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Comparing the scale of modelled and recorded current flood risk: Results from England

Edmund C. Penning-Rowsell

FHRC, Middlesex University, London, UK

Correspondence
Dr. Edmund Penning-Rowsell, FHRC, Middlesex University, London, UK.
Email: edmund@penningrowsell.com

Abstract

As the Sendai framework recognises, understanding the nature and severity of risk is an important prerequisite to sensible risk reducing measures. The UK has been in the forefront of assessing the scale of flood risk at a national level to inform investment and policy directions but the scale of this risk, as modelled, has reduced since 2014. This paper compares the most recent modelled version of national flood risk, in the form of the Environment Agency's State of the Nation report, with loss figures quantified in terms of insurance claims data for the period 1998 to 2018. Depending on assumptions, the results show that the modelled results are between 2.06 and over 9.0 times the comparable flood losses measured in terms of the compensation paid to flood victims by insurance companies. The reasons for these differences remain unclear but several possibilities are reviewed. Many of these reasons appear implausible, but the divergence between the two sets of results should encourage the users of this data to consider carefully their assessments of the true scale of flood risk that the country faces, and perhaps promote similar comparisons in other countries.

KEYWORDS

divergences, insurance claims, modelled results, national flood risk

1 | INTRODUCTION

As in many countries of the world, the UK has seen significant and serious flooding over the last three decades, specifically there in 1998, 2000, 2007, 2013/14, and 2015/16. Damage has been considerable. The UK government continues to invest substantially in flood risk reduction measures, supported by the Environment Agency and other risk management authorities including Lead Local Authorities (Defra, 2020). Legislation has also been passed, creating new roles and responsibilities, indicating the seriousness with which the problem has been taken. The UK Cabinet Office continues to produce a national risk register (Cabinet Office, 2018) showing flooding from rivers and at the coast to be one of the most serious perils affecting the country (see also Penning-Rowsell, 2014, tab. II).

A multi-year annual average of flood damages is valuable as a metric of risk because it includes a contribution from major and minor flooding, and can be used alongside other inputs to gauge the level of annual investment necessary to help reduce risk. The Environment Agency's NaFRA (National Flood Risk Assessment) exercise, to calculate such an average, has been conducted over many years, at considerable cost. First published in 2000 (under a NAAR acronym) the Assessment and its results have recurred every year or so, each time with results from improved (or at least different) methods and data (Penning-Rowsell, 2014, tab. I). The aim has been to calculate the national annual average flood damages in the countries concerned (the UK; England only, etc.) as a measure of the aggregate risk faced from flood events of different severity and probability (i.e., return period). The concepts of annual average damage (AAD) and expected annual damages (EAD) are used interchangeably here, although the former tends to be backward looking and the latter forward looking.

The results are important. They are used, with other information, in the Environment Agency's Long Term Investment Scenarios (LTIS), designed to demonstrate the economic worthwhileness of expenditure to reduce flood risk. Therefore they form part of the Agency's evidence to UK central government—principally to Defra and the Treasury—for grant-in-aid for the continuation of its c. £0.5billion per annum investment in flood risk management (FRM) infrastructure and other risk reducing measures. The NaFRA results are thus central to the UK's process of national hazard appraisal and risk reduction effort.

The UK is not alone here: the accurate assessment of risk is the first of four priorities in the Sendai framework agreed by all nations in 2015: “Disaster risk management should be based on an understanding of disaster risk in all its dimensions” (UNISDR, 2015, p. 14). All European Union countries have obligations under the EU Floods Directive to assess their flood risks, on a catchment basis, as the foundations for their Flood Risk Management Plans. But few other countries have the UK's strong and systematic evidence based approach to policy making and the commitment to FRM investment. The latest stage of this NaFRA exercise began in 2015 and was completed in 2018 under the project's “State of the Nation” title (hereinafter SoN), this time limited to just flood risk in England following the devolution of separate flood risk management responsibilities to Wales and Scotland.

This paper seeks to compare two quantifications of current flood risk for England: a set of updated NaFRA results (from the SoN project) compared to the record of flood losses as measured by insurance claims following flood events. Flood insurance in the UK is widespread and has been for many years (Penning-Rowsell, Priest, & Johnson, 2014). There is no attempt here to assess potential flood damage in the future, from whatever cause. The approach here continues similar research published some years earlier (Penning-Rowsell, 2014), and the aim of the comparison here is in part to validate the most recent NaFRA modelling and in effect to help calibrate its risk assessment models. Since 2014, the modelled level of annual average national risk from NaFRA has been reduced from over £1.0bn by more than 33%. The question remains as to whether current modelled levels of risk are now more in line with the insurance based annual average assessment and vice versa. In this respect the value of NaFRA—and similar national assessments elsewhere in the world—is only as great as its ability accurately to measure current risk and thereby provide a platform for subsequent exercises such as guiding risk reduction investment and forecasting flood losses in the future under different climatic and socio-economic conditions.

2 | THE STATE OF THE NATION (2018) FLOOD RISK ANALYSIS

The State of the Nation project (Environment Agency, 2018a) has been the first national-scale update to NaFRA since 2008, initiated in July 2014 and reporting 4 years later (Environment Agency, 2018a). The aim was to form a new country-wide picture of the flood risk from rivers and the sea (HR Wallingford, 2018).[1]

2.1 | Changes in assessment modelling and data inputs

Initial trials were sometimes problematic and a review via local Environment Agency staff had shown that deficiencies in the input data, methods, and process had given rise to “implausible results in certain locations. These results could therefore not be published” (HR Wallingford, 2018, p. 1). Hence the continued refinement of the State of the Nation (SoN) project. By 2018, a total of 17 technical reports were produced, reflecting many alterations and adjustments to the approaches previously adopted.

In summary these alterations included, inter alia, the following changes to the methods of calculating risk and their inputs (HR Wallingford, 2018):

- Developing a new method for assessing expected annual damages (EADs) as a post-process after the RASP probabilistic risk “engine” had been run (see Hall et al., 2003). Pilots had demonstrated that the post-process calculation of risk method was reliable and gave comparable results to the pre-existing run-time approach yet had significant advantages in terms of enabling the incorporation of the results of screening and validation (see below);

- Screening the results by systematically comparing them with other Environment Agency flood management data;
- Validating the results by local Environment Agency staff, who were the able to apply manual changes to the flood likelihood categories in their locations (High (> 3.3% annually); Medium (3.3% to 1%); Low (0.1%); and Very Low (< 0.1%)) where they considered their local information to be more accurate than the modelled assessment of likely flood probability. Many changes were made, particularly reducing property numbers by 24% in the High probability band and increasing them by 591% in the Very Low band (Table 1).
- Much greater use and incorporation of detailed local modelling, leading to significant reductions in this type of local Environment Agency manual changes;
- Many alterations to the land use of the flood risk areas, to correct for deficiencies, principally by examining those locations showing maximum damage potential which might have been erroneously categorised (for example a local market place where temporary market stalls operate, or a location containing a number of shipping containers, each stall or container having separate address points);
- Only counting risk for those properties that are located within Flood Zones 2 and 3,[2] omitting those with a lower probability of occurrence (i.e., greater than 1:1,000 years or lower than 0.1%), thus matching previous assessments;
- Using more up-to-date potential flood damage data for non-residential properties (NRPs), resulting from the update of the Multi-coloured Manual in 2013 (Penning-Rowsell et al., 2013).

