MODELLING THE IMPACT OF SPENDING ON DEFENCE MAINTENANCE ON FLOOD LOSSES

Summary Report

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Executive Summary

To support Flood Re and the Association of British Insurers (ABI), JBA carried out a research project evaluating the benefits of maintaining flood defences over a 30-year period for several different spending scenarios. This study explored the relationship between inland flood defence maintenance and flood defence failure due to breaching (caused by structural failure). It also estimated the total benefit derived from river flood wall and embankment defences and the associated upkeep costs of these defences.

Key Finding 1: river flood defences provide a benefit of £568m per year.

- The total river flood loss without raised flood defences results in estimated modelled flood losses of approximately £956m per annum. With the defences in place, inland river flood loss reduces to £388m per annum. This estimate does not consider the effect of maintenance, or the possibility that a defence fails. The benefit of flood defences, performing as they were designed to do, is therefore £568m per annum.

  Four flood defence maintenance regimes were tested to determine the impact on breach failure and effective defence lifespan before replacement. The maintenance regime varied on the amount spent. The current maintenance regime was assumed to be target condition grade 3 (Fair condition). The three other maintenance regimes were a 50% increase in maintenance spending, 50% decrease in maintenance spending and a minimum spend scenario.

Key Finding 2: losses due to river flood defence breaching are not sensitive to adjusting the balance between defence maintenance and capital spending.

- The results of the analysis show that losses due to breaching were not sensitive to the different spend scenarios. Annual river flood losses only varied by £0.2m, with the increase in flood losses due to breaching lying between £1.3m and £1.5m.

Key Finding 3: recent experience has demonstrated that well-funded flood defence systems rarely breach.

- This reflects a robust baseline protection standard to which defences are maintained, or replaced, and corresponds to a documented record of very few real world defence breach events. The breach record is sparse despite several severe flood events in recent years. This appears to show that as long as a defence is not allowed to deteriorate to, and remain in, a very poor condition, defence systems in the UK are unlikely to breach.

Key Finding 4: for every £1 increase in maintenance spending almost £7 is saved in capital spending.

- The impact of maintenance on the long-term cost of flood defences was also modelled by considering the impact on the effective defence lifespan. Unit maintenance and capital cost were supplied or calibrated against Environment Agency data. Defences were considered to need replacing once they deteriorated to condition grade 4 (Poor condition). The results show that an increase in maintenance spending can extend the life of the defences significantly and thus reduce the overall capital replacement costs. The increase in maintenance costs is more than offset by this reduction in capital spending. This trend in maintenance spending is also true in reverse: if maintenance spending is cut, flood defence lifespan decreases and the overall annual costs increase in the long term. Ultimately for every £1 increase in maintenance spending almost £7 is saved in capital spending.

  The cost of defence upkeep, the flood damage prevented and the overall net benefit of the defences, as an average annual benefit, is presented for each of the tested scenarios in the table below. The greatest benefit (£371m) was achieved by increasing spending on maintenance by 50%.

Scenario	Maintenance Cost £m	Capital Cost £m	Benefit £m	Net Benefit £m
Minimum spend	2	443	566	121
Decrease spend	14	316	566	236
Current spend	27	255	567	284
Increase spend	42	154	567	371

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Abbreviations

AAL .... Average Annual Loss

DEFRA .... Department of Environment, Food & Rural Affairs

EA .... Environment Agency, England

EIOPA .... European Insurance and Occupational Pensions Authority

FSR .... Flood Studies Report

1 Introduction

1.1 Flooding and economic losses in the UK

Flooding in the UK continues to have a devastating impact on society. Severe flooding causes damage to property, infrastructure and agriculture. It can also tragically result in loss of life. Flooding in the last two decades has occurred after more extreme rainfall and has caused more economic damage than has previously been seen. Six of the ten wettest years on record have occurred since 1998 (Met Office, 2020) and overall in the UK, the period 2010-2019 has been 5% wetter than 1961-1990 (Met Office, 2020). More details on recent flood events are given below, emphasising the ongoing need to maintain flood defences protecting property.

- The flood events that occurred during the 2013/14 winter months incurred total economic damages of approximately £1.3 billion (Environment Agency, 2016). The winter flood events of 2016 (following storms Desmond, Eva and Frank) caused an estimated £1.6 billion in damages (Environment Agency, 2016).
- The flooding of summer 2007 occurred after one of the wettest May and June periods since records began in 1766. Over 55,000 homes in the Midlands and Home Counties were flooded, with losses totalling £3.2 billion in economic damages (Thorne, 2014).

The economic cost of flooding in 2019/2020 was estimated to be £78 million. The cost would have been £2.1 billion higher without flood defences (Environment Agency, 2021). This emphasises the importance of maintaining flood defences across the UK. In 2020 the Environment Agency announced an investment in flood defences (for both capital and revenue) of £5.2 billion, creating approximately 2,000 new flood and coastal defences to improve protection to 336,000 properties in England by 2027 (Environment Agency, 2020). However, flooding remains a significant risk in the UK.

