RIVER AVON TIDAL FLOOD RISK MANAGEMENT STRATEGY

Economic Appraisal– Briefing Report

October 2016

Prepared for Bristol City Council

Issue	Date	Details	Prepared by	Checked by	Approved by
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2	13/07/16	Updated with client comments and comments from internal and external workshops	**Niamh Cahill** Assistant Coastal Engineer	**Jonathan Short** Principal Consultant (Coastal)	**David Dales** Director
3	26/07/16	Damages reporting finalised after further discussion on revised text and approach.	**Niamh Cahill** Assistant Coastal Engineer	**Jonathan Short** Principal Consultant (Coastal)	**David Dales** Director
4	09/08/16	Incorporation of benefits, PF scores and GVA for preferred option phase (draft for comment)	**Niamh Cahill** Assistant Coastal Engineer	**Jonathan Short** Principal Consultant (Coastal)	**David Dales** Director
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Limitations

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1 INTRODUCTION

1.1 Overview and purpose of this report

As part of the development of the River Avon Tidal Flood Risk Management Strategy ('The Strategy') AECOM is carrying out an economic appraisal. The appraisal includes valuation of the potential damage that could result from tidal flood risk as a result of a 'Do Nothing' scenario and the benefits that could be obtained by various 'Do Something' options.

'Do Nothing' is a hypothetical 'walk away' scenario and represents an absolute worst case in terms of potential flood risk and therefore damage. Determining the 'Do Nothing' damage helps demonstrate the scale of the potential issue being faced and provides a baseline against which the benefits of 'Do Something' options can be compared and evaluated. 'Do Minimum' is another scenario which has been assessed as part of the economic appraisal. The 'Do Minimum' scenario effectively represents the status quo of operations and reactive management. 'Do Minimum' can be used to indicate the maximum level of potential benefit that could be achieved by strategic management to improve protection against tidal flooding above current practice.

This briefing report presents the methodology and results of the economic assessment of the 'Do Nothing' and 'Do Minimum' scenarios. It also compiles the benefits of the various 'Do Something' options which have been appraised during the preferred options phase of the Strategy. This work therefore forms a key part of The Strategy development process, and helps inform the appraisal of options and the development of a business case for preferred management options.

1.2 Economic Appraisal

The aim of an economic appraisal, within a flood risk strategy, is to determine whether flood risk management options are worthwhile and to ensure that the most efficient allocation of resources is achieved.

To do this, the economic appraisal undertaken in this study compared the potential flood damages associated with undertaking no remedial works / maintenance to the defences along the frontage and carrying out regular maintenance to the existing defences in order to maintain the current flood protection level. The base date of the appraisal is January 2016.

This provides a rational and systematic framework for assessing the advantages and disadvantages of alternative options. This is achieved by expressing all of the potential flood damages in a directly comparable unit of measurement; in monetary terms. By doing so, the costs and benefits of different options can be directly compared and treated in the same manner during the analysis. In economic terms, the most efficient option is defined as that which provides the greatest level of well-being for society as a whole. An option is considered to be 'justified' if the benefits outweigh the costs.

The appraisal of options in the Strategy was carried out using the framework of the HM Treasury and Environment Agency Flood and Coastal Erosion Risk Management appraisal guidance (FCERM-AG, 2010). FCERM-AG represents the latest standard of assessment for all flood and coastal risk projects in England. As part of this economic appraisal, pre-2012 properties have been considered in order to comply with the FCERM Grant in Aid rules which state that 'For all outcome measures, benefits in relation to any new properties (residential or non-residential) or existing buildings converted into housing after 1 January 2012 will not be counted' ('Flood and Coastal Resilience Partnership Funding' Defra, 2011).

