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Surface water flooding technical annex: investment analysis

This annex sets out how the Commission has used flood modelling analysis on the impact of different investment levels on the reduction in surface water flood risk in England by 2055.

A consortium of flood experts,[1] led by Sayers and Partners LLP, were appointed to deliver modelling for the study. The model used is the Future Flood Explorer[2] framework.

The Commission asked Sayers and Partners LLP to assess the indicative investment needed to deliver drainage improvements for which the benefits outweigh the costs. The model allowed the implementation of interventions, and their associated costs and benefits, to vary according to the geographical and other characteristics of each area, to mimic the fact that each individual area will require a tailored solution. This broadly followed the approach set out in Chapter 2, implementing above ground before below ground measures.

The modelling used two scenarios for climate change: a 2 degree increase in global mean temperatures compared to preindustrial levels, and a 4 degree increase, using the Met Office's UKCP18 climate projections convection permitting model.

For each of the portfolios, a wide range of benefits were accounted for. The benefits fall into three broad categories:

- damage avoided to properties, business and infrastructure, including statistical risk to life and the negative mental health effects of flooding
- savings from merging investment in combined sewer overflows with surface water flood risk reduction investment
- wider benefits, including health benefits from the provision of new green space.

Since little is known about current asset condition and the extent of its impact, the model assumes drainage is working at full capacity, and so does not account for investment in maintenance. This means all estimates included in the report do not include investment for maintenance of existing drainage.

The model operates at a national scale and makes assumptions about local conditions and future efficiencies in infrastructure solutions. Real conditions will not always align with the model's assumptions and, as discussed in Chapter 3, the model is based on the Environment Agency's current assumptions about properties at risk, which may change following the National Flood Risk Assessment process in 2024. This means it is unlikely that it will identify the optimal portfolio in every location – the more detailed modelling recommended in Chapter 3 should do this more effectively, providing the basis for the quantified plans that are recommended in the Chapter.

In summary, the model:

- **estimates current and future surface water flooding risk** in England up until 2100 through climate change and population growth scenarios, in terms of (a) expected annual damage (£) and (b) number of properties at high and medium risk of flooding[1]
- **defines a broad set of possible solutions to surface water flooding ('adaptation portfolios')** based on infrastructure interventions which could be costed and realistically implemented to reduce flood risk
- **measures the costs and benefits** of implementing each adaptation portfolio in every square kilometre in England
- **assesses the impact of different levels of investment** in adaptation portfolios across England on reducing (a) expected annual damage and (b) the number of properties at high and medium risk of surface water flooding by 2055.

This annex should be read alongside the Commission's main report and the technical report produced by Sayers and Partners (hereafter, Sayers et al.),[3] which describes in greater detail the modelling they have undertaken for the Commission.

The rest of this paper sets out additional analysis undertaken by the Commission to supplement insights from the model, in order to understand:

- future changes in the weighted average cost of capital, its impact on the model's net present value and on future water bills.
- the level of investment appropriate in each climate scenario explored by the model
- how to invest in a way that is robust to climate change uncertainty
- plausible ranges to put around estimates of costs and benefits.

It begins by describing the objective and key constraints given to the model.

1. Inputs: model objective, co-benefits and scenarios

The model was instructed to choose adaptation portfolios for each square kilometre in England, with a view to minimising the value of flood damages (maximising protection), for a given amount of expenditure between now and 2055. Since the model estimates flood damages up to the year 2100, the interventions funded between now and 2055 should be expected to remain appropriate for many years afterwards.

However, the model was also instructed to estimate a range of other impacts associated with this 'optimised' level of property protection. This allows for a full cost-benefit analysis of various intervention options. In addition to the flood damage avoided and the capital, operational and carbon costs associated with interventions, the cost benefit analysis considers:

- environmental benefits of interventions like sustainable urban drainage systems
- reduced costs associated with the government's storm overflow discharge reduction plan

The Commission explored how different its recommended level of investment might be if the model were asked to optimise against this wider set of benefits and found only modest differences.[4]

The number of properties at risk in the future, and so the extent of flood damages, is inherently uncertain. The modelling was applied to various scenarios of the future which between them describe the potential effects of climate change and new property development. Two potential climate warming scenarios and three different assumptions about new property development were incorporated into four scenarios in total:

1. a rise of **2 degrees** in global mean temperatures by 2100, and **no additional risk** from new developments in areas at risk of surface water flooding
2. a rise of **2 degrees** in global mean temperatures by 2100, and a **'low' increase in additional risk** from new developments in areas at risk of surface water flooding
3. a rise of **4 degrees** in global mean temperatures by 2100, and **no additional risk** from new developments in areas at risk of surface water flooding
4. a rise of **4 degrees** in global mean temperatures by 2100, and a **'high' increase in additional risk** from new developments in areas at risk of surface water flooding.