Despite this considerable effort and many changes, it has been recognised and was recommended that further detailed comparisons are made on the State of the Nation results, to verify whether the methods now provide better EAD results for the national assessment of flood risk (HR Wallingford, 2018, p. 1). This paper might be considered an unofficial and hence independent part of that comparison.

3 | THE STATE OF THE NATION RESULTS

The total numbers of properties assessed in the SoN modelling to be at flood risk in England is 2,590,616 (Table 1), comprising 1,936,716 residential dwellings and 293,247 NRPs (Environment Agency, 2018a) (Table 2). The balance (360,653) is properties "unclassified," meaning that for this 14% of the total we have no information on their characteristics. The overall total compares with 2,400,000 properties assessed by NaFRA 2008 and 2,137,000 by NaFRA 2006 (Penning-Rowsell, 2014, tab. 1), an increase from 2006 to 2018 of some 12%.

The total SoN estimated annual average economic damages is £0.664bn, and Table 2 shows that the largest fraction of this remains accounted for, as in the past NaFRA analyses, by flooding to residential properties, although the contribution from unclassified properties, at 34.2% of the total, is worryingly high, given the lack of information about these properties and their flood damage susceptibilities. The Environment Agency (2018a) reports that this £0.664bn total represents a decrease from the previous estimated total of £0.900bn (calculated in an April 2017 NaFRA analysis [unpublished]) by some 26%.

This decrease in calculated AAD is attributed to correcting errors in the underlying property data set, and improvements in modelling method and data with the much greater use of detailed local modelling, leading to fewer manual changes (see above). The change in the numbers of properties within each flood likelihood category is also seen as important (Table 1), driven by the use of a continuous defence line dataset providing crest levels for the areas between the river and the floodplain and allowing the coast to be more accurately represented. Also

TABLE 1 The State of the Nation (SoN) versus the previous NaFRA analysis: properties in different probability bands, here shown as return periods (Environment Agency, 2018a)

	Total numbers of properties at risk				
	Total high >1 in 30 years	**Total medium 1 in 30 to 1 in 100 years**	**Total low 1 in 100 to 1 in 1,000 years**	**Total very low less than 1 in 1,000 years**	**Total**
NaFRA in 2017[a]	268,851	541,029	1,747,912	106,482	2,664,274
SoN 2018	203,629	693,741	1,064,459	628,787	2,590,616
Difference	−65,222	152,712	−683,453	522,305	−73,658

[a] Unpublished but recorded in Environment Agency (2018a).

TABLE 2 The results in the State of the Nation analysis (Environment Agency, 2018a)

Item	Residential	Non-residential	Unclassified	Total
Total annual average damage (£bn)	0.246	0.191	0.227	0.664
Percentage of total	37.0%	28.8%	34.2%	100.0%
Number of properties (000 s)	1,937	293	361	2,591
Annual average damage per property	£127	£651	£629	£256

mentioned were the 1.5 million new or improved modelled water levels incorporated into the National Fluvial Loading dataset (Environment Agency, 2018a, p. 3).

It is also known that the excessive flood depths created by the previous NaFRA modelling have been addressed, at least in part, by capping those flood depths to the level of nearest flood defence asset: simply put, water levels on the floodplain can be no higher than the height of the crest of that defence (or riverbank) that the flood waters overtopped. In five pilot studies in SoN Phase 1 in Abingdon, Aylesbury, Carlisle, Chelmsford and Reading this capping reduced annual average damages by 67.9% (using detailed depth/damage data) or by 58.6% (using the Weighted Annual Average Damage [WAAD] statistic) (Panzeri, 2015, p. 45).

It is clear from their reports on the SoN 2018 that the Environment Agency sees the results obtained as a significant improvement on those from the previous analyses. The earlier comparison (Penning-Rowsell, 2014) and its critique of the NAAR and earlier NaFRA results, with their UK AAD values well over £1bn, appears to be vindicated. In the analysis for this paper the objective has been to see the extent to which the SoN's total annual average damage of £0.664bn compares with the other source of information on the flood risk to which England is exposed.

4 | THE ANALYSIS OF RECORDED RESIDENTIAL PROPERTY FLOOD DAMAGES TO 2018

It is instructive to update the Penning-Rowsell et al. (2014) analysis to the year 2018, not least because we appear to have had serious flooding in the winter of 2013/14, some localised flooding in 2012, and a major event in 2015/16 (Storm “Desmond” and other “named” events at this time). This up-dating is only possible in the first instance using residential flood insurance claims, employing the collated insurance claims records from members of the Association of British Insurers (ABI). From this data we need to estimate the likely overall total of both residential and non-residential losses to match NaFRA/SoN totals (see below). This paper has used a slightly revised set of ABI data (hereinafter referred to as ABI (2019), the product of some adjustments by the ABI to the grossing up of its members' results to yield better annual totals.[3]

4.1 | Adjustments for inflation and betterment

To compare the flood insurance claims record with the *State of the Nation* modelled annual average flood damages in a “like-for-like” manner requires the former to be adjusted in several important but convoluted ways (Table 3). To make these change transparent for each years' data the full spreadsheet is provided (Table 4).

To achieve comparable data, all the ABI flood claims figures (converted, first, to 2018 prices via the Consumer Prices Index [Table 4, column B]) have to be converted to national economic values by, secondly, deducting any taxation elements. Claims from flood insurance policies are for costs incurred which will have included the Value Added Tax that UK residents paid when purchasing new equipment or paying for drying out and cleaning their dwellings, or for repairs to rectify any structural damage and for redecoration. This Tax varied during the period being analysed here, from a low of 15% in 2008/09 to 20% after January 2011, and 17.5% in between; the three different rates have been used in this adjustment.