1.2 Historical flood defence breach

From research carried out on historical events it was found that flood defence breach (failure) is not a significant problem in the UK. A key area of interest for this study was the damages that occur as a result of structural failure. In particular, related to differences in maintenance spending scenarios. In order to do so it is necessary to understand the historic performance of flood defences in the UK.

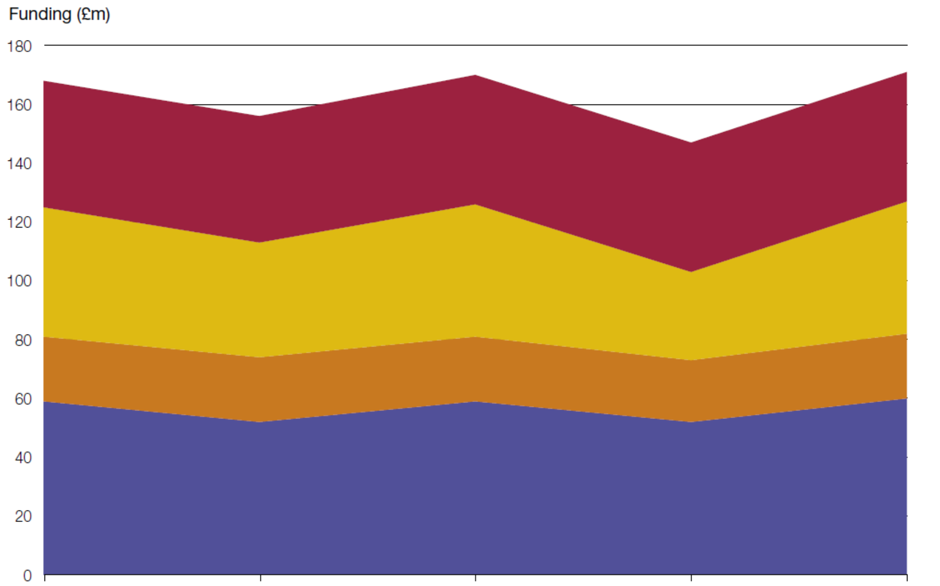
Events were researched over the last 23 years – including the June and July floods 2007, the Cumbria floods 2009, and Storms Desmond, Eva and Frank amongst others. It was found that while the UK has suffered major flood events there have not been widespread flood defence breaches (failures). Many flood defences were overtopped, but this generally did not lead to structural failure. Research carried out within this project suggests there has been under-reporting of breaches, perhaps because they often occurred in areas where little damage was caused by the breach.

Damage does occur to defences during flood events and some of this requires emergency repairs to ensure the structural integrity of defences. There is no systematic collection of flood defence breaches and therefore it is likely that breaches have occurred that were not recorded.

The limited data available point to the likelihood that a major, large geographical-scale flood event will typically cause in the order of 10 defence breaches. It may be reasonable to estimate that a very large event, the like of which we have not seen, might cause in the order of 100 breaches, but we should not expect thousands. For minor events, either in terms of geographical scale or rainfall intensity, we should generally see no defence breaches for most events. The historical record of failures implies that maintained defences fail infrequently.

1.3 Assessment of four maintenance scenarios

Estimates of current maintenance spending on flood defence assets are not widely available other than the review by the National Audit Office in 2014[4]. This suggested that maintenance spending between 2010-11 and 2014-15 was in the region of £160m annually, with approximately 35% applicable to maintaining defences.



	2010-11	2011-12	2012-13	2013-14	2014-15
OPS	43	43	44	44	44
Conveyance	44	39	45	30	45
MEICA	22	22	22	21	22
Defences	59	52	59	52	60
Total	**168**	**156**	**170**	**147**	**171**

Figure 1: Distribution of funding for asset maintenance and other preventative work (information extracted from NAO 2014 report)4

The assessment set out here demonstrates the benefits of maintaining river flood defences over a 30-year period. In particular, the impact of maintenance spending on damages due to flood defence breach (structural failure). The assessment accounted for flood walls and embankments. Four spending scenarios are considered over a 30-year period. The spending scenarios include:

- Minimum spending – reduce maintenance spending to the legal minimum
- Reduced spending – decrease maintenance spending by 50%
- Maintain current maintenance spend
- Increased spending – increase current maintenance spending by 50%

The modelling of potential losses was carried out using JBA's UK Flood catastrophe model. JBA's UK Flood Model 2018 has been updated to include 2019 river flood defended areas for the purposes of this study (referred to hereafter as JBA's UK Flood Model). This model simulates loss to property from flooding across the UK and has been utilised to model river flood.