Consistent with the Commission's work on managing uncertainty, it has chosen scenarios that reflect a relatively wide range of alternative futures without comment on how likely each scenario might be. In relation to climate change, the Commission supports government's commitment to the Paris Agreement which aims to limit global temperature rises to well below 2 degrees and preferably to 1.5 degrees. The inclusion of 2 degree and 4 degree scenarios does not in any way suggest the Commission believes these are more, less or equally as likely as 1.5 degrees. All are possible and it is prudent to explore scenarios that involve higher temperatures, particularly when there may be opportunities for interventions which work equally well under multiple scenarios.

The technical report by Sayers et al. describes how each of these scenarios were parameterised. It references Office of National Statistics' projections of population [5]growth to motivate changes in the number of properties at risk due to new development, and the Met Office Convection-Permitting Model[6] to translate changes in global mean surface temperatures into rainfall scenarios.

2. Adjustments to the model: adding a cost of capital

Estimates in the modelling do not include the cost of raising finance to fund interventions. The Commission has therefore added its own assumptions about the cost of financing interventions to add an additional level of realism to the costs. These financing costs are incorporated into the 'net present value' estimates used to identify the cost-beneficial level of investment and the impact on water bills (see also the impact and costings note).

Financing costs reflect the need for private businesses to borrow or issue equity (shares) to raise money for capital projects, and the return expected by lenders and shareholders for their investments. The costs of debt and equity are combined to give a weighted average cost of capital. They accumulate annually, increasing the total cost of a project. But they also spread the costs into the future. To help compare costs incurred in different time periods, a discount rate can be applied which reflects society's preference for the present compared to the future. The discount rate reduces the 'present value' of costs and benefits borne in the future. Whether spreading costs into the future leads to an increase or decrease in their present value depends on whether the costs of finance are higher or lower than the discount rate.

Following HM Treasury's Green Book, Sayers et al. use a discount rate of 3.5 per cent and this is carried throughout the Commission's report.

Based on economic forecasts from March 2022, this analysis assumes that over the period 2025 to 2055 the water industry's cost of capital will average around 4.5 per cent in real terms, relative to CPIH. This would add around 20 per cent to the present value costs of below ground interventions. Interventions delivered by the water industry earlier in the period would face a lower[7] cost of capital and this is most likely to be the case for above ground interventions, for which the analysis assumes a weighted average cost of capital of 3.5 per cent. This adds nothing to the present value costs of above ground interventions because the cost of finance is exactly offset by the social discount rate[8].

In price review 2019, Ofwat assumed the water industry's weighted average cost of capital would be 3.4 per cent in real terms relative to CPIH. This includes assumptions about the overall cost of debt and equity and one component of these in particular: the 'risk free' rate of return on an investment. Since then, long-run expectations of the risk free component of debt and equity (as measured by the gilt rate) have risen. To calculate an average over the period 2025 to 2050 the Commission has therefore adjusted the risk-free component of the PR19 weighted average cost of capital, based on the difference in long run gilt rate assumptions from the Office for Budget Responsibility between the time PR19 was set[9] and this work in 2022[10]. Above ground interventions are more likely to be pursued in the nearer-term, due in part to the generally higher net present values they are expected to deliver and also following the solutions hierarchy from Chapter 2. So, they are unlikely to face the higher costs of capital towards the end of the 30 year period. Using the same methodology as the long-run cost of capital, over the period 2025 to 2040 the weighted average cost of capital is expected to be around 3.5 per cent so this is applied to above ground interventions.

By convention, no cost of capital is applied to publicly funded interventions.

The decision rules which drive results in the Future Flood Explorer framework involve ranking location-specific interventions according to the ratio of their benefits and costs – interventions with a higher benefit per pound spent appear higher up the ranking. Whilst the addition of the cost of capital will tend to reduce the benefit cost ratio of below ground interventions, these already have substantially lower benefit cost ratios than SUDs so the order of interventions in the ranked list is largely unaffected. The addition of the cost of capital does not affect conclusions about the most cost-beneficial level of investment at a national scale, whilst providing a more realistic assessment of the level of protection that can be afforded for a given budget.

Since the Office for Budget Responsibility published its assumptions about long run gilt rates in March 2022, expectations of future gilt rates have risen substantially in the short term and fallen in the longer term. Gilt rates in the 2050s are now expected to be lower than they are today. No account has been taken of this in the analysis. One possible consequence of a higher cost of capital in the short run is to make above ground interventions relatively more expensive (though likely still substantially better value for money than below ground interventions wherever they are practical). The Commission does not expect this to material influence any of the recommendations in the main report.