Also, thirdly, again to convert the financial losses (those suffered by the householder) to economic losses to the nation we need to eliminate the “betterment” element in flood loss compensation as included in the insurance pay-outs (see Penning-Rowsell, 2014, endnote 2, for details of this important adjustment). These insurer payments are generally for new equipment, to replace that damaged in the flood, under the “new-for-old” insurance policies that have been near-universal in the UK since the end of the 1990s.[4] The resident acquires some “betterment” in this process, and that needs to be deducted (i.e., the difference between a new television and the flood-damaged old one that was part-way through its life and had given service and value in that respect). The *State of the Nation* results use flood loss information from the “Multi-coloured Manual”

TABLE 3 Factors used to adjust the ABI flood claims record to match the NaFRA/State of the National modelled flood damages

Adjustment: Rationale	Columns in Table 4	Factor (see text)	Objective
1. To allow for price inflation between the ABI record and 2018	B.	UK consumer prices index indices for each year in question	To standardise on 2018 values (the same as the SoN)
2. To exclude the value added tax element within claims	C.	VAT levels for each year in question	To change financial values to national economic values (see text)
3. To exclude the "betterment" element within claims	D.	62.5% of financial claims	To change financial values to national economic values (see text)
4. To up-rate the claims data for estimated lack of insurance cover	E.	Multiply by 1.17	The ABI data does not cover those not insured.
5. To separate flood claims in England only from the ABI's UK dataset	F.	Excluding Northern Ireland, Scotland and Wales	To make the claims record fully compatible with NaFRA/SoN
6. To exclude the likely level of surface water flooding damages in the ABI data	G.	Deduct 40% (as per Horritt, 2014)	NaFRA/SoN does not include surface water flooding
7. To account for the market share of ABI members	H.	Up-rate by 1.25 (based on ABI source: See text)	Not all retail insurers belong to the ABI
8. To up-rate the claims data for residential plus non-residential, from the residential-only dataset	See text	Multiply by 1.79	To make the claims record fully compatible with NaFRA/SoN

datasets, which exclude all such taxation elements, which are transfers within the economy rather than real resource costs, and also deducts this betterment to give "average remaining value" adjustments (Penning-Rowsell et al., 2013, pp. 96–67).

4.2 | Adjustments for non-insurance and for England only

The next adjustment, fourthly, is needed because the ABI data reports on those claiming on insurance policies, but not all UK residents are insured for flood losses so the claims data will not include those losses for which no insurance compensation is paid. The best data on non-insurance by households comes from Office for National Statistics (ONS) data from a sample of c. 5,000 UK residents in their annual *Living Cost and Food Survey* (ONS, 2016).[5] This reports that 21.79% of households (in the UK, minus Scotland) had not bought domestic contents or structural flood insurance in 2014. What cannot be adjusted for is under-insurance, but which is known to occur, because there is no good data on the extent of that factor on claims totals. This remains to be researched.

Fifthly, the ABI data is for the whole of the UK. The 2017 CCRA report for the Climate Change Committee, as reported by Sayers, Horritt, Penning-Rowsell, and Fieth (2017), figs. 4 and 5), indicates that of the total residential Expected Annual (economic) Damage (EAD) across the UK, "England contributes (c.) 79% ..., Scotland 12% ..., Wales 6% ... and Northern Ireland 2% ... to this overall number." That result is based on an emulation of the RASP-derived flood damages for the countries concerned, and therefore closely resembles what the State of the Nation exercise and its modelling was designed to provide. The figure of 0.7892 is therefore used to deflate the UK AAD to yield an England-only result. As indicated in Table 4 (col. F) this figure is £0.1218bn or £122 m (residential only).

"Surface water flooding."

"Surface water flooding" is defined as "flooding (that) occurs when intense rainfall overwhelms drainage systems." The significance here is that "Around 35,000 properties were affected by surface water during the major floods of 2007" (Environment Agency, n.d., p. 1) and a total of 55,000 were flooded from all sources (Pitt, 2008, p. ix). The National Audit Office, based on a reference to the ABI, indicates that "Insurance claims for surface water flooding from the 2007 floods outnumbered claims for river or tidal flooding by 6:1" thereby giving a figure of 85% (NAO, 2011, p. 12). Pitt gives surface water flooding as a "high proportion .... compared with flooding from rivers" although the interim report's two-thirds figure remained "unclarified" (Pitt, 2008, p. xii, 7). The EA's Chief Executive recently suggested a figure of more than

TABLE 4 Adjustments to the ABI (2019) raw data (see Table 3). All figures are at 2018 prices, and all in £bn except column A and the factors

Year	A. ABI raw data (supplied 2019) (£m)	B. ABI data inflation adjusted	C. Deducting VAT	D. Deduct betterment	E. Data adjusted: No insurance cover	F. Adjusted data (England only: See text)	G. Adjusted for surface water flooding (SWF)	H. Adjusted for the ABI having c. 80% of the market
1998	124.4	0.1908	0.1624	0.1015	0.1298	0.1024	0.0802	0.1002
1999	52.9	0.0799	0.0680	0.0425	0.0543	0.0429	0.0336	0.0420
2000	242.4	0.3560	0.3030	0.1894	0.2421	0.1911	0.1496	0.1870
2001	156.1	0.2210	0.1881	0.1175	0.1503	0.1186	0.0929	0.1161
2002	114.9	0.1608	0.1368	0.0855	0.1093	0.0863	0.0676	0.0845
2003	61.3	0.0836	0.0711	0.0444	0.0568	0.0448	0.0351	0.0439
2004	59.9	0.0801	0.0682	0.0426	0.0545	0.0430	0.0337	0.0421
2005	155.4	0.2019	0.1719	0.1074	0.1373	0.1084	0.0849	0.1061
2006	62.3	0.0779	0.0663	0.0414	0.0530	0.0418	0.0327	0.0409
2007	972.6	1.1910	1.0136	0.6335	0.8100	0.6393	0.5005	0.6257
2008	272.7	0.3202	0.2785	0.1740	0.2225	0.1756	0.1375	0.1719
2009	150.4	0.1766	0.1535	0.0960	0.1227	0.0968	0.0758	0.0948
2010	102.0	0.1167	0.0993	0.0621	0.0794	0.0626	0.0490	0.0613
2011	52.0	0.0586	0.0488	0.0305	0.0390	0.0308	0.0241	0.0301
2012	335.0	0.3663	0.3052	0.1908	0.2439	0.1925	0.1507	0.1884
2013	140.6	0.1513	0.1261	0.0788	0.1008	0.0795	0.0623	0.0778
2014	269.6	0.2857	0.2381	0.1488	0.1903	0.1501	0.1176	0.1469
2015	293.6	0.3114	0.2595	0.1622	0.2074	0.1637	0.1281	0.1602
2016	219.9	0.2300	0.1917	0.1198	0.1532	0.1209	0.0947	0.1183
2017	53.8	0.0549	0.0458	0.0286	0.0366	0.0289	0.0226	0.0283
2018	73.6	0.0736	0.0613	0.0383	0.0490	0.0387	0.0303	0.0379
Mean	188.8	0.2280	0.1932	0.1207	0.1544	0.1218	0.0954	0.1192
NaFRA/ SoN								0.246
Factor		0.1208	0.8473	0.6250	1.2786	0.7892	0.7830	1.25

50% for surface water flooding (Environment Agency, 2018c). Analysis of the 2000 flood also indicated a large fraction of total damages from this type of flooding (Penning-Rowsell, Chatterton, Wilson, & Potter, 2002), with insurance expert David Crichton (2001, p. 184) reporting a figure of "over 40% of the £700m worth of flood claims."

Insurance payments are made irrespective of the source of flooding, so include for this type of flooding, whereas the *State of the Nation* analysis includes only "flooding from rivers and the sea" (Environment Agency, 2018a, p. 1). A detailed Environment Agency sponsored review by Matt Horritt (Horritt, 2014) of the results in Penning-Rowsell et al. (2013) concluded in this respect that "Claims data (i.e., as with the ABI [2019] data) are likely to include significant contributions from sources other than rivers and the sea. For direct comparison with NaFRA outputs .... claims figures should be reduced by 30–50% to allow for surface water (flooding)" (Horritt, 2014, p. 11).