2 Current maintenance state

2.1 Environment Agency defences in England

This section outlines the current maintenance state of Environment Agency defences in England. An assessment of the Environment Agency's defences in 2000 showed that 64% of linear defences were classed as "Good" or "Very Good"[1]. The same assessment carried out in 2021 reduces this percentage to just 33%[2]. A report by the National Audit unit in 2007 and 2014 highlighted possible deficiencies in the Environment Agency's flood defence funding in order to sustain defences to their target condition grade. In 2007, the EA stated: *"The Agency estimates that an extra £150 million a year would be needed over the next ten years to bring all its systems up to their target condition"*[3]. Each year new flood defence schemes are being built which increases maintenance demand. However, instead of increasing, maintenance spending has actually been reduced. Between 2010 and 2014, excluding a one-off emergency repair fund, total maintenance spending decreased by 14%[4]. In an effort to direct maintenance where it provides the most economic return, high consequence defences have been targeted at the expense of low consequence defences. In 2007 all low consequence defences, approximately half of all defences at the time, were maintained at the lowest allowable maintenance regime. This results in faster deterioration of the defences. In 2021, the Environment Agency confirmed that their maintenance regime now aims to implement target condition grade 3 for the majority of their assets, approximately 85%[5].

2.2 Assessment of defence condition in the UK

This section summarises the condition grade for walls and embankment defences across the UK maintained by governmental organisations. The condition grade is an important metric in determining the remaining life of a defence. Condition grade is based on the Condition Assessment Manual, CAM, (Environment Agency 2012). There are five grades, with their general descriptions provided below:

Table 1: Condition Grade Description.

Condition Grade	Description of condition
1	Very good
2	Good
3	Fair
4	Poor
5	Very poor

Environment Agency and Natural Resources Wales' spatial flood defence datasets were used to assess general state of wall and embankment defences. The data was supplemented with JBA data to provide a more complete picture. Figure 2 shows the current maintained state of flood defences in England and Wales. Defences classed as "Fair" have some defects that could reduce performance but the risk of failure due to breach remains low. Unless failure of a defence would result in significant damage, maintaining a defence in fair condition is considered to be an acceptable target. The vast majority of defences (wall and embankments) across the UK (~92%) are in a fair or better condition. Approximately 6% are considered poor requiring further investigation and repair. Approximately 2% are considered very poor requiring immediate replacement or significant reconstruction.

[1] Inland Flood Defence - National Audit Office Report HC 299 Session 2000-2001: 15 March 2001
[2] Based on England wall and embankment's condition grade from JBA's shapefile "UK_DefenceLines_forPDF"
[3] NAO - Building and maintaining river and coastal flood defences in England - HC 528 Session 2006-2007 | 15 June 2007 – Pg 19
[4] Strategic flood risk management – DEFRA and National Audit Office - HC 780 – November 2014
[5] Email communication between A.Rushworth of the Environment Agency and R.Power of JBA dated 9 April 2021

The Environment Agency has defined defence deterioration rates for a range of defence types and maintenance regimes. The method employed in this study assumes that a change in defence maintenance spend can be interpolated between the deterioration rates of each maintenance regime. The current defence maintenance regime is assumed to be representative of target condition grade 3. The Environment Agency also specifies a fastest, average, and slowest deterioration rate for each maintenance regime. The interpolation between difference maintenance regimes has been based on the ‘average’ deterioration rate. The higher the spend in maintenance regime the slower the defence deterioration rate. The same asset deterioration rates have been applied to the defences in the rest of the UK.

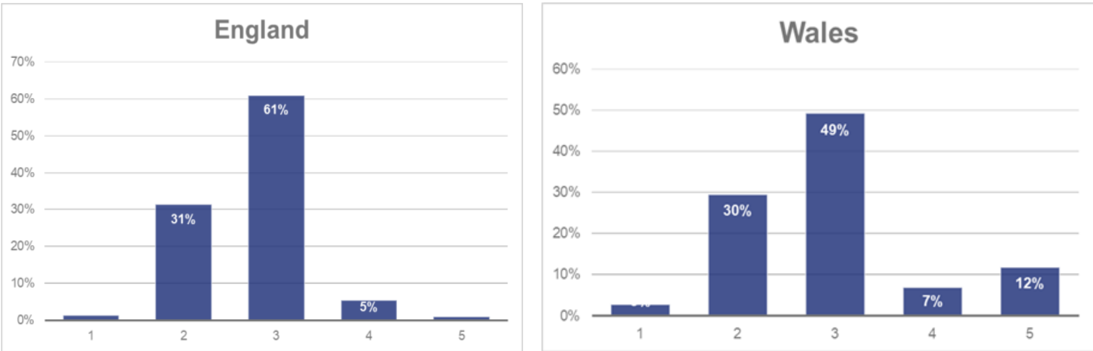


Figure 2: Defence condition grade (wall and embankment) breakdown by country.

