can be taken into consideration using a multi-criteria approach. This can involve scoring each element that is to be taken into consideration, and then weighting the elements within the calculus to arrive at the multi-criteria result. In effect, this involves converting these "intangible" effects into monetary values using as a benchmark one of the factors that has been quantified in money terms during the economic analysis.
- 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 by life insurance companies.
- Certain environmental aspects are also difficult to quantify in economic terms, and they have to be left with detailed descriptions. Particularly difficult is the complete elimination of sites of scientific value, species, or particular vegetation assemblages. These can be valued at the cost of replacing them either at the site or in an alternative location, but this is controversial and such transfer values are often distrusted as a true measure of the effect of the flood risk management measures on environment values.

As indicated above, the best approach here is to describe in full the potential effects of the flood risk management scheme – positive or negative – and leave it to the decision-makers to make the decision, guided by those descriptions and by the economic analysis provided. In this respect technologies such as Appraisal Summary Tables or Proformas (see Appendix 2) can be useful in standardizing the approach to these descriptions, but this is no panacea.

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".

As reinforced by the stakeholders surveyed in FLOOD CBA 2 Task B3 (see the B3 report, Figures 4 to 6) it also needs to be remembered that proper stakeholder engagement will be an important mechanism whereby these investment appraisal considerations are foregrounded, rather than left to specialist analysts and decision-makers. Thus one important part of the role of stakeholders in this respect is to bring forward considerations that cannot easily be quantified, so that the appraisal teams and decision makers can discuss these and review them comprehensively.

Chapter 2: Steps in the appraisal process

In this chapter we set up the steps necessary to take in order to appraise any intervention in the field of flood risk management. In this respect it refers extensively to the Guidelines produce for the FloodCBA project, where these steps are covered in much greater detail (Appendix 3 here)(FHRC 2014). As such the objective here is to identify the main steps in this process, so as to locate the pursuit of understanding of different standard of protection and safety standards in that context.

2.1 THE NECESSARY STEPS AS DESCRIBED IN THE FLOODCBA GUIDELINES (FHRC, 2014) [see Appendices 1 and 3]

Step 1: Locate the flooding problem and the "benefit area" [Flood CBA Guidelines 2.1, 2.6 and 2.4]

Any appraisal of flood risk management interventions starts with some characterization of the nature of the flood problem being faced at the site in question (Figure 1). To this end it is useful to have some history of flooding, and information thereby provided, and maps of the flood extent for events in the past. Newspaper diagrams, photographs and text can also help to identify the nature of the problem, and its likely severity. Stakeholder engagement is useful here, because local people often have local knowledge about their flooding problems that is missed in national databases and overall assessments.