But there is uncertainty here. Whilst some of the estimates of surface water flooding given above are very high, we choose, first, to be cautious in this respect. The latest Climate Change Risk Assessment (CCRA) for the UK Climate Change Committee (Sayers et al., 2017) indicates that surface water flooding amounts to some 19.26% of UK flood damage. However we know that the percentage in 2007 was much higher (see above), so we use 50% there and Crichton's 40% for 2000. For the other years we use the CCRA figure of 19.26% (the overall mean is 21.7%). The result in Table 4 (col. G) gives an AAD value of £0.0954bn. Results described later in this paper, secondly, take Horritt's 40% as an assumed upper bound for this SWF effect.

4.3 | Coverage of the market by the ABI

The ABI does not cover via its members the whole of the residential insurance market. There is no compulsion for retail and other insurers to become members of the

Association, and some have not taken up membership. This means that the ABI's flood damage claims record underestimates the total flood damage experienced in the country, and this needs to be corrected. The only information we have on the percentage penetration of ABI membership is an estimate of 80%,[6] so the claims record has been uprated by a factor of 1.25. Other non-ABI insurers might operate through Lloyds of London but its role in domestic insurance is considered to be very small.[7] Ideally, we should also correct for excesses (deductibles) that the individual householder has to cover, but their magnitude is not systematically reported. A recent estimate (Penning-Rowsell, 2020) puts them at c. £350 or 2.9% of average claims (Figure 1). This element of annual flood losses should not be ignored but an adjustment adding to claims values, not made for this paper, would have only a very small effect on the AAD values discussed here.

The annual average figure from this ABI membership adjusted assessment is thus £0.1192bn or £119.2 m (Table 4, col. H) rather than the £0.0954bn cited above. The four adjusted claims records for 2000, 2007, 2008, and 2012 are significantly above the average for the last 21 years, but seven intervening years show much lower flood damage claims, especially in 2011 and 2017 (Figure 2).[8] Only 1 year (2007) has an adjusted claims total that exceeds the comparable NaFRA/SoN residential AAD total of £0.246bn.

5 | CONVERTING THE RESIDENTIAL-ONLY FLOOD CLAIMS RECORD TO MATCH THE FULL NAFRA/SON RESULT

As indicated above, the insurance claim record from the ABI reliably only covers flood damage to residential properties (for non-residential properties, "storm" and "flood" claims are combined). Yet NaFRA and SoN cover both residential and non-residential categories (and those labelled "unclassified" [Table 2]). In the absence of better information, we need to use the ratio of residential losses to the total of both residential and non-residential losses to make the insurance database and the initial results given above comparable to the full NaFRA/SoN result. This is a large adjustment, but we now have better data on the relationship of residential to non-residential property (NRP) damages to guide this adjustment.

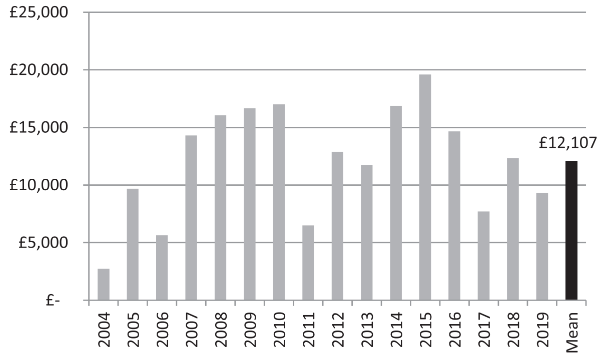

FIGURE 1 ABI data (not inflation adjusted) on annual residential flood claims averages based on 267,000 claims. These are financial values; economic values would be c. 47% lower (column D/B in Table 4)

The best information available on this matter is derived from the three floods occurring in the years 2007, 2013/14 and 2015/16 (Table 5). Between them they account for £3.863 billion of flood damage, and the weighted average fraction of this attributed to residential properties is approximately 55.6%. To use the residential-only flood damage data as a basis of giving an estimate of this NRP value we need to multiply the former estimate of £0.1192bn by 0.7983 (Table 5), yielding a mean estimated NRP AAD of £0.0952bn.

We also need, finally, to adjust this figure for insurance penetration. However, it is likely that virtually all businesses insure and would claim for flood losses. An assumption is necessary here and we assume that 95% of all business are insured and the claims of the remaining 5% are not counted within the adjusted ABI data, necessitating us uprating that £0.0952bn to £0.1002bn or £100.2 m (i.e., multiplying by 100/95). This compares with a SoN/Nafra AAD figure for NRP and unclassified properties of £0.418bn (£418 m): 4.17 times greater. The total adjusted AAD based on the ABI claims (residential plus estimated non-residential) then comes to £0.2194bn, compared with the NaFRA/SoN total of £0.664bn: 3.03 times as much (Table 6, col. C.).

6 | FURTHER ISSUES AFFECTING AVERAGE FLOOD LOSSES

Having obtained the result described above, we need to consider whether any other factor needs to be considered when arriving at an estimated current annual average flood damage figure for England. In this respect we can be guided in part by reactions to the paper published in 2014 (Penning-Rowsell, 2014) including the detailed review in 2014 (Horritt, 2014) of the first presentation of this analysis (Penning-Rowsell, 2013). That review analysed the length of the insurance data record, the meteorology of the period then being analysed (then 1998 to 2010), the extent of coastal and uninsured losses, the question of surface water flooding (see above), and the magnitude of the major flood event in 2007.

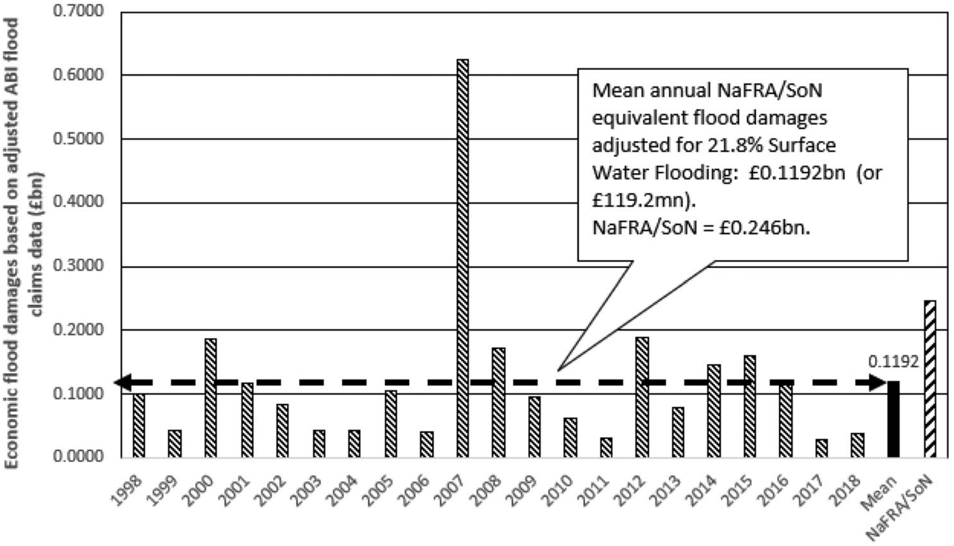

FIGURE 2 The adjusted ABI flood damage record for the 21-year record (residential properties only)