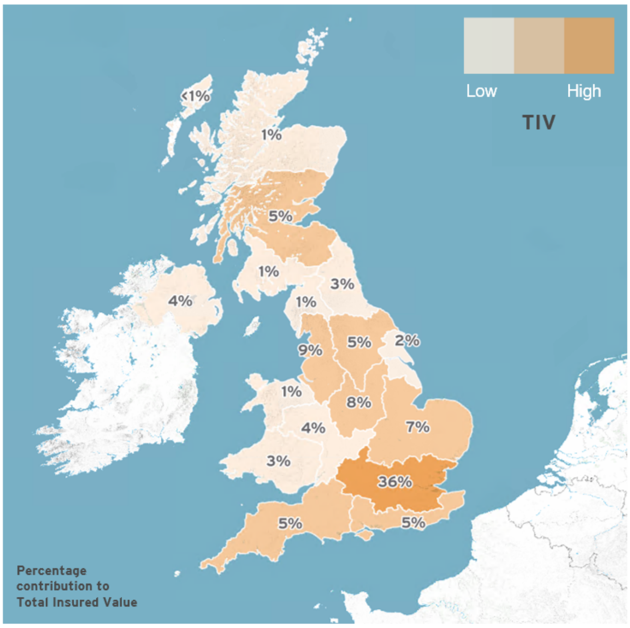
Figure 2 shows a breakdown of defence (wall and embankment) condition grade broken down by country. It can be seen that the majority of defences are in a fair or better condition. Where flood defence condition grade information was unavailable, as was the case for Scotland and Northern Ireland, the defences were assumed to be in condition grade 3 (fair).

3 Average Annual Loss

3.1 Defended Modelled Loss

Average Annual Loss represents the expected cost of flooding on average per year. This annual cost is calculated by averaging the losses over each year of the simulation, in this case 10,000-years. The Total Insured Value (TIV) is the rebuild or replacement value of assets included under an insurance policy and includes buildings, contents and business interruption values. The distribution of TIV by region in the UK is illustrated in Figure 3.

Total Insured Value (TIV)
Residential and Commercial

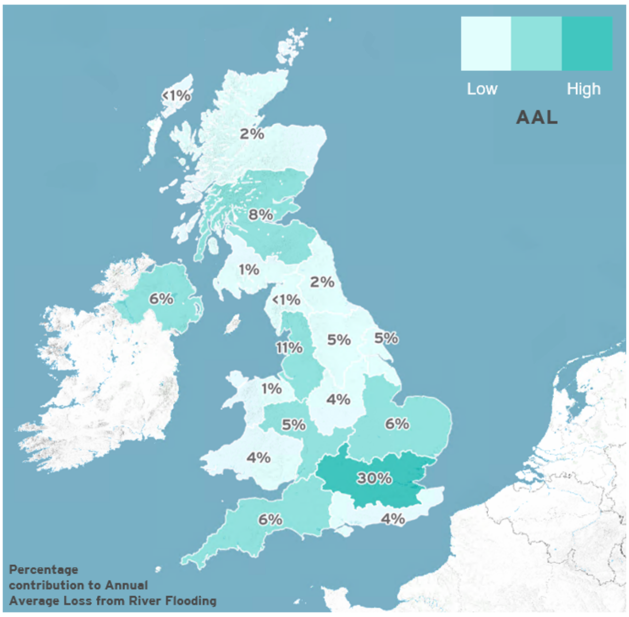


	Total Insured Value £ billions	Percentage of Total
London and Home Counties	1,570	36%
North West England	417	9%
Central Midlands	355	8%
East England	313	7%
South West England	241	5%
Yorkshire	219	5%
Southern England	210	5%
Central Scotland	206	5%
West Midlands	164	4%
Northern Ireland	155	4%
South Wales	153	3%
North East England	144	3%
Humber	80	2%
North Wales	53	1%
Northern Scotland	48	1%
Southern Scotland	32	1%
Cumbria	24	1%
Scottish Isles	6	0.1%

Figure 3: Percentage of Residential and Commercial Total Insured Value in the UK by region.

Given the current state of flood defences in the UK, the annual average loss (AAL) as a result of river flooding to residential and commercial property[6][7] is estimated at **£388 million**. At a regional level, loss from river flooding correlates generally with the distribution of TIV as indicated in Figure 4.

Annual Average Loss (AAL) from River Flooding
Residential and Commercial



	Annual Average Loss £ millions	Percentage of Total
London and Home Counties	117.44	30%
North West England	41.71	11%
Central Scotland	31.31	8%
East England	23.16	6%
South West England	23.34	6%
Northern Ireland	23.51	6%
Yorkshire	19.45	5%
West Midlands	20.91	5%
Humber	18.14	5%
Central Midlands	17.27	4%
Southern England	13.79	4%
South Wales	15.08	4%
North East England	9.15	2%
Northern Scotland	5.96	2%
North Wales	3.63	1%
Southern Scotland	3.45	1%
Cumbria	0.44	<1%
Scottish Isles	0.03	<1%

Figure 4: Percentage of AAL from river flooding to Residential and Commercial Property in the UK by region.