3. The appropriate level of investment for a given climate scenario

The model assesses the relationship between different levels of national investment in adaptation portfolios and reducing (a) the number of properties at high and medium risk of surface water flooding and (b) expected annual damage by 2050. There are 52 expenditure levels tested in total for both scenarios that involve no additional risk from new development (the only difference between these scenarios is the degree of climate warming). These range from £1 billion to £101 billion in real terms, undiscounted, over the period 2025 to 2055. The expenditure level is made up of capital costs, operational costs, carbon costs and support costs. All of these costs are also included in the net present value. Sayers et al. describes costs in further detail.

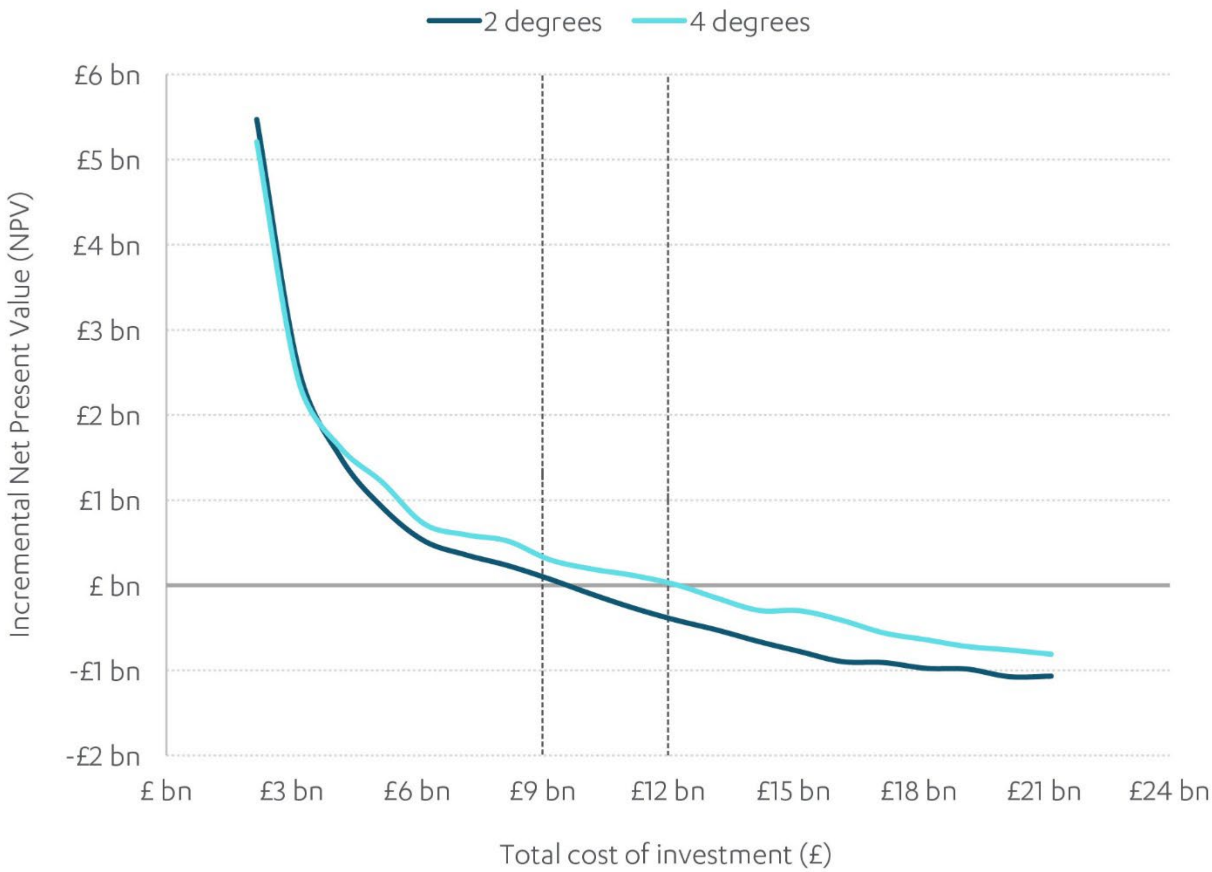
Testing this many levels of investment allows the Commission to determine the most appropriate level of investment in any given scenario. That is the level of investment expected to deliver the highest net present value. The Commission believes this is an appropriate threshold because investing beyond it would mean delivering schemes which cost more than they deliver in benefits. This is similar to the approach described in the Environment Agency's Long Term Investment Scenarios 2019 (LTIS).