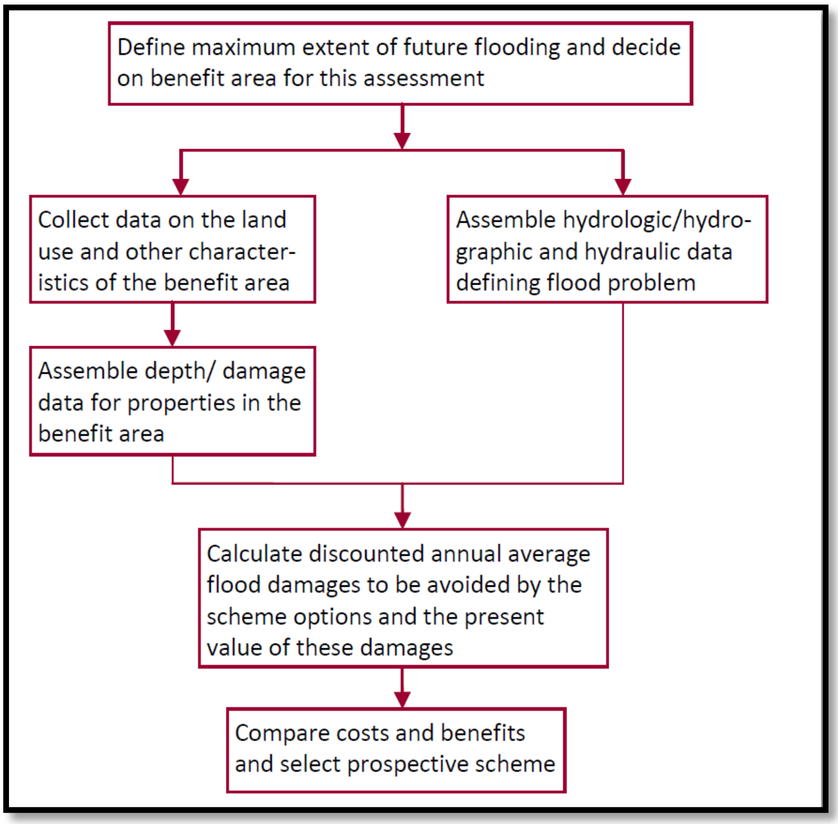

Figure 1. Stages in the assembly of the relevant data

The “benefit area” is the area of maximum likely flooding, within which properties are at risk but would benefit from flood risk reduction (Figure 1). The area of maximum likely flooding is not necessarily the same as the extent of flooding in the past, because past floods may not have exceeded a certain threshold of severity which could be exceeded in the future. Also, there may be benefits from protecting areas at the very margins of the flood extent area, because these will have their risk reduced by certain channel improvements or bypass channel interventions that lower the level of flood water across the whole of the floodplain. These benefits are termed Above Design Standard benefits.

With regard to climate change, it may be necessary to extend the existing benefit area, being the area likely to flood now, into areas where flood severities with increased precipitation or sea level rise might grow as climate change produces increased precipitation levels, increasing sea levels, and possibly increased fluvial flood flows. Urban areas are particularly susceptible to high-intensity summer convective rainfall, which some climate change forecasts show are about to increase significantly, and therefore the extent of flooding in these situations could extend markedly beyond areas traditionally subject to inundation.

Step 2: Assemble the relevant information and maps [Flood CBA Guidelines 2.5]

Within the benefit area, it is important to identify different land uses. This is because these different land uses have different flood damage potential, and this needs to be recognised in any appraisal. It is particularly important to separate out residential and non-residential properties, not least because the data on flood damages for the latter category is usually represented as damage per square metre of the floor space of the relevant buildings.

The potential flood damage data or depth/damage data can be collected from the site in question, based on historical floods, or analysts can use the “synthetic” flood damage data available from Middlesex University (FHRC, 2014). This can be adjusted for different countries by the ratio of the GDP of the UK to the GDP of the country in question, in order to uprate or deflate those values appropriately.

Hydrological data is essential to any appraisal of flood risk interventions (Figure 1). Basically this data should quantify the return periods of floods affecting the site (the average length of time between events of similar magnitude), based either on historical analysis or modelling. In coastal locations, hydrographic data is used on the return period of tidal surges, representing maximum flood depths. A range of return periods is necessary, starting with a return period of the flood that just causes damage. A range of return periods often is characterised by the 5, 10, 25, 50 and 100 year floods, but others can be used. In some circumstances it is necessary to go beyond this and have the return periods of 200 or 500 years. This is partly because these floods are important in driving the Above Design Standard flooding effect, as described above.

Although accuracy is important in all this data, in many situations high quality data may not be available. Our advice here is to use whatever data is available, and undertake some form of sensitivity analysis when the results become available, to test the sensitivity of the results to changes in the data that may be of questionable quality. Such an approach is far superior to not proceeding at all, not least because some data has very little effect on the final results, particularly the potential damages from the most extreme floods, since these are rare and their contribution to annual average damages is small. The economic significance of the very rare events is often misunderstood.