TABLE 5 The relationship been residential and non-residential flood damages from three major UK floods (all damages in £bn)

Flood event	2007[a.]	2013/14[b.]	2015/16[c.]	Totals	C (%)	
A. Residential damages	1.5	0.32	0.35	2.17		
B. Non-residential damages	0.91	0.27	0.513	1.693		
A + B	2.41	0.59	0.863	3.863		
C = A/(A + B)	62.2%	54.2%	40.6%		56.17%	Unweighted
Total event damages	3.9	1.3	1.6	6.8		
Weighted “C” (%)	35.7%	10.4%	9.5%		55.61%	Weighted by £ of flood overall
Uplift factor (i.e., 1/55.61%)						1.79829

[a.] Chatterton, Viavattene, Morris, Penning-Rowsell, and Tapsell (2010).
[b.] Chatterton et al. (2016).
[c.] Environment Agency (2018b).

6.1 | A “wetter than normal” period 1998 to 2010 and thereafter

Since c. 1998, the UK by some analysis appears to have been in a relatively “flood rich” period (Muchan, 2019). To investigate this matter Horritt (2014, p. 6) uses 50 years of flood records (from 1960 to 2009) “to adjust for short term climatic variation.” Table 7 shows c. 70% more floods in 1998–2009 than the long term average and that “The .... 1998–2010 (insurance claims) average should be reduced by 40% to allow for this being a significantly wetter than average period” (Horritt, 2014, p. 8). The significantly wetter than average period surely continued after 2010, not least given the protracted 2013/14 flooding and the all-time record rainfall amounts and flood flows in 2015/16 (Marsh et al., 2016).

However, we choose not simply to adjust the final results here by this 40% factor without some reflection. Whilst we accept Horritt's argument, the question arises as to whether the average over the 21-year record is what we want, or whether a longer term average is to be sought (i.e., 1960–2018) and, hence, over how long a period. The NaFRA/SoN analysis does not clarify this: there is no time over which its averages are deemed to be assessed. Rather than decide one way or another on this matter, we present both results (Table 6; Rows 7–9 and 10–12).

6.2 | The length of flood damage record and its characteristics

For many hydrologists, using a record covering only 21 years from which to calculate an average (the 1998 to 2018 period used here for the flood damage data) would be problematic. In terms of record length Horritt indicates that the Penning-Rowsell et al. (2014) “analysis is based on 13 years of record, from 1998 to 2010, and so a fundamental question is how representative is the

TABLE 6 Results from the analysis of the 1998–2018 ABI flood claims record in comparison with the NaFRA/State of the Nation (SoN) results with different assumptions (for full explanation, see text)

Row		Assumptions	A. Based on ABI data (£bn)	B. State of nation equivalent (£bn)	C. B/A (to three significant figures)
1	Residential properties	SWF at 21.7%	0.119	0.246	2.06
2	Non-residential *and* *"unclassified"* properties	Ditto	0.100	0.418	4.17
3	Total	Ditto	0.219	0.664	3.03
4	Residential properties	SWF @ 40%[a]	0.091	0.246	2.69
5	Non-residential *and* *"unclassified"* properties	Ditto	0.077	0.418	5.44
6	Total	Ditto	0.168	0.664	3.95
7	Residential properties	Horritt's WTN assumption[b]	0.072	0.246	3.44
8	Non-residential *and* *"unclassified"* properties	Ditto	0.060	0.418	6.95
9	Total	Ditto	0.132	0.664	5.04
10	Residential properties	Both SWF and WTN as per Horritt (2014)	0.055	0.246	4.49
11	Non-residential *and* *"unclassified"* properties	Ditto	0.046	0.418	9.07
12	Total	Ditto	0.101	0.664	6.58

[a] SWF (Surface Water Flooding) at a 40% reduction (as suggested in Horritt (2014, see text).

[b] WTN ("Wetter than normal") at a 40% reduction (as suggested in Horritt, 2014) as opposed to nil% (see text).

TABLE 7 Long term average number of floods per year since 1960 in the period ending 2010 (from Horritt, 2014, tabs. 2–4)

Period	5 year	20 year	50 year	100 year
1960–2009	104	25	8.4	3.1
1998–2009	147	44	15	5.7
Increase	+41%	+76%	+78%	+84%

average which is estimated from this data. Two methods have been used to answer this question: an analysis of annual maximum flow data from HiFlows UK, and evidence from the R&D project SC060088 (Keef et al., 2011) on spatial coherence in flood risk" (Horritt, 2014, p. 3).

He concludes from the former that "The 12 year average looks fairly stable, implying we should be able to extract a useful average from 12 or 13 years of data" (Horritt, 2014, p. 4) and from the latter that: "Spatial coherence in flooding means that it is possible to make a meaningful estimate of annual damages from a 12 year record, provided an adjustment is made to better represent the long term average" (Horritt, 2014, p. 8). Given the extension of the insurance claims record covered here from 13 years to 21 years, we should be even more confident that a meaningful estimate of the current annual average damages can be produced.

The ABI data might be seen as a sample of all the floods and their damage in the UK for all time. However, we believe that the data used here is a total population for the 21 years of record. It is not a sample of what damage was caused or might be caused then: it is the total population of claims (albeit adjusted for non-response to the ABI, as mentioned above). Repeated requests to the ABI (akin to a multiple-pass simulation) would give the same values, not a large variance. Others may disagree with this judgement, and seek to calculate a variance for this data that might include the NaFRA/SoN annual averages. This could be debated further but our view here is that the averages we show here are the best estimate of current AAD. In parallel with the basic NaFRA/SoN results, we conclude nothing about AADs/EADs into the future.

6.3 | The damage in coastal flood events[9]

Regarding coastal flood risk in England the issue here is whether the 21-year flood damage record analysed here adequately recognises this risk. Recent research for the Joseph Rowntree Foundation, using an emulator of the NaFRA process, gives coastal flooding at nearly 40% of the total UK risk (Sayers et al., 2017, figs. 4–7). Regarding coastal flooding Horritt (2014) suggests that total flood risk is equal to fluvial risk plus 70% (i.e., coastal at 41.2% of total). Our view is that these figures are both too high.

We come to this conclusion because, in terms of the longer record, coastal flood events of any seriousness have only occurred three times in the last 90 years (the East Coast in 1953; Towyn in 1990 and over a large area in 2013/14). This compares with at least eight serious fluvial events (1947; 1968; 1998; 2000; 2007; 2012; 2013/14; 2015/16). In 2013/14, many coastal defence structures were damaged, but serious coastal flooding only occurred either very locally or in the town of Boston, where 590 homes and 105 businesses were flooded.[10] Nevertheless, even in this, the most coast-dominated event for over 20 years, only 51% of the £590 m residential and non-residential flood damages were at the coast (Chatterton et al., 2016, tab. 3.2).