A key finding is that the incremental benefits of further spending on surface water flooding start high and fall rapidly as investment increases. Such clear 'declining marginal returns' present a strong rationale for investing up to the point where incremental benefit has fallen to the level of incremental cost. At this point, the investment provides the greatest overall return to society.

All sources of cost and benefit are captured in this analysis, including environmental benefits, water company financing costs and reduced costs associated with the government's storm overflow discharge reduction plan.

Figure 1 below shows the 'declining marginal returns' associated with higher levels of investment, and the value of investment that would provide the greatest overall returns if the world warmed by 2 and 4 degrees Celsius. In the 2 degree scenario, an overall investment by 2055 of £9 billion would give the greatest return whereas in the 4 degree scenario, £12 billion offers the greatest return.

Figure 1: Incremental costs and benefits at different levels of investment, by scenario



4. A robust level of investment across all climate scenarios

With more intense rainfall expected in a 4 degree world, the capacity of flood infrastructure to absorb or transport rainfall would need to be higher. Individual interventions can be made robust to a range of different scenarios by considering whether they might be added to incrementally in future or need to be built with more extreme scenarios in mind. If infrastructure could be delivered incrementally, it may be possible to invest enough for a 2 degree world and add to it if necessary. This may well prove the case for many above-ground interventions. However below ground interventions tend to have a fixed capacity and need to be upgraded from 'end to end' to have the desired effect. Adding capacity to a pipe network is expensive and best done once rather than in successive increments (for an illustration of this, note the discussion in appendix E, section E.4.1, Sayers et al. around the significantly higher capital costs of upgrading piped drainage beyond the 1-in-30 design standard). Where there is a need for below ground intervention to significantly increase drainage capacity, perhaps because other options in the solutions hierarchy have been exhausted and there are a significant number of properties still at risk, it is prudent to make the intervention large enough to cope with the rainfall expected in a 4 degree world.

The investment strategy as a whole can also be made robust to a range of climate scenarios by setting an investment trajectory consistent with a 4 degree world and recognising there will be an opportunity to review in later years. The extra £3 billion required to build infrastructure that is suited to a 4 degree world would still deliver some benefits in a 2 degree world by protecting more properties from more extreme rainfall. Whilst this perspective is insufficient to demonstrate that the risks of investing for 4 degrees are lower than those from investing for 2 degrees, it does show these risks are manageable. More information on the likelihood and impact of intense rainfall will become available long before 2055, so if it becomes clear that the world will warm by much less than 4 degrees, investment plans can change.

The recommendation to invest £12bn in surface water flooding infrastructure does not mean that the 4 degree warming scenario is the most likely. The Commission acknowledges the inherent uncertainty in predicting climate change and in the face of this uncertainty has examined how robust different investment strategies are to a range of possible futures.

5. Ranges around costs and benefits

In both the 2 and 4 degree climate scenarios (with no increased risk from new developments), investing £12bn is expected to achieve around a 60 per cent reduction in the number of properties in areas at high risk of flooding. However, there is considerable uncertainty in the costs and benefits associated with delivering this 60 per cent risk reduction: it could cost more or less than £12bn and deliver more or less benefit than expected in each scenario.

The Commission examined risks associated with each of the major components of the cost and benefit estimates through literature review and consultation with experts. Table 1 shows the set of risks identified through this exercise and the possible magnitude of impact for each one, including key details like the asset affected and whether the impact is location specific. Note that in this table 'magnitude of impact' is an assessment of how the risk could affect the specific element of cost or source of benefit. The impact of each individual risk on total cost or total benefit will typically be smaller. There is no robust way to assign probabilities to any of these risks, so the Commission made a judgement as to how each risk associated with each component of the analysis might compound or offset the others in the aggregated estimates of total costs and benefits. Following this process, a plausible range was identified around both the total costs and total benefits which attempts to exclude the least likely combinations of different risks whilst remaining honest about the degree of uncertainty within the estimates.