Step 3: Mapping out the loss probability curve ad calculating the discounted Annual Average Damages [Flood CBA Guidelines 2.2 and 2.6]

The loss probability curve is essential to any appraisal of flood risk reduction interventions (Figure 2). The diagram in Figure 2 brings together the hydrological data, the damage data, and plots the relationship between flood probability and damage as this loss probability curve. The difference between these curves with and without interventions is the annual average benefit of those interventions.

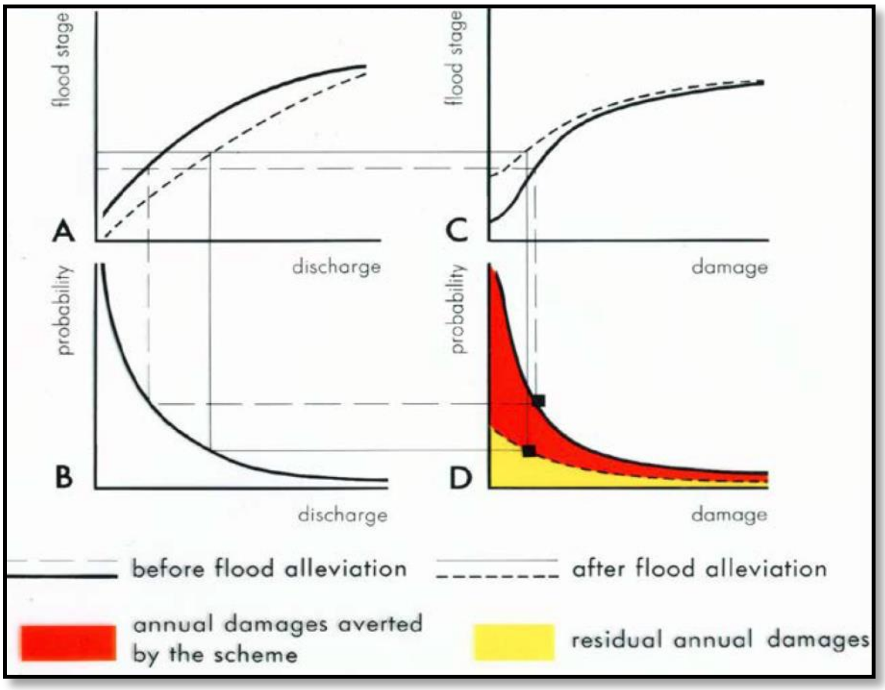

Figure 2: The derivation of the loss probability curve (bottom right)

Care should be taken to include a sufficient number of future floods to represent the loss probability curve accurately. This means that at least 5 floods should be looked at, including the flood that initiates flood damage (see above).

The area under the loss probability curve is the annual average damage at the site. This sum in € or £ needs to be discounted over the life of the prospective intervention schemes (say 50 years or 100 years, or less for some non-structural measures), so as to yield the capital sum it is worthwhile investing to achieve those benefits from those interventions. The reason that we discount these sums is because in general society values resources in the future at a lesser value than resources now, not least because if we had those resources now and invested them they will yield a return over a period of time in the future. There are other reasons for discounting which are dealt with in FHRC (2014).

Discount rates vary across different countries, generally related to the alternative use of the capital involved, but in the UK we have a tapering discounted rate with time (3.5% to 2.5%) so that benefits in the far distant future are not dismissed because using the 3.5% discount rate to generate present values means these values can be very low.

Step 4: Interpreting the results[Flood CBA Guidelines Chapter 3]

The steps enumerated above result in the calculation of the capital sum it is worth investing to reduce the risks represented by the floods in the future that have been used in the calculations. These benefit sums need to be compared with the discounted costs of the scheme, including capital costs and maintenance costs (and any decommissioning costs).

In this way the ratio of benefits to costs can be calculated, which indicates which schemes are economically worthwhile pursuing. In addition, however, it is necessary to calculate the benefits minus the costs, because this shows the return on investment. It is usually the case that both indices are calculated, the one indicating the ratio of benefits to costs and the other the difference between these two sums.