There is therefore very little evidence that coastal flood risk is in reality very high: the probabilities of serious events leading to massive flood damage (in the order of many £bns) are very low (annually probably less than 0.1%). This possibility is certainly not to be ignored but the contribution to overall AAD/EAD would be low, simply because of those very low probabilities. Horritt (2014) indicates that the data used for the 1998–2010 EAD includes only a very small coastal component because of high coastal standard of protection.

Unfortunately, there is no fluvial/coastal breakdown of the 2018 SoN results to help us here. However, the inclusion of the 2013/14 flooding in the extended 21-year insurance data record used here suggests that coastal flooding is not ignored in the AAD we have presented here as averaged from actual events, and that this is not therefore a reason for the divergence between the NaFRA/SoN AAD and the claims based equivalent.

6.4 | The environment agency data for 2007 and onwards

The 21-year flood damage record used here includes an ABI (2019) figure for residential property damage in the 2007 event of £0.973bn or £1.191bn at 2018 values (financial). This is the highest value by a significant margin within that record so we need to give it particular attention; deflated to economic values this gives a figure of £0.6335bn (2018 prices; £0.6257bn in Table 4, col. H).

Environment Agency reports give much higher values for 2007. Chatterton et al.'s (2010, p. 21) analysis yields a total of £2.410bn for residential and non-residential economic damages (2010 prices), a discrepancy Horritt (2014) thought (as it turned out incorrectly) might apply to the whole ABI flood damage record. In fact this discrepancy is a function of the chronology of the data available on the 2007 event. Chatterton's early figure (dated 2009 and sourced from the ABI) was superseded by the later ABI figure of £0.973bn above for actual claims and this must be considered more accurate.

The EA's estimation of damages in major floods since 2007 has continued (Chatterton et al. (2016); Environment Agency (2018b)). But when the EA residential flood damage data for 2007 (higher values than the ABI data) and 2013/14 and 2015/16 (both lower) is inserted into the final AAD calculations presented here it makes a net AAD reduction, but of only 2.27%. For consistence, therefore, we use here just the ABI (2019) data for these events.

6.5 | A different flood damage scenario for extreme events[11]

The 21-year-old record analysed here contains major events including in 2007 and in 2015/16, when long-term UK hydrometeorolgical records were broken across a widespread area (Environment Agency, 2018b). The question arises, however, is whether even more extreme events might have a different flooding characteristic leading to significantly higher damage values as a result of breaching or overtopping of major defences and captured in the NaFRA/SoN modelling. Again, this is not about flooding in the future but the flooding that could occur now.

The flood claims record we have analysed does include events where breaches occurred (in 2013/14 on the East Coast) and cases of overtopping in Lancaster in 2015/16 (Environment Agency, 2018b, p. 33). We think a change in flood character in very extreme events is possible, but the evidence is sparse. For example Gouldby, Lhomme, Jamieson, Hornby, and Laeger (2015) investigated this issue and their damage curve rises steeply between the 200 and 300 year return periods, but flattens off substantially after the c. 330 year return period. The increase between the event damages for the 330 year flood and the 1,000 year flood is only approximately 13.5%.

The Thames Barrier and other raised defences at the coast could fail, but the evidence from 2013/14 is that most East Coast defences, whilst damaged, did not fail completely except in isolated circumstances. In the UK we have relatively few raised fluvial defences (one of the principal exceptions being Nottingham). In any case, any breaches or overtopping from very much rarer events than those analysed here, for example the 1,000 or 10,000 year flood events, would make negligible contributions to current annual average damage values. Merz, Elmer, and Thieken (2009) showed similar findings: long return period events contribute only a small percentage of their total AAD values. Different damage scenarios cannot reasonably account for the divergence between the NaFRA/SoN AAD and the claims based equivalent.

7 | ASSESSMENT

Taking on board all the points above, Table 6 gives results from our analysis. This shows in Column C a range of factors by which the Nafra/SoN results exceed those from the claims record we have analysed.

We leave it to readers to make their own judgements in this respect as to which variant of the analysis is most appropriate, whether it be the very modest adjustment for surface water flooding (Table 6, rows 1 to 3), the larger adjustment based on Horritt's 40% (rows 4–6), and the further adjustments for “wetter than normal” conditions (rows 7 to 9 and 10 to 12). What is clear from these results is that those for the non-residential and the “unclassified” properties exceed the NaFRA/SoN results by a much larger margin than do those for just the residential sector.

Taking a different approach, the NaFRA/SoN project arrived at an AAD figure for England of £0.664bn. One statistic that may be revealing, however, is that probably in only four of the last 126 years (2007; 1953; 1947; 1894) have there been floods in England that resulted in damage that might match or exceed that £0.664bn average. In 122 years this has not been the case. The chance of a long run or current annual average being £0.664bn in these circumstances appears to be slim.

8 | A COMPARISON WITH AN EXTRAPOLATION APPROACH[12]

Notwithstanding the point above about seeking in this analysis an estimate of current annual average flood damages, and that we are dealing generally in this paper with a population not a sample (see footnote 12), a criticism could be that it does not consider the full range of flood probabilities and thus all the events that could occur within a 21 year period. Such a full range could only be explored by an extrapolation of the data using fairly standard statistical analyses. This is described below.

8.1 | Method

The version of the adjusted ABI data used in this extrapolation and reported here was the combined Residential and Non-residential estimated damages (derived as explained above) with the 40% Horritt reduction for surface water flooding (i.e., excluding the “Water Than Normal” adjustment). The results of the analysis above show this as in the middle of the range of totals in Table, broadly equivalent to Row 6 of Table 6).[13] Hereinafter, we label this version the “Extrapolation Dataset.”

The 21 years of record were checked against a standard statistical test (Crow, Davis, & Maxfield, 1960, Ch. 4) using the hypothesis that it is a random sample from some (unknown) stationary distribution. It was found that, at the 95% confidence level, the adjusted damage values would be accepted as such a random sample: there is no significant evidence of trend in time detected by this test. Damage in 2007 is clearly an outlier, but a chance occurrence. With 21 data values, and assuming a random sample, the mean value of the parent distribution can be approximated with reasonable certainty, although estimates of the variance (second moment) of the distribution will have greater uncertainty and all higher moments (including skewness and kurtosis) will be unreliable.

The annual flood damage data series has a single value per year and so has a similar character to an annual maximum river discharge series. Hence a trial plot was made using similar tools as for a hydrological assessment of frequency of annual maximum discharge. The Gumbel reduced variate was used as the independent variable and the natural logarithm of the damage in £ millions as the dependent variable (Wilson, 1990, p. 237).

An initial plot of damage against reduced variate was not well represented by a straight line fit. Hence, the plot of L_n(damage £m) against reduced variate was examined, and this appeared well fitted by a straight line ($R^2 = 0.951$) (Figure 3). The gradient of the fitted distribution is strongly influenced by the 2007 flood damages value. The sensitivity of this was examined by seeking out annual damages (or estimates) for historic events (1953; 1947) and using these to adjust the plotting positions for 2007, 2012, 2000 as appropriate. This was found not to have more than a trivial influence on calculated AAD values (changing these by less than 1%).