1.3 Strategy appraisal period

The Strategy appraisal period is 100 years. In order to develop managed adaptive options and account for factors such as climate change, options were appraised over 3 time periods (often referred to as epochs):

- Short term (2015 – 2030)
- Medium Term (2030 – 2065)
- Longer term (2065 – 2115)

1.4 Scenarios Evaluated

A range of scenarios were considered as part of the economic assessment. These comprise the Do Nothing and Do Minimum scenarios as well as seven Do Something options. The Do Something options are referred to a Strategic Options A to G. For more details of what the Strategic options involve, refer to the Preferred Option Report. The following scenarios were considered as part of the economic assessment:

- Do Nothing – Baseline for comparison. No action is taken to maintain the current flood defences.
- Do Minimum – Continue the status quo of operations and reactive maintenance to the existing flood defences. No further measures are introduced to raise the frontage levels.
- Option A: Property Level Protection (epoch 1, 2015), Low Defences (epoch 2, 2030), High Defences (epoch 3, 2065)
- Option B: Property Level Protection (epoch 1, 2015), High Defences (epoch 2, 2030), maintain High Defences (epoch 3, 2065)
- Option C: Property Level Protection (PLP) (epoch 1, 2015), Tidal Barrier (epoch 2, 2030), maintain Tidal Barrier (epoch 3, 2065)
- Option D: Low Defences (epoch 1, 2015), Low Defences (epoch 2, 2030), High Defences (epoch 3, 2065)
- Option E: Low Defences (epoch 1, 2015), Tidal Barrier (epoch 2, 2030), maintain Tidal Barrier (epoch 3, 2065)
- Option F: High Defences (epoch 1, 2015), maintain High Defences (epoch 2, 2030), maintain High Defences (epoch 3, 2065)
- Option G: Do Minimum (epoch 1, 2015), Do Minimum (epoch 2, 2030), High Defences (epoch 3, 2065)

1.5 Pill / Shirehampton and Defacto Defences updates

Following a review of the original damage estimation the Client requested that a number of modifications be made to the original modelling including the introduction of third-party 'defacto defence' structures (buildings, walls, raised structures) and the representation of the defences for the Pill / Shirehampton region. These model changes were identified following the production of a visual walkover structural assessment of the flood defence structures undertaken by Arup.

AECOM re-ran the flood modelling with these changes incorporated and used the resulting flood depths to inform the economic analysis and estimation of PV damages. These changes resulted in a reduced number of properties at risk and slightly lower damages for the Do Nothing and Do Minimum scenarios, as was expected given the improved defences being considered. A detailed analysis of the results can be found in the subsequent sections of this report.

2 ESTIMATING 'DO NOTHING' DAMAGES

2.1 Estimating flood depths and extents - hydrodynamic modelling

To support an economic appraisal of damages, the 'Do Nothing' flood depths simulated using the CAFRA WS3 hydrodynamic model. Do Nothing' depths were simulated for a range of return periods for four periods in time; 2015, 2030, 2065 and 2115.

The model simulations included the latest estimated extreme water levels and these were corrected for future sea level rise changes through the 100 year appraisal period (see baseline review briefing report and Modelling Report for further details on scenarios, modelling methodology and results). Table 2-1 below presents the extreme water level scenarios used in modelling simulations.

Note that the modelled depth data used to underpin the economic appraisal presented in this report is from the unmodified WS3 model setup. Prior to finalising the economic appraisal, further model modifications to account for the effect of defacto defences and 1-D model limitations at Pill and Shirehampton will be implemented (subject to approval of a compensation event) and this may reduce the flood depths (and damages) for lower return period events compared to that presented here.