If the ratio of benefits to cost is below 1.0, this indicates that intervention in question is not worth pursuing, at least in economic terms. Benefit cost ratios above 10.0 should be viewed with some skepticism, because often these high values result from errors in the calculation; to achieve such a high value require serious flooding on a large scale for much of the time, and this is generally unlikely, mainly because it is likely that it would have been tackled before or property would not be located there (or abandoned).

2.2 THE FLOOD CBA 2 “PROFORMAS” [SEE APPENDIX 2]

In Appendix 2, we present a series of proformas which match the steps indicated above, but in much more detail. There are designed to help analysts collect the relevant data, and use it to calculate the benefits of different interventions to reduce flood risk at a particular site.

To help the analyst in this respect, we have provided elsewhere examples from Oxford of how this data is collected and used. This is not the place to describe the Oxford flood alleviation scheme, which will be presented elsewhere (FLOOD CBA 2 Deliverable D1).

These proformas will be used by the Greek, Spanish and Portuguese partners in their analysis of their case studies, and also be used in the training material presented to stakeholders in autumn 2017. It should be noted in this respect that the proformas are a summary of the process of assessing the benefits and costs of flood risk reduction interventions, and the related standard of safety provided, and any full appraisal undertaken for a real prospective flood intervention scheme should start with these proformas but recognise that more detail will be required for the appraisal to be comprehensive and rigorous.

Chapter 3: Standards of flood protection and safety

3.1 GENERAL ISSUES

When seeking the highest possible (affordable) standards of flood protection and hence the highest standards of safety, decision makers have to evaluate the nature of the flooding that might be experienced at the site in question, and look to see what benefits will be generated by some flood protection measures there, in terms of flood damage to be avoided in the future (see above).

Ideally, they should look at flood protection measures with different standards of protection, and select the one which maximises the benefits and minimises its costs in relation to those benefits. The standard of safety is thereby maximised in relation to how much it costs to provide that safety.

This is classical Cost Benefit Analysis (CBA) and the proformas in Appendix 2define in detail the whole approach. Obviously some benefits may not be measurable, which is where Multi-criteria Analysis (MCA) has to be used to take these matters into consideration. That approach is particularly relevant in cases where the effects of different options can be assessed, but where it is difficult to value them in monetary terms. The MCA approach can also be applied in cases where only part of the benefits of a flood prevention measure can be captured in monetary terms, and where it is expected that the non-monetised effects will be significant for the results of the analysis. Cost-benefit considerations can be included as one (albeit central) criterion of a Multi-Criteria Analysis, but at the same time complemented by other, non-monetary factors.

3.2 INCREMENTAL BCA AND SAFETY STANDARDS

The description of the process of project appraisal in this document so far leads the analyst to achieve benefit cost ratios for particular interventions. These indicate the stand-alone merits of those proposed investment decisions, taken one at a time. Such an approach has been current until several years ago in the UK when it was appreciated that two problems occurred:

1. In many circumstances the highest ratio of benefits to costs occurs with very low levels or standards of intervention. The classic example here for residential properties is to provide the house at risk with two sandbags, one for the front door and one for the back door! This is cheap, but not very effective. Or rather it is effective at preventing small floods but sandbags work ineffectively and cannot cope with long flood durations (they leak) or high flood depths (ditto). Therefore such an appraisal of the economics of flood interventions is flawed because the interventions are not effective for anything but the smallest events.
2. As one progresses towards more ambitious interventions the ratio of benefits to costs may still be favourable (i.e. > 1.0) but those interventions represent worse value for money than

lesser interventions. Indeed, this is generally the case because as interventions get more and more ambitious, costs rise inexorably. This rise usually outpaces the rise in the benefits provided: it is disproportionate.