8.2 | Extrapolation results

Estimated event damage values were extracted from the Gumbel analysis (Table 8). These were then entered into the standard table that yields by integration the area under the loss-probability relationship, that area representing the AAD (Penning-Rowsell et al., 2013, p. 61). With the Extrapolation Dataset, we found that the best estimate annual average damage figure from the extrapolation exercise was lower by 23.63% than the equivalent simple average of all 21 damage data items.[14] This factor was then applied to the results in Table 6 (row 6) to give the results in Table 9.

There are, of course, uncertainties here (see Table 10). Estimates of uncertainty from the limited data series' length are significant since the Gumbel fitting is done in a logarithmic domain. The uncertainty in the estimates for damage by the extrapolation increases significantly with return period (see Table 8). The same would apply to the NaFRA/SoN result, but its upper and lower estimates are not published. The results of our analysis of uncertainty in this respect show that the £0.664bn NaFRA/SoN AAD total is more than 2.5 times even the upper estimate from the extrapolation exercise (Table 10).

Very extreme events might produce a different result, possibly at the coast where raised defences are common. The extrapolation method allows us to assess the contribution to AAD from events over a certain threshold. We can thereby represent a situation where rare but catastrophic events might cause overtopping or breaching of defences and high damages (see above). However, in this regard Figure 4 shows that the relative contribution to total AAD from events greater than a 100-year return period is small (as, we noted, Merz et al. (2009) also found). With the Extrapolation Dataset, for floods in excess of 100-year return period (and up to 1:1,000 years) this is only 14.9%. If such flooding at the coast (contributing perhaps 23.7% to UK AAD; Sayers et al., 2017) were three times as severe in terms of event losses than the Gumbel analysis yields (with the 1,000 year flood causing more than £10bn of residential and NRP losses) then total AAD rises by only 6.27%. The fraction of AAD then represented by events greater than 100 years still does not exceed 33%.

This indicates that a change in the mechanism of flooding brought about by extensive breaching and overtopping—in any case not unrepresented in the ABI dataset—would not have the effect in raising our calculated AADs to anywhere near NaFRA/SoN levels. The principal driver of risk as measured by AAD/EAD is generally not the rare and extreme events but those that occur much more frequently. The key results here suggest that the difference between the AADs from NaFRA/SoN and the ABI flood claims dataset cannot be explained by the latter not including the very rarest events.

9 | DIFFERENCES BETWEEN MODELLED AND RECORDED FLOOD LOSSES: POSSIBLE CAUSES

The difference between the NaFRA/SoN AADs and those derived from the ABI's flood insurance claims database is large (Table 6, col. 3). We reflect here on what might be the cause or causes of this difference.

9.1 | The losses modelled for the NRPs

We return to the issue of residential versus NRP losses because the modelled NRP losses are very high within NaFRA/SoN compared with the 2007, 2013/4, and 2015/6 floods results as used here to up-rate the residential data to yield the total that includes NRP losses.

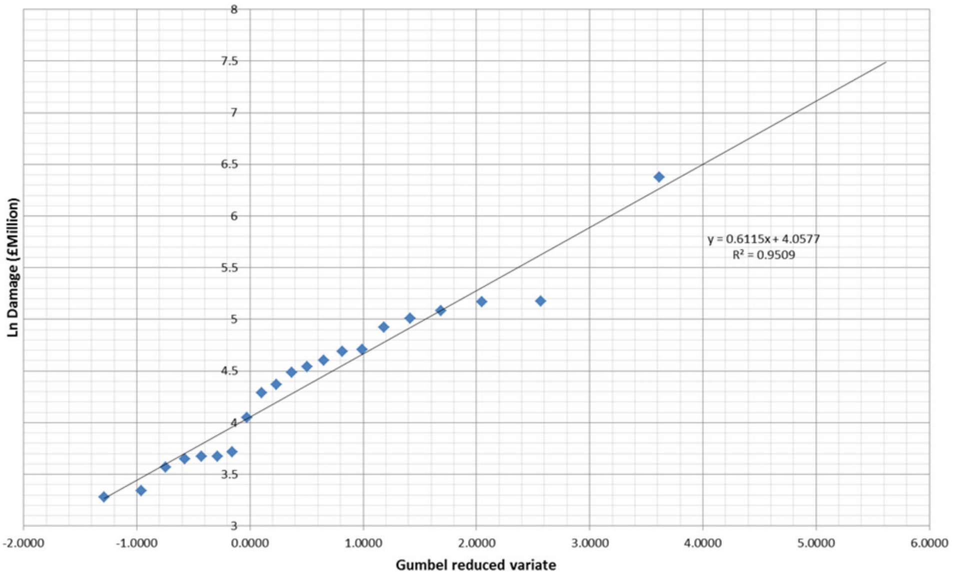

FIGURE 3 Analysis of the ABI flood claims record using the "Extrapolation Dataset" (see text)

TABLE 8 Results from the Gumbel analysis for upper and lower estimates (see text) from the Extrapolation dataset (i.e., The adjusted ABI data with Horritt's suggestion of a 40% reduction for surface water flooding)

Return period T year	Best estimate loss (£bn)	Lower estimate loss (£bn)	Upper estimate loss (£bn)
2.333	0.082	0.061	0.110
5	0.141	0.094	0.231
10	0.221	0.134	0.425
20	0.340	0.189	0.763
25	0.390	0.211	0.918
50	0.594	0.295	1.625
75	0.758	0.359	2.265
100	0.901	0.412	2.864
150	1.149	0.500	3.986
200	1.366	0.574	5.038
250	1.561	0.639	6.040
350	1.909	0.750	7.940
500	2.364	0.890	10.609
750	3.012	1.080	14.747
1,000	3.578	1.238	18.627

TABLE 9 A comparison of AAD values based on (a) the extrapolation analysis and (b) the equivalent simple average of adjusted ABI flood claims (all £bns)

Scenario	A. Based on the reduced variate extrapolation (best estimate)	B. The equivalent simple average of adjusted ABI damage claims (Table 6, rows 6 and 12)	C. NaFRA/SoN	C/A
Horritt's 40% less for surface water flooding (SWF)	0.128	0.168	0.664	5.17 times
Horritt's 40% SWF, and 40% for "wetter than Normal"	0.077	0.101	0.664	8.62 times

TABLE 10 Upper and lower AAD estimates based on the Gumbel extrapolation

	AAD from the extrapolation dataset (£bn)	With the correction for the 80% ABI coverage (£bn)	Ratio of estimates	Nafra/SoN AAD @ £0.664bn compared to these results
Upper estimate	0.2114	0.2643	2.30	2.51 times
Best estimate	0.0921	0.1151	1.00	5.77 times
Lower estimate	0.0533	0.0666	0.58	9.96 times

Note: "Extrapolation Dataset" scenario used (i.e., with Horritt's 40% adjustment for surface water flooding). Residential and non-residential properties combined to compare with full NaFRA/SoN AAD.