Table 2-1. Extreme Tide Levels at the mouth of the Avon (Medium Emissions 95%tile scenario adopted by the Strategy)

Epoch	Return Period	Tide Level (m AOD)		
		Upper End SLR	Medium Emissions 95%ile SLR	High Emissions 95%ile SLR
2015	2yr	8.69	8.69	8.69
	20yr	8.94	8.94	8.94
	75yr	9.00	9.00	9.00
	200yr	9.13	9.13	9.13
	1000yr	9.45	9.45	9.45
2030	2yr	8.78	8.77	*Not considered*
	20yr	9.03	9.02	*Not considered*
	75yr	9.09	9.08	*Not considered*
	200yr	9.22	9.21	*Not considered*
	1000yr	9.54	9.53	*Not considered*
2065	2yr	9.11	9.01	9.08
	20yr	9.36	9.26	9.33
	75yr	9.42	9.32	9.39
	200yr	9.55	9.45	9.52
	1000yr	9.87	9.77	9.84
2115	2yr	9.84	9.43	9.59
	20yr	10.09	9.68	9.84
	75yr	10.15	9.74	9.90
	200yr	10.28	9.87	10.03
	1000yr	10.60	10.19	10.35

The flood model results were output to GIS to facilitate the inspection of flood depths for assets within the flood areas for the range of return periods.

2.2 Identifying properties at risk - residential

Inspection of the flood modelling results for a range of timeframes in GIS allowed the baseline 'Do Nothing' flood risk to be established for the strategy area.

To identify individual properties at risk, Bristol City Council provided an address point dataset (National Receptor Database, 2011) which included the property address, post code, property type (e.g. residential – flat, residential – detached) and property coordinates for all residential assets within the strategy area. The database was checked to remove duplicate address points and also to rationalise the number of flats counted in the assessment. For example, where single locations had multiple residencies, these were reduced to include only ground floor flats.

The NRD data also included sub-buildings (e.g. garages, sheds etc.) which are located within residential property boundaries. These were removed from the property database using the Land and Property Gazetteer (LPG, 2016) data provided by Bristol City Council in order to avoid double counting of the residential flood damages at each property. This data included a Multi-Coloured Manual code (Penning-Rowsell 2015) for each property depending on its type (e.g. flat, detached, etc.) and this was used in conjunction with the estimated flood depth from the hydrodynamic model in order to assign a monetised damage figure for each property.

Following the collation of the NRD and LPG data into a single dataset for the study area it was noted that a number of properties remained unclassified. As a result it was necessary to assign an appropriate MCM code in order to proceed with the economic analysis. The average floor area for dwellings in Bristol was calculated as 90m² while the average floor area for commercial premises was 260m². All unclassified properties under 90m² were assigned the MCM code for dwellings while all properties over 260m² were assigned the commercial MCM code. A manual check was undertaken on all properties which fell within this floor area range in order to assign an accurate building use. A manual check was also carried out to assign the correct MCM classification for the 100 properties with the largest floor areas. This was to ensure that these properties, which could potentially generate the largest amount of damages, were accurately represented.