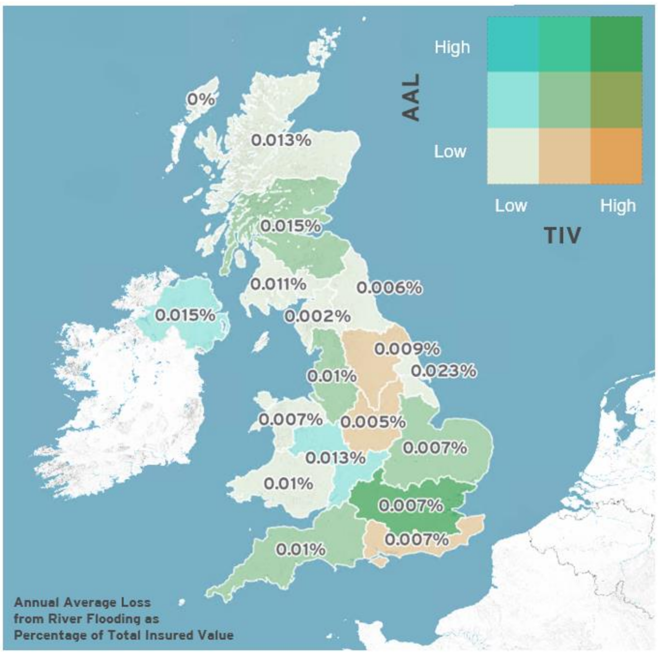
[6] Residential market portfolio supplied by Guy Carpenter
[7] Commercial portfolio incorporates data using PERILS UK Flood Exposure and Loss Database

For example, London and the Home Counties contributes to 30% of the AAL and contains 36% of the TIV. North Wales and Northern Scotland contribute 1% and 2% respectively to the AAL and both contain 1% each of the TIV.

The ratio of Total Insured Value (TIV) and Annual Average Loss (AAL) was calculated by region and shown in the table in Figure 5. This indicates the proportion of the TIV in each region exposed to river flooding. The model indicates that regions such as Humber, Central Scotland and Northern Ireland, have the highest *proportions* of their value exposed to flooding. Cumbria and the Scottish Isles the lowest proportions.

The map in Figure 5 is shaded as a thematic bivariate map comparing TIV in shades of orange and AAL in shades of blue. When these colours are combined it highlights areas of high *absolute* value and high *absolute* loss in green, whilst areas of low absolute value and low absolute loss are in white. Using this method highlights that whilst the Humber has a high *proportion* of value at risk to flood, the low *absolute* insured value results in a low contribution to AAL. Furthermore Yorkshire, the Central Midlands and the South East contribute a relatively low proportion to the AAL despite a significant share of the TIV. Northern Ireland and the West Midlands contribute a relatively high proportion to the AAL despite a low share of the TIV.

Correlation of Total Insured Value (TIV) and Annual Average Loss (AAL) from Flooding



	Annual Average Loss as Percentage of Total Insured Value
Humber	0.023%
Central Scotland	0.015%
Northern Ireland	0.015%
West Midlands	0.013%
Northern Scotland	0.013%
Southern Scotland	0.011%
North West England	0.010%
South West England	0.010%
South Wales	0.010%
Yorkshire	0.009%
London and Home Counties	0.007%
East England	0.007%
Southern England	0.007%
North Wales	0.007%
North East England	0.006%
Central Midlands	0.005%
Cumbria	0.002%
Scottish Isles	<0.001%

Figure 5: A bivariate thematic map indicating the relationship between high total insured value and high annual average loss from river flooding in the UK by region.

The breakdown of the annual cost of river flooding between countries and by residential and commercial exposures is detailed in Table 2.

Table 2: Current Annual Average Loss of River Flooding by Country and by exposure type

	Average Annual Loss River Flooding Residential		Average Annual Loss River Flooding Commercial	
England	£224.3 m	80%	£82.6 m	78%
Scotland	£30.5 m	11%	£10.3 m	10%
Wales	£12.7 m	5%	£3.9 m	4%
Northern Ireland	£14.4 m	5%	£9.1 m	9%
UK	**£282.0 m**		**£105.8 m**	

Without the mitigating impact of flood defences, the cost of river flooding could increase from the current £388 million to **£956 million annually** as shown in results from JBA's UK Flood model in the following section.

3.2 Average Annual Loss for four spending scenarios

The four spending scenarios were evaluated to estimate the impact on river flood losses. This was carried out utilising JBA's UK Flood Model with the addition of a new probabilistic defence failure module. The spending scenarios included:

- Minimum spending
- Reduced spend - decrease current maintenance spending by 50%
- Maintain current maintenance spending – (current target condition grade 3)
- Increase current maintenance spending

The average annual loss for each of the spending scenarios is shown in Table 3 with little difference (~1%) between scenarios. From research outlined in Section 1.2, it was found that flood defence breach is infrequent in the UK which is reflected in the national level results below. Calibration of JBA's probabilistic defence failure module reflects this.