The solution to this problem is to look at the incremental benefit cost ratios. By this we mean that for any intervention one examines the increase in benefits over a lesser intervention and compares that increase with the increase in costs. If the increase in cost is greater than the increase in benefits, we say that the incremental benefit cost ratio is less than 1.0. Such an intervention is not worthwhile, or not as worthwhile as the lesser intervention. This matter is dealt with in Proforma F, in Appendix 2.

The general point here is that analysts should not be content simply to observe that asimple "stand-alone" benefit cost ratio is greater than 1.0, but investigate the benefit cost ratios of more ambitious and less ambitious interventions to see whether that simple ratio represents some form of optimum.

In regard to safety, the incremental benefit cost ratio indicates the intervention that maximises the difference between benefits and costs at a particular site. This may well not represent the maximum level of safety, which we define as a very low probability of flooding causing minimal damage and no injury or loss of life. This means that the economically optimal solution is unlikely to provide the highest level of safety, because that high level of safety is likely in most circumstances only to be provided if the standard of protection is very high, with high consequential costs.

This matter is often misunderstood by decision makers, who require analysts to provide a justification for very high (and unrealistic) standards of protection and therefore very high (and unrealistic) standards of safety. But this can be very wasteful economically, and decision-makers should recognise that high levels of safety are often inordinately expensive and could divert resources away from other uses of the finance, such as to build hospitals, libraries or care homes. In the end economics is a process of making hard decisions about alternative investments, and providing the highest level of safety from flooding is often not economically efficient.

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Appendix 1.

The FLOOD CBA "Guidelines" report (FHRC, 2014)

Appendix 2

FLOOD CBA 2 Case Studies: 'Proformas' to guide data gathering

The objective here is to **compare** the benefits of future flood risk reduction (not flood "control" or "defence") with the costs of doing so. To do this we need estimates of likely future flood damages to be averted by any interventions, and the capital and recurring costs of thosepossible interventions to reduce those damages.

So one has to look at **all aspects of flooding** in a case study area, and make some estimates (if there is no better data) of the **costs** of possible interventions.

We formulate this investigation as a series of **27 tasks**, broken down and grouped into **six "Proformas"'A' to 'F'.**In each case the Proforma is a set of tasks. We suggest in the Proformas the **approximate % of total effort** that should be given to each Proforma and its tasks.

If some of your **DATA** (good, bad or indifferent) **IS MISSING** FOR ANY STAGE, YOU MAY HAVE TO MAKE APPROXIMATIONS (even GUESSES), pending better data becoming available. You can always test, at the end, if the poor data makes any difference to the overall results; you may be surprised.

Proforma	The rationale	Overview: Tasks to be completed	Approx. % of the total effort	Comments
Proforma A	Collecting information regarding the site that is to be assessed.	**For the site**: 1. A topographic map of the catchment in which the site is located (say at 1:100,000) 2. Detailed map of the site (say at 1:5,000 or 1:10,000 scale), showing individual properties at risk of flooding 3. The administrative authorities relevant at the site (e.g. for urban planning; flood risk management; emergency response) 4. Any flood risk management (FRM) appraisal rules and guidance that are relevant to the site	**5%**	Most countries have readily available maps of the type required here.

Proforma	The rationale	Overview: Tasks to be completed	Approx. % of the total effort	Comments
Proforma B	Collecting details about (a) the current flood risk situation and (b) the key features at risk today and in the future from flooding at the site.	5. **For the site (in the past)**: Collect information on flood extent/history in the past (maps of flooding; numbers of properties affected, and their types [e.g. residential; non-residential etc]; photos; etc) 6. **For the site (in the past)**: Collect information on any flood damages and/or disruption to economic activities (i.e. traffic; railways; agriculture) in the past 7. **For the site (in the past)**: Collect details of any injuries and loss of life in floods in the past here. 8. **For the site (now and in the future):**Collect data on flood hydrology (flows; flood return periods; flood extents, etc) for the site 9. **For the site (now and in the future):** Collectinformation (e.g. maps) on modelled or estimated future flood extents (geographical **areas**) by return period (e.g. for the 2; 5; 10; 20; 50; 100 year floods). This may be possible with or without data from Task 8, above (i.e. they may not relate direct to the flow data but might be estimated from other information/judgements). 10. **For the site (now and in the future):**Collect data on property numbers and types [e.g. residential; non-residential etc] in each of those **areas** 11. **For the site (now and in the future):** Collect data on population numbers (estimated) in each of those **areas**.	**20%**	Investigate all data collected for the **Floods Directive** in your country. Item 9 here is particularly important as it forms the basis of Tasks 9, 10 and 11 below.