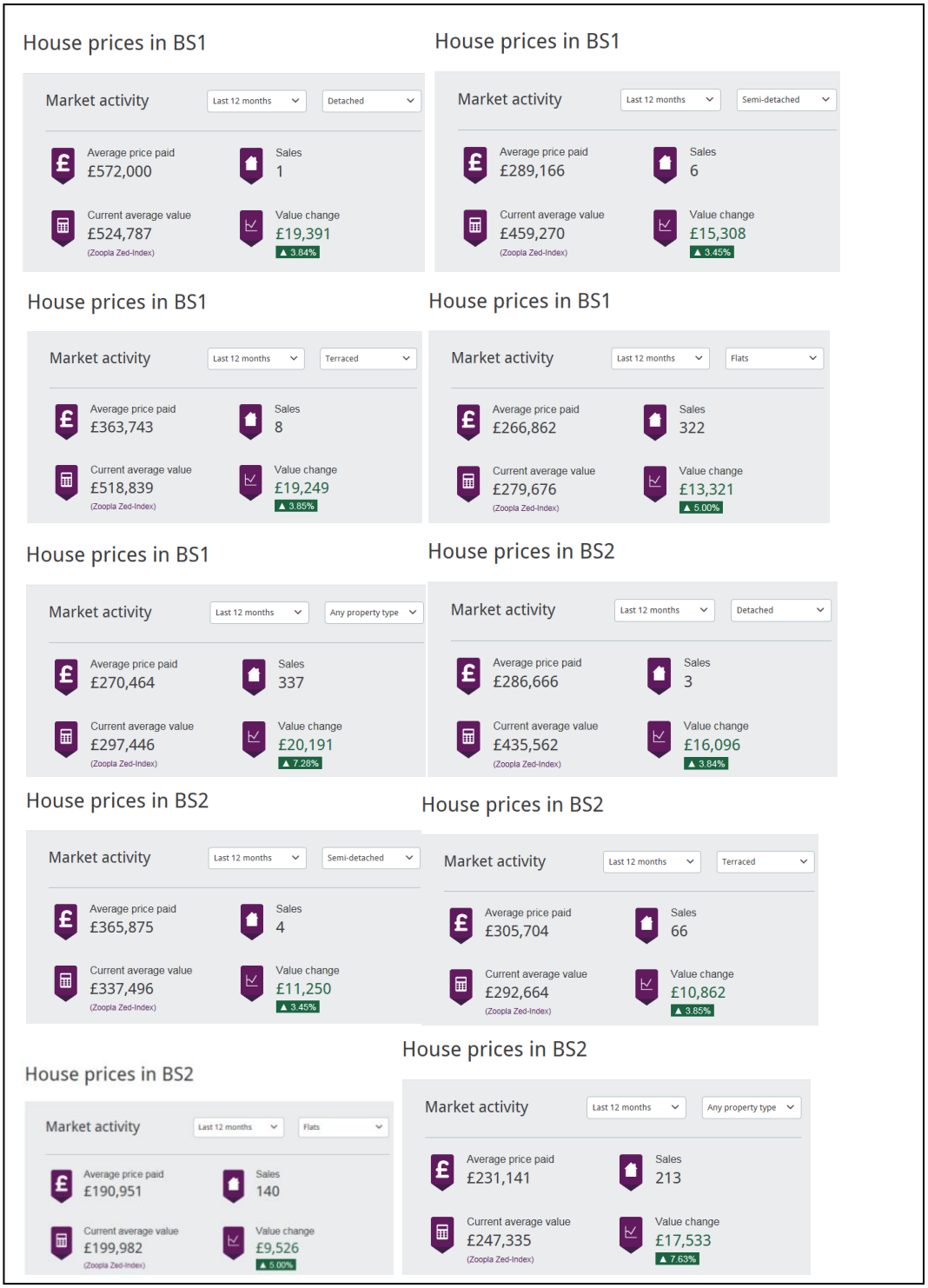
Flood depths for each individual property were obtained by conducting a point inspection in GIS. The depths were determined at the centroid of each property using the property location and the flood modelling results for each scenario. This was based upon LiDAR data rather than threshold survey data given the strategic nature of the project. No basement areas have been allowed for in the economic analysis, therefore flood damages were only counted for flood depths greater than the property level. The flooding threshold was taken as 0.001m as per the MCM (2013) guidance. All flood damages below this threshold level were ignored. The property data considered as part of this study is based on 2011 information and it should be noted that older properties may not have raised floor levels thus increasing their risk of flooding. The threshold level figure is based on the average threshold height and is a reasonable assumption in the absence of any detailed survey information relating to property thresholds and basements. Such an approach is appropriate for a strategy level study such as this one.