Table 3: Average Annual Loss per spending scenario

Spending Scenario	Average Annual Loss £m
Minimum spend	389.3
Decrease spend	389.2
Current spend	389.1
Increase spend	389.1

Modelled losses suggest the inclusion of defended river areas or river flood defences reduces the national average annual loss significantly, by approximately **59%.** This highlights the significance flood defences have in reducing losses to river flooding across the UK. **In order to maintain such a significant reduction it is important flood defences are maintained to a reasonable condition.**

4 Maintenance costs for four spending scenarios

4.1 Maintenance spending for four scenarios

Four maintenance spend scenarios were tested against the JBA river flood defence data to assess the relative impact of maintenance spending on whole life costs between spending scenarios. Whole life costs include both the maintenance of defences to keep assets fit for purpose and at a target condition grade, and the periodic refurbishment or replacement of assets when they deteriorate to the point of failure. Whole life costing requires a model of the deterioration of assets (the time it takes to reach the point of failure), together with the costs of maintaining and replacing the assets.

These spend figures are hypothetical and assume that current maintenance spending is equivalent to target condition grade 3. Unit maintenance costs produced by the Environment Agency were extracted from FCRM Asset Management Maintenance Standards version 3 and were updated for inflation. Unit capital replacement costs were extracted from publicly available documents with indicative unit rates[8] and then calibrated to recent Environment Agency capital spending.

- Asset deterioration rates use standard Environment Agency figures for walls and embankments as described in the Environment Agency's report "Assessment and measurement of asset deterioration and whole life costing".
- A capital replacement cost was assumed to occur when the defence degraded to condition grade 4.

[8] Cost estimation for fluvial defences – summary of evidence Report –SC080039/R2

- Total present value costs for the 30-year period were assessed using European Insurance and Occupational Pension Authority (EIOPA) and HM Treasury Green Book discount rates. They were converted back to an annual average cost estimate.

The current Environment Agency spend on maintenance, repair and restoration of assets is in the region of £210 million to £230 million per annum. The latest EA budget for flood and coastal erosion risk management released in March 2021 shows that funding will increase by almost 25% for 2021-2022. Figure 6 plots the estimated capital and maintenance costs for each of the tested spend scenarios.

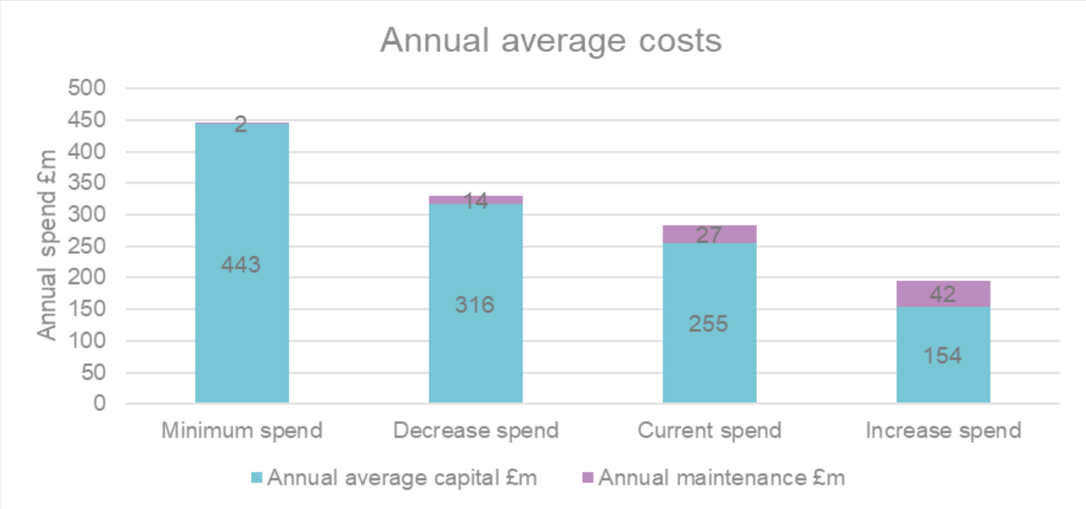


Figure 6: Annual average upkeep costs.

The results show that as maintenance spending is increased, the capital spend requirement decreases. This is a result of the life of the defences being extended when a higher level of maintenance is provided. The total estimated annual capital and maintenance spend for each scenario modelled is provided in Table 4. The variance in total costs from the current spend scenario is also shown, indicating that the increased spend scenario could reduce total long-term average costs by approximately £56m.

Table 4: Total estimated annual costs

Scenario	Maintenance Cost £m	Capital Cost £m	Total Cost £m	Relative difference to current spend £m
Minimum spend	2	443	445	+193
Decrease spend	14	316	330	+78
Current spend	27	255	252	
Increase spend	42	154	196	-56

Table 5 provides a breakdown of the average increase and decrease in life expectancy of a defence between the different maintenance spend scenarios (relative to the current maintenance regime). **Table 5 shows that if maintenance spending was halved then on average defence lifespan would decrease by 12 years, while increasing maintenance by 50% increases defence lifespan by an average of 8 years**. Figure 6 shows that the capital saving is much greater than the increased cost of maintenance and results in lower overall spending.

Table 5: Average increase in defence life expectancy

Spending Scenario	Extended years in life
Minimum spend	-16
Decrease spend	-12
Current spend	0
Increase spend	8

4.2 Capital replacement costs for four maintenance scenarios

The analysis clearly identifies that the impact of varying levels of maintenance is significant on the frequency of asset replacement/capital spending. **Increased spend on maintenance can delay asset deterioration and minimise longer term capital replacement costs**.