Proforma	*The rationale*	*Overview: Tasks to be completed*	*Approx. % of the total effort*	*Comment*
Proforma C	Overview of the **impacts that are expected under the "do-nothing" or the "baseline" scenario**.	12. Undertake research into all the available depth/damage function data that might be used in the appraisal (both Residential and Non-Residential properties) etc. 13. Assign likely future flood damage values (in €) to each property for each return period using whatever data is available, even approximations 14. Total the damage values for each return period areas. 15. Tabulate the loss-probability function to calculate future annual average damages for the site as a whole (see **Table C11in Annex C for a detailed example**). The result is the annual average of those damages.	**25%**	Task 15: Without quantifying this loss-probability function the analysis cannot proceed further.

Proforma	*The rationale*	*Overview: Tasks to be completed*	*Approx. % of the total effort*	*Comments*
Proforma D	An assessment of the **possible future changes and/or interventions** that may affect the site	16. Review all likely interventions to reduce flood risk at the site and their likely effective functional lives (i.e. when they remain effective) 17. Decide on a shortlist of, say, 3- 6 interventions at different costs and hence different standards of protection. 18. Estimate the likely whole life costs of each of the above interventions (i.e. capital costs and recurring maintenance costs), as economic costs (i.e. not including taxation elements).	**25%**	Take a wide view as to what interventions to consider: do not include just high cost schemes.

Proforma	The rationale	Overview: Tasks to be completed	Approx. % of the total effort	Comments
Proforma E	Assess the potential of a range of flood risk prevention measures and assess their efficacy based on **CBA and/or MCA** methods	19. Discount the annual average damages (**from Task 15**) over the life/lives of the proposed interventions (e.g. multiply the annual average by 29.9 for a 3.5% discount rate for a 100-year scheme life). The result is the 'present value' of those damages (see the **Table in Annex C11, final column, for an example and Annex E15 for an explanation of discounting**) 20. Discount the recurring estimated recurring maintenance costs of each intervention, to get a full present value of the costs of each intervention. 21. Make up a table of interventions (in ascending order of cost), showing (a) the present value of all damages to be avoided and (b) the present value of all costs 22. Calculate the ratio of benefits to costs. Calculate the value of benefits minus costs 23. Undertake sensitivity analysis by varying key inputs, e.g. • Changing the return period of some of the future floods; o the return period of the smallest flood and (i.e. halving it or doubling it) o (b) the return period of flood that just causes some flood losses (i.e. halving it or doubling it) • Changing the discount rate; • Doubling and then halving the average size of the non-residential properties; Keep the sensitivity results as separately saved spreadsheets.	**10%**	Make sure you are clear why we need to discount both costs and benefits (i.e. to bring them all to the same point in time: the present)

Proforma	The rationale	Overview: Tasks to be completed	Approx. % of the total effort	Comments
Proforma F	To enable conclusions to be drawn	24. Assess any costs and benefits that the above analysis does not take into account. Make a judgement as to how large these are likely to be: could they be "decision changers". If so, consider a full MCA analysis. 25. Draw conclusions as to the economic efficiency of each proposed intervention 26. Draw conclusions as to the sustainability of each proposed intervention 27. Make recommendations as to which intervention to pursue further with (a) public consultations etc and (b) detailed design	**15%**	Make sure you have enough time on a case study/scheme to spend on interpretation: do not spend all the resources on modelling and economics!