Table 1: sources of risk and magnitude of impact

Risk item	Element affected	Asset type	Magnitude of impact on element	Source
Land purchase, because the central case assumes land is owned by the responsible party	Capex cost	Above-ground	+15%	Commission assumption
Construction disruption, faced by the public whilst pipes are being replaced/upgraded	Societal cost relevant to capex only	Below ground	+5%	Commission assumption
Effect of a less benign climate, especially on asset lives and maintenance need	Capex and opex	All assets	2 degrees: +15% 4 degrees: +25%	Sayers et al. assumption
Optimism bias, reflecting that past projects used to estimate the central case may have been the 'low hanging fruit'	Capex and opex	Largely above ground	+10%	Commission assumption
Management efficiencies, as SUDS are more widely implemented and organisations learn how to minimise costs	Capex and opex	Above ground	-20%	Commission assumption
Strategic savings, from a larger programme of investment or catchment approach that may bring economies of scale	Capex and opex	All assets	Urban: -10% Rural: - 5%	Sayers et al. assumption
Zero carbon concrete become cost-competitive, thus avoiding the relatively high cost of carbon included in estimates for later years	Carbon cost	Below ground	-5%	Commission assumption
Per-property value of flood damages	Expected Annual Damage	Properties	+15% -15%	Environment Agency Long Term Investment Scenarios[11]
Interventions are tailored better to local needs, delivering more than the fairly generic interventions suggested by national-scale modelling	Expected Annual Damage and wider benefits	Properties and natural capital	+10%	Commission assumption
Revised estimates of value of wider benefits, perhaps due to new research or real-world experience	Wider benefits	Natural capital	+50% -50%	Commission assumption
Greater interactions with programme to reduce combined sewer overflows	Cost saving to other parties	All assets	+50%	Commission assumption

The Commission has assumed a range of +20 per cent to -15 per cent around the central estimates. Sources of cost escalation could include: onward treatment costs, land purchase costs, optimism bias, construction disruption and the effects of a less benign climate. On the other hand, management efficiencies, strategic savings from taking a catchment-based approach and widespread uptake of cost-competitive low/zero carbon concrete could all drive costs below the central estimate[12].

Benefits are assumed to lie within the range -10 per cent to +15 per cent around the central estimates. The high end of this range might be achieved by finding more bespoke solutions for each place than the generic set of adaptation portfolios used in the model, or from greater savings to the programme for upgrading combined sewer overflows. Uncertainty in the 'per unit' value of flood damages and the wider benefit of SUDs could drive benefits up or down.

Applying these ranges, the Commission concludes that achieving a 60 per cent reduction in the number of properties at high risk would cost somewhere in the range of £10.5 billion to £14 billion and deliver benefits worth £23 billion to £29 billion. Whilst it is relatively unlikely that the highest end of the cost range and the lowest end of the benefit range would happen simultaneously (or vice versa), it is illustrative to note that these estimates imply the ratio of benefits to costs would lie in the range 1.6 to 2.8.

References

[1] Paul Sayers, Sam Carr, Dr Matt Horritt, Paul Eccleston, Dr James Miller, Dr Bruce Horton, and Prof. Richard Ashley.
[2] A model which has been used for various reports in the past, for example the third Climate Change Risk Assessment
[3] Sayers, P.B., Ashley, R, Carr, S., Eccleston P, Horritt M, Horton, B, Miller, J (2022). Surface water – Risk and investment needs. A report by Sayers and Partners for the National Infrastructure Commission, London.
[4] Ibid, page 22.
[5] Office for National Statistics, 2018, https://www.ons.gov.uk/peoplepopulationandcommunity/populationandmigration/populationprojections
[6] Met Office, 2018. https://www.metoffice.gov.uk/pub/data/weather/uk/ukcp18/science-reports/UKCP-Convection-permitting-model-projections-report.pdf
[7] The Office for Budget Responsibility's March 2022 Long Run Determinants spreadsheet shows the gilt rate below 2 per cent until 2029, rising to around 4.2 per cent in the early 2040s, and declining only marginally to 3.9 per cent by 2055. At the time of publication, this is no longer the case. Figures are presented here to accurately reflect assumptions used in the analysis, recognising market expectations may be more up to date.
[8] Following the HM Treasury Green Book, Sayers et al. apply a social discount rate of 3.5 per cent per annum
[9] Chosen to reflect long-run expectations when Ofwat published its early view on the cost of capital in PR19. Office for Budget Responsibility, March 2018: https://obr.uk/download/long-term-economic-determinants-march-2018-economic-fiscal-outlook/
[10] Office for Budget Responsibility, March 2022: https://obr.uk/download/long-term-economic-determinants-march-2022-economic-and-fiscal-outlook/
[11] Jacobs, 2019. Long Term Investment Scenarios: Additional Analysis. Topic 13 technical report – Progress in knowledge since LTIS 2014 – Surface Water Flooding (Unpublished). Prepared for Environment Agency
[12] Zero carbon concrete is included in this list because its use would reduce carbon costs, which by 2055 are expected to be substantial. The material itself may be more or less expensive than traditional concrete.