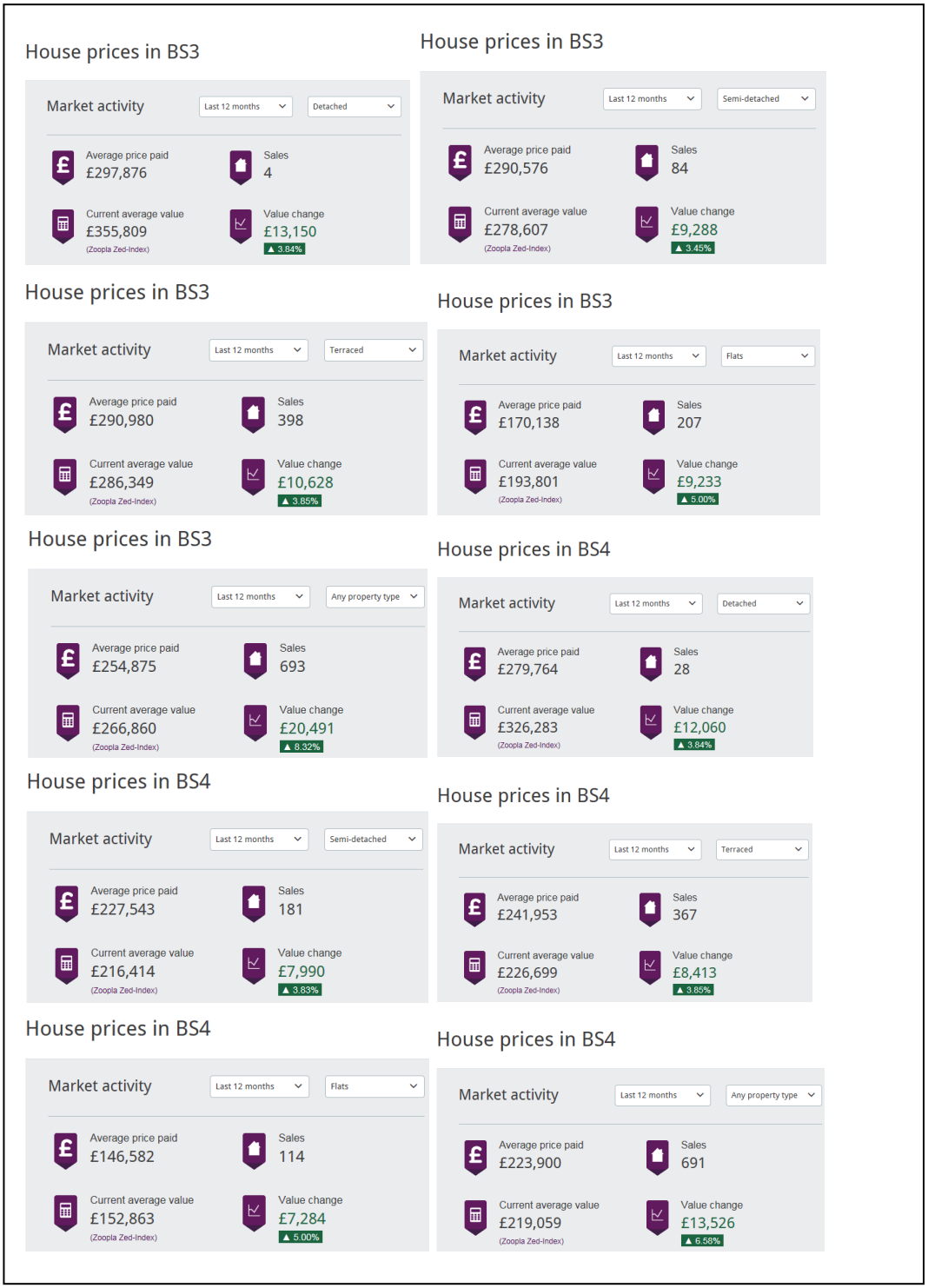
The value of each residential property was required to consider potential write-off and capping of damage values within the economic analysis. Average house sale prices over the past year were obtained based on data provided by Zoopla (www.zoopla.co.uk) for a range of postcodes in the Bristol area (see Table 2-2). The data was averaged by property type (detached, semi. terrace, bungalow and flat) for each of postcode region. These were then applied to each property in the appraisal, for the purpose of write-off and capping.