- **The net benefit between the current spend and increased spending scenario is estimated to be in the order of £87m per annum.**

The study found that, over the analysis period, **reducing the level of maintenance spending to 50%** of the baseline resulted in shortening the reliable lifespan of defences when compared to the current maintenance regime. The cost impact of this is that:

- The total 30-year maintenance and capital spending came to £11.1bn, an increase of £1.6bn on the £9.5bn baseline.
- **For every £1 of reduced maintenance spend, there will be an increase of almost £4.5 in capital costs annually.**

The study found that, over the analysis period, **increasing the level of maintenance spending to 150% of the baseline resulted in the lengthening of the reliable lifespan of defences so that capital expenditure is delayed.** The cost impact of this is that:

- The total 30-year maintenance and capital spending of £6.5bn, a decrease of £2.9bn on the £9.5bn baseline.
- **For every £1m of extra maintenance spending, there will be an annual capital cost saving of almost £7m.**

5 Overall net benefits from maintenance

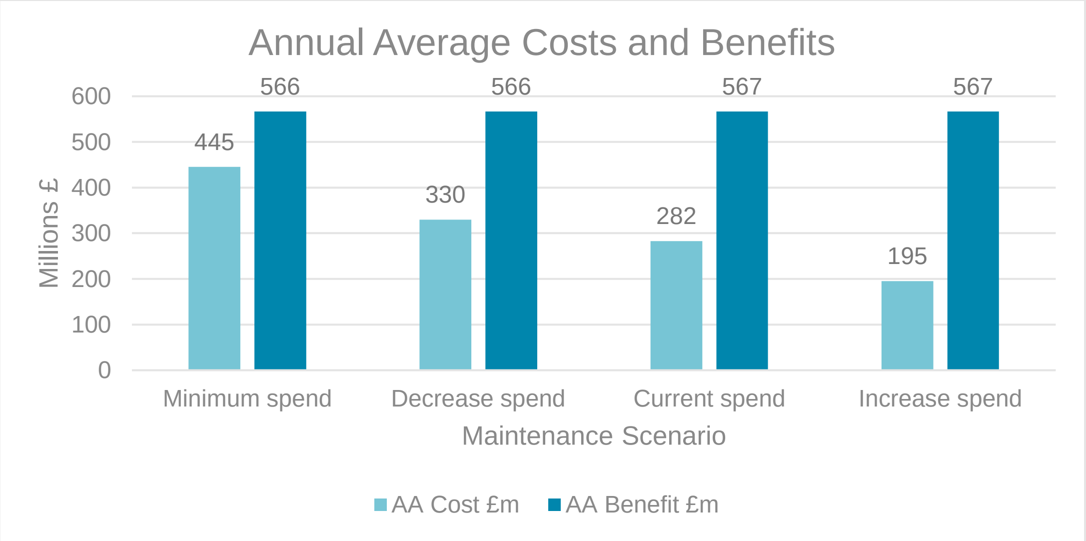


Figure 7: Annual average costs and benefits.

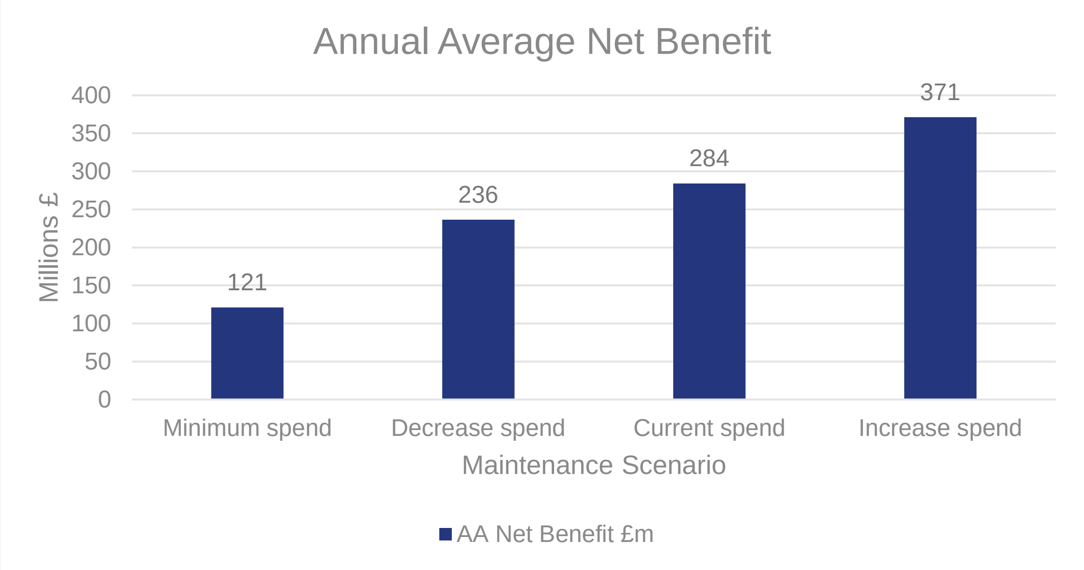


Figure 8: Annual average net benefit

Figure 7 shows the cost of maintaining the defences alongside the benefit derived from the defence (the benefit being the flood damages avoided). The benefit is almost the same for each scenario, showing the limited flood loss caused by breaching due to different maintenance regimes. The net benefit is the difference between the cost of sustaining the defences and the flood loss avoided. Figure 8 shows the net benefit for each scenario. This shows that there is a positive net benefit for all scenarios, with the net benefit ranging from £121m to £371m per annum.