The equivalent Residential AAD figure in the SoN to the 55.6% used here (Table 5) is just 37.0% (£0.246bn out of a total of £0.664bn). This raises the question as to whether NaFRA/SoN is under-valuating residential flood losses (or over-valuing NRP and "unclassified" losses). The fault if there is one possibly lies in the unclassified category: this appears to be far too high at an AAD per property of £629 compared with just £127 per residential dwelling (Table 2).

The implication of the £629 figure is that each unclassified property has nearly five times the flood damage potential of the average residential property, which seems unlikely.

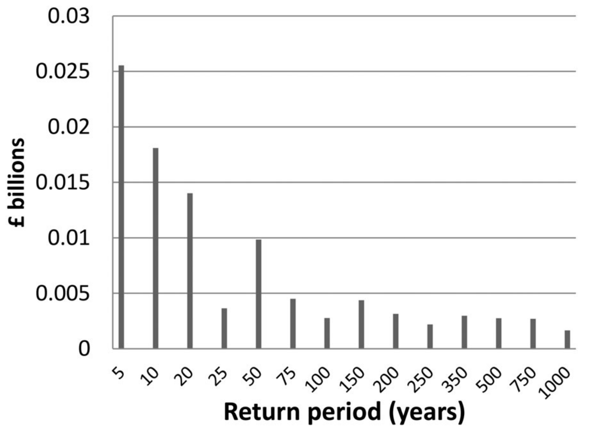

FIGURE 4 The contribution to annual average damages (AADs) from events with specific flood return periods, showing the dominance of low return period events (Extrapolation Dataset: best estimate)

9.2 | Flood depths, fragility curves, and frequent floods

Previous versions of NaFRA have exaggerated flood depths, leading to excessively high event loss figures (Penning-Rowsell, 2014). As indicated above this has been addressed by capping flood depths, but the possibility remains that the modelled flood depths are still too great. This cannot properly explain the significant divergence of the modelled results from the claims figures, as the WAAD risk statistic (weighted annual average damages) was eventually apparently used in the SoN project and this does not depend upon modelled flood depths (Environment Agency, 2018a).

It is possible that the fragility curves describing the extent of breaching of defences are still flawed, leading to higher than is reasonable degrees of spilling of floodwaters on to the floodplain (perhaps particularly at the coast). The relative lack of cases of breached or overtopped defences in the UK with which to calibrate these curves may be a problem here. It is also possible that NaFRA/SoN somehow exaggerates the damages from the short return period and hence frequent events, not least because these are the events that generate most of the AAD (Figure 4).

9.3 | Incident management and flood damage data in NaFRA/SoN

It is also possible that NaFRA/SoN takes inadequate notice of the fact that much damage is eliminated by good incident management (and therefore lower than expected flood insurance claims are the result). Another possible and related factor is if the Multi-Coloured Manual data sets used in NaFRA/SoN suggest higher losses than incur in reality. The mean insurance claims from the subset of ABI (2019) data which includes property numbers (since 2004), when deflated from financial to economic values, give a mean of less than £7,000 per residential property (£12,107, financial: Figure 1), which is surprisingly low.

10 | CONCLUSIONS

This paper describes research comparing two sets of data on flood risk, using data for England. Considerable divergences have been found (Table 6).

The lessons that we draw from this analysis are that any country's modelling of flood risk—not just in the UK—needs support with some form of calibration or validation. Particular attention needs to be given to many of the data inputs. This includes the features at risk (the exposure data), the effect of defence failures if they drive risk, the algorithms that spread flood waters on to floodplains, and the accuracy of flood probabilities, especially the high ones. Surveys of damage from floods that occur need to be systematic and rigorous, so as to allow appropriate calibration of any flood loss functions, for example as depth/damage curves or their equivalent. Weaknesses in any of these inputs will distort risk calculations and thereby undermine the cases for sensible risk reducing actions.

We return to our question as to whether current modelled levels of risk are now more in line with the insurance based risk assessment and vice versa. We have found, depending on assumptions, that our results for England show that the Environment Agency's NaFRA/SoN modelled values of annual average flood damage are between 2.06 and over 9.0 times the comparable flood losses as measured in terms of the compensation paid to flood victims by insurance companies. The reasons for these large differences are not clear, and we speculate about what might be their underlying causes. No cause is validated, but none appears particularly convincing. The divergence between the two sets of results should encourage the users of this data to consider carefully their assessments of the true scale of flood risk that England faces, and thus the scale of the interventions that are planned. Risk analysts in other countries might gain from seeking similar comparisons of modelled and recorded flood damages to guide their interpretation and use of their model results.

ENDNOTES

[1] This type of investigation is continuing, leading to "NaFRA2" results in c. 2023/24.

[2] Flood Zone 2: An area with between 0.1–1% chance of flooding from rivers, or between 0.1–0.5% chance of flooding from the sea, in any year. Areas within flood zone 3 are deemed to have a 1% or greater annual probability of flooding from rivers or 0.5% or greater annual probability of flooding from the sea.

[3] This grossing up takes the survey results from ABI members and adjusts the total for any non-response, based on each member's share of the market. The non-response necessitating this is indicated to be less than 10% (Morgan, ABI, personal communication, 2019).

[4] Alisa Dolgova, Manager Prudential Regulation, ABI. E-mail 18.2.2020; Laura Hughes, Manager, General Insurance, ABI. E-mail 3.3.2020.

[5] See https://www.ons.gov.uk/surveys/informationforhouseholdsandindividuals/householdandindividualsurveys/livingcostsandfoodsurvey

[6] Personal Communication, Rachael Pearson, ABI (20.9.2019) relayed by Mike Steel (EA).

[7] Personal communication, Matt Crossman (National Infrastructure Commission) and ex ABI.

[8] Data for 2019 from the ABI (16.7.2020) gives residential flood damage claims of £0.121bn (13 k claims). Adjusting this in the same way as with the 21-year record yields a value of £0.0632bn, or only 53% of the £0.1192bn 21-year average. Extending and therefore updating the record from 21 to 22 years would therefore see the ABI data based AAD reduce further, albeit by only a small amount.

[9] The contribution of Paul Bates to this issue, notably concerning flooding in the Severn Estuary, is appreciated.

[10] http://www.boston.gov.uk/index.aspx?articleid=6508

[11] This issue was first raised by Ben Gouldby, whose contribution is therefore acknowledged.

[12] The assistance of Paul Samuels in this element of the analysis is gratefully acknowledged. For this extrapolation only the data here are treated as if they were a sample.

[13] The analysis did not allow for the c. 80% ABI coverage of the market as this was not known at the time. See text later in this paper where this adjustment is made.

[14] Paul Samuels has commented to me privately: “This is not unexpected from the mathematics of the analysis.”

DATA AVAILABILITY STATEMENT

Data sharing is not applicable to this article as no new data were created or analyzed in this study.

ORCID

Edmund C. Penning-Rowsell https://orcid.org/0000-0002-5333-8641

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