Annexes (numbered as per proformas: Annex A2 relates to Proforma 2, etc.)

Annex A2.

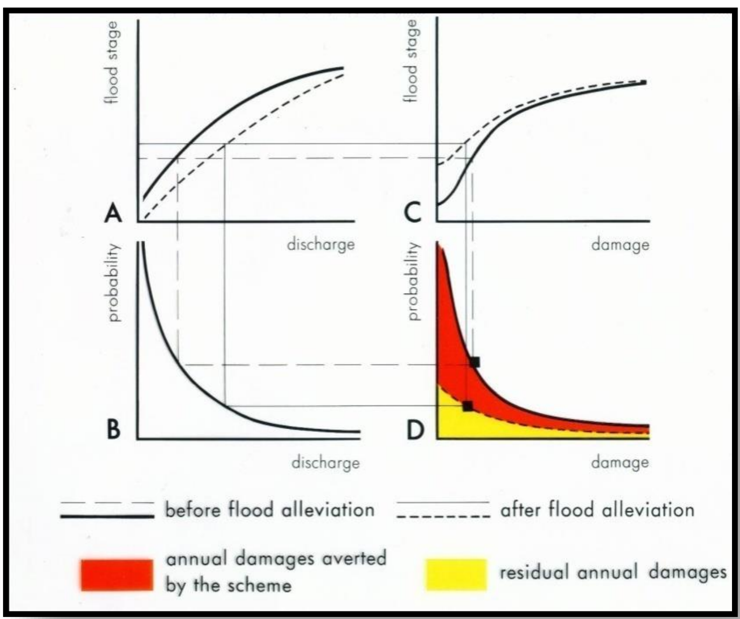
This type of map can be found from a number of sources. These can be town plans, national surveys, local taxation maps or even tourist maps. The key ingredient is individual properties located if possible, or failing that groups of properties that can be checked in the field, and also for non-residential properties an idea/estimate of the floor space size of the property because often flood damage data comes as damage per square metre rather than as damage per property. Engineering consultants often have access to digital maps at a very high degree of resolution and these should be used if possible. The more detail here the better, as these maps will be central to the whole process of assessing future potential flood damages for different degrees of flood severity.

Annex A4.

These rules usually emanate from the national government Department for Treasury matters. Thus in the UK we have the "Green book" setting out the rules for appraising investment of public money on public infrastructure such as roads, telecommunications, environment, energy etc. (HM Treasury 2003). Within different sectors of public enterprise there will be additional manuals setting out the investment rules in that field, such that the UK Environment Agency has developed a very complex set of rules, based on the Treasury Green Book, for investing in flood risk management schemes which involve government contributions towards their cost. It is likely that in other countries there will be at least some documentation spelling out the rules for investing public money, and these should be pursued and adhered to as far as possible. Inherent in each of these sets of rules is a comparison of the benefits derived from that investment in public infrastructure compared with the costs to the government (and nation) of its implementation. These benefit-cost rules may be simple or complex depending on the government's inclination towards that kind of economic efficiency criteria.

Annex B4

In order to calibrate the all-important loss-probability curve, to obtain an estimate of the annual average damage at the case study location, the assessment of at least 5 future floods of different severities and return periods is necessary. This will allow a good definition of the upwards facing concave loss-probability curve ("D" below), rather than a triangular area if just 2 floods are looked at (see Penning-Rowsell et al, 2013, 61).