As the benefit from the defences for each scenario is more or less the same – the difference in net benefit between the scenarios is dependent upon the savings derived by the adopted maintenance regime. As described earlier, an increase in maintenance spending results in an extension of the life expectancy of a defence and thus reduces overall capital replacement spending.

The net benefit using the HM Green Book method was also derived. The difference between the two methods is down to the chosen discount and inflation rates. Discount rates are much higher and the inflation rate is zero when using the Green Book method. This means that future costs are represented differently. The annual average cost of defence upkeep and the net benefit between the two methods are compared in the table below. The comparison shows that the lower maintenance spending regimes are far more costly overall and result in a lower or negative net benefit while the current and higher spend maintenance scenarios are cheaper and result in a far greater net benefit. Table 6 presents the EIOPA costs and net benefits depicted in Figure 7 and provides a direct comparison with the equivalent Green Book costs and net benefits.

Table 6: Annual average cost and net benefit (£).

Scenario	EIOPA Cost £m	Green Book Cost £m	EIOPA Net Benefit £m	Green Book Net Benefit £m
Minimum spend	445	731	121	-164
Decrease spend	330	472	236	94
Current spend	282	252	284	315
Increase spend	195	142	371	425

6 Conclusion

The study assesses the benefits of maintaining flood defences over a 30-year period, exploring the correlation between flood defence maintenance and flood defence failure due to breaching.

- The study found that **defences are reasonably well maintained across the UK** with 92% of defences in a 'fair or better' condition.
- Four flood defence maintenance regimes were considered as part of this study to determine the impact of flood defence failure. Each maintenance regime varied the amount of spending.
- While flood events have been increasing in recent years, with many defences overtopping, **there is little evidence of flood events causing widespread defence failure in the UK**. A calibrated probabilistic flood defence failure module was developed as part of this study reflecting the relatively low occurrence of flood defence breach. This is reflected in the four spending regimes modelled, with ~1% difference between each.
- **Modelled river flood defences reduce average annual losses by approximately 59%,** a saving of approximately £567.8m. This highlights the positive impact flood defences have on reducing river flood losses across the UK. It also emphasises the importance of maintaining these defences in order to reduce further the likelihood of defence breach and to mitigate flood risk.
- Upon assessing the impact of maintenance on the long-term costs of flood defences, results show that **an increase in maintenance spending can extend the life of defences, therefore reducing the overall capital spend requirement**.
- If maintenance spending is reduced, the lifespan of defences decreases which in the long-term causes an increase in overall costs.

Considering the cost of maintaining defences, the losses they can prevent and the overall net benefit of defences as an annual average benefit, the study found that the highest maintenance spend scenario, **a 50% increase on current spending, resulted in the highest long-term benefit of £371m**.

7 Limitations

The following are the current known limitations within this study:

- Data availability and completeness: The Environment Agency and Natural Resources Wales defence databases are incomplete in some areas and the defended river areas are often only available where detailed hydraulic models have been built. Data for Scotland and Northern Ireland are not published as Open Data and are more limited in coverage. JBA has generated a more complete set of defended areas which have been mapped onto the published flood defence datasets.
- Process: The analysis was carried out using JBA's UK Flood Model 2018 with the addition of updated 2019 river defended areas dataset as well as a newly developed probabilistic (structural) defence failure module for river flood.
- Flood defence types: The study is suitable for the assessment of the annualised loss of maintenance scenarios relating to two physical flood defences. **The study has been carried out exclusively on two types of raised defence: walls and embankments.** The study therefore does not include assessment of the impact of spend on other types of flood mitigation measures, for example:

- Physical flood defence of other types:
  - Flood barriers – for example the Thames Barrier and Foss Barrier
  - Internal drainage boards, including the pumping systems required to be used continually in order to ensure these areas remain dry

    - Pumping stations for surface water
    - Other mechanical and electrical systems
    - Pumping of water in other areas
    - Demountable defences
    - Flood protection maintained by organisations other than the Environment Agency
    - Flood storage schemes
    - Property flood resilience measures
    - Temporal reactive flood responses: the study does not take into account manmade adjustments made to exposure during flooding. For example, the deployment of sandbags, or use of property level protection measures
- Climate change: This analysis does not consider climate change
- Coastal: This analysis does not consider coastal flooding or defences

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