Annex C11

Loss-probability calculation (£ or €)							Discounted AAD (£/€000)
Return Period (years)	Exceed probability	Damages	Interval probability	Mean damages	Interval damages	Cumulative interval damages	
2	0.500	£34,774					
			0.300	£289,727	£86,918	£86,918	£2,599
5	0.200	£544,680					
			0.100	£835,623	£83,562	£170,480	£5,097
10	0.100	£1,126,566					
			0.060	£1,527,714	£91,663	£262,143	£7,838
25	0.040	£1,928,861					
			0.020	£2,224,713	£44,494	£306,637	£9,168
50	0.020	£2,520,565					
			0.010	£2,965,820	£29,658	£336,296	£10,055
100	0.010	£3,411,074					
			0.005	£4,032,474	£20,162	£356,458	£10,658
200	0.005	£4,653,874					
			0.002	£4,887,397	£8,146	£364,604	£10,902
300	0.003	£5,120,921					
			Total annual benefit/damage =		£364,604		

This table in effect is the integration of Graph D in Figure 2 (bottom right hand quadrant): the area in the orange and yellow areas. It is the usual way of quantifying the area under a curve, in this case taking "slices" of flood probability ("interval probability") and multiplying that by the average damage values in those slices ("mean damages"). The result is the annual average damages (or benefits if those damages can be averted).

Annex E15.

Discounting (from Wikipedia):

Since a person can earn a return on money invested over some period of time, most economic and financial models assume the discount yield is the same as the rate of return the person could receive by investing this money elsewhere (in assets of similar risk) over the given period of time covered by the delay in payment.The concept is associated with the opportunity cost of not having use of the money for the period of time covered by the delay in payment. The relationship between the discount yield and the rate of return on other financial assets is usually discussed in such economic and financial theories involving the inter-relation between various market prices, and the achievement of Pareto optimality through the operations in the capitalistic price mechanism, as well as in the discussion of the efficient (financial) market hypothesis.

In the UK we use a tapering discount rate, so as not to diminish too much the benefits from investment that might occur in the distant future. So, with the 3.5 per cent Test Discount Rate reducing to 3 per cent at year 30 and to 2.5 per cent at year 75, and given the 100-year time horizon, the relevant discount factor is 29.9(HM Treasury 2003). This is what is used in the Table in Annex C11 here. Note that the AAD column is in £/€ 000s. Do not confuse this “year 30” or “year 75” with return periods of floods: this “year 30” or “year 75” is the number of years into the life of the scheme.

Annex E17 Oxford Flood Alleviation scheme: summary economics (from CH2MHill)

Option number	**Option 1**	**Option 2a**	**Option 2b**	**Option 3**	**Option 4**	**Option 5**
Option name/details	Do Nothing	Do Minimum	Do Minimum (extend)	Defences	Channel and Medium Culverts	Channel, Medium Culverts and Defences
COSTS:						
PV capital costs		0.0	4.0	7.6	92.9	96.5
PV operation and maintenance costs		17.4	17.4	17.6	20.4	20.6
Total PV Costs £m	0.0	17.4	21.4	25.1	113.3	117.0
BENEFITS:						
PV monetised flood damages	1,237.4	315.2	297.8	267.9	122.1	89.8
PV monetised flood damages avoided		922.2	939.6	969.5	1,115.3	1,147.6
Total monetised PV damages £m	**1,237.4**	**315.2**	**297.8**	**267.9**	**122.1**	**89.8**
Total monetised PV benefits £m		**922.2**	**939.6**	**969.5**	**1,115.3**	**1,147.6**
Total PV damages £m	1,237	315.2	297.8	267.9	122.1	89.8
Total PV benefits £m		922.2	939.6	969.5	1,115.3	1,147.6
DECISION-MAKING CRITERIA:						
excluding contributions						
Based on total PV benefits (includes benefits from scoring and weighting and ecosystem services)						
Net Present Value **NPV**		905	918	944	1,002	1,031
Average benefit/cost ratio **BCR**		**52.8**	**43.8**	**38.6**	**9.8**	**9.8**
Incremental benefit/cost ratio **IBCR**			**4.3**	**8.1**	**1.9**	**1.9**