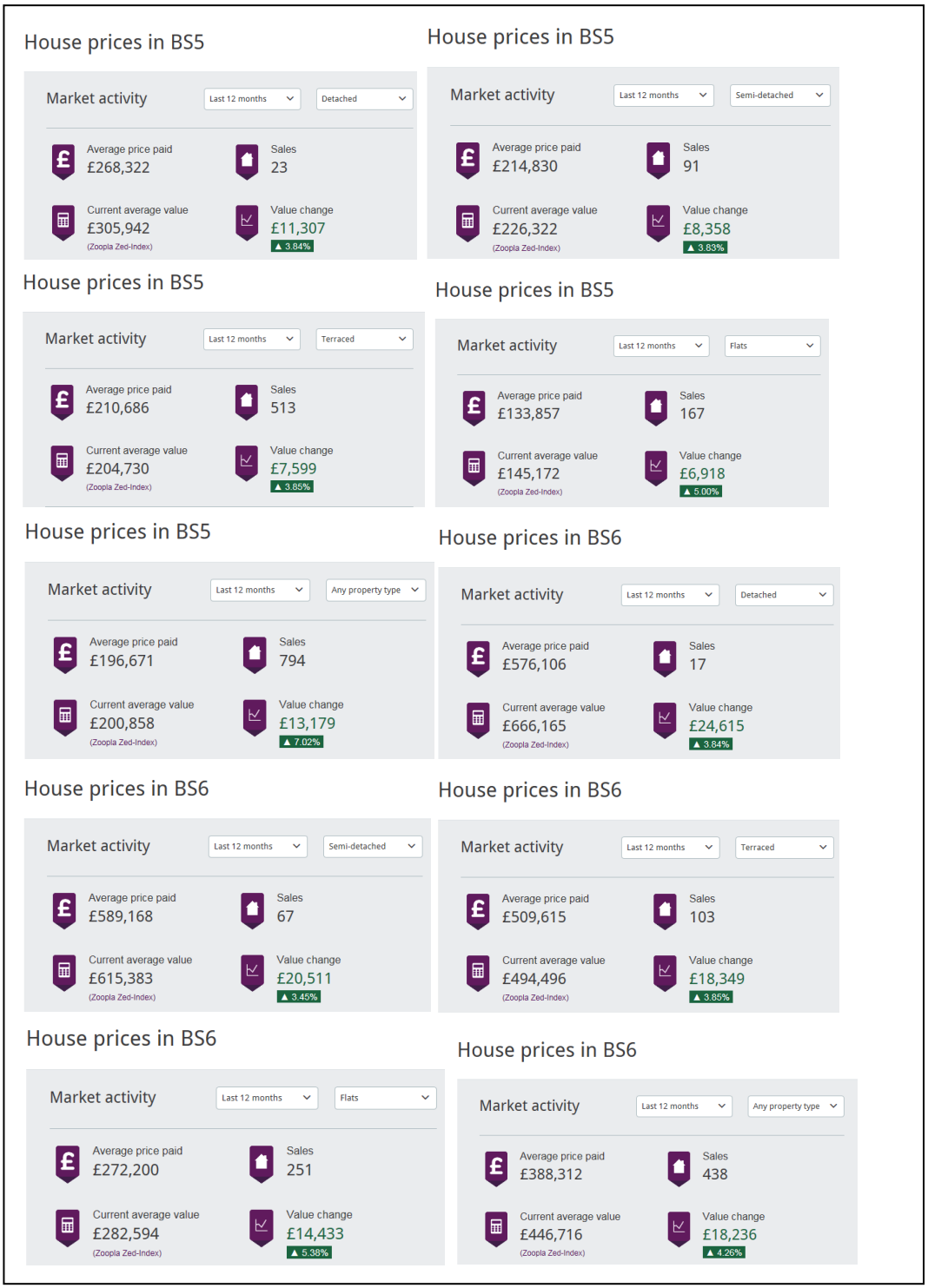
Table 2-2. Average sold price per postcode July 2015 - July 2016 (source: zoopla.co.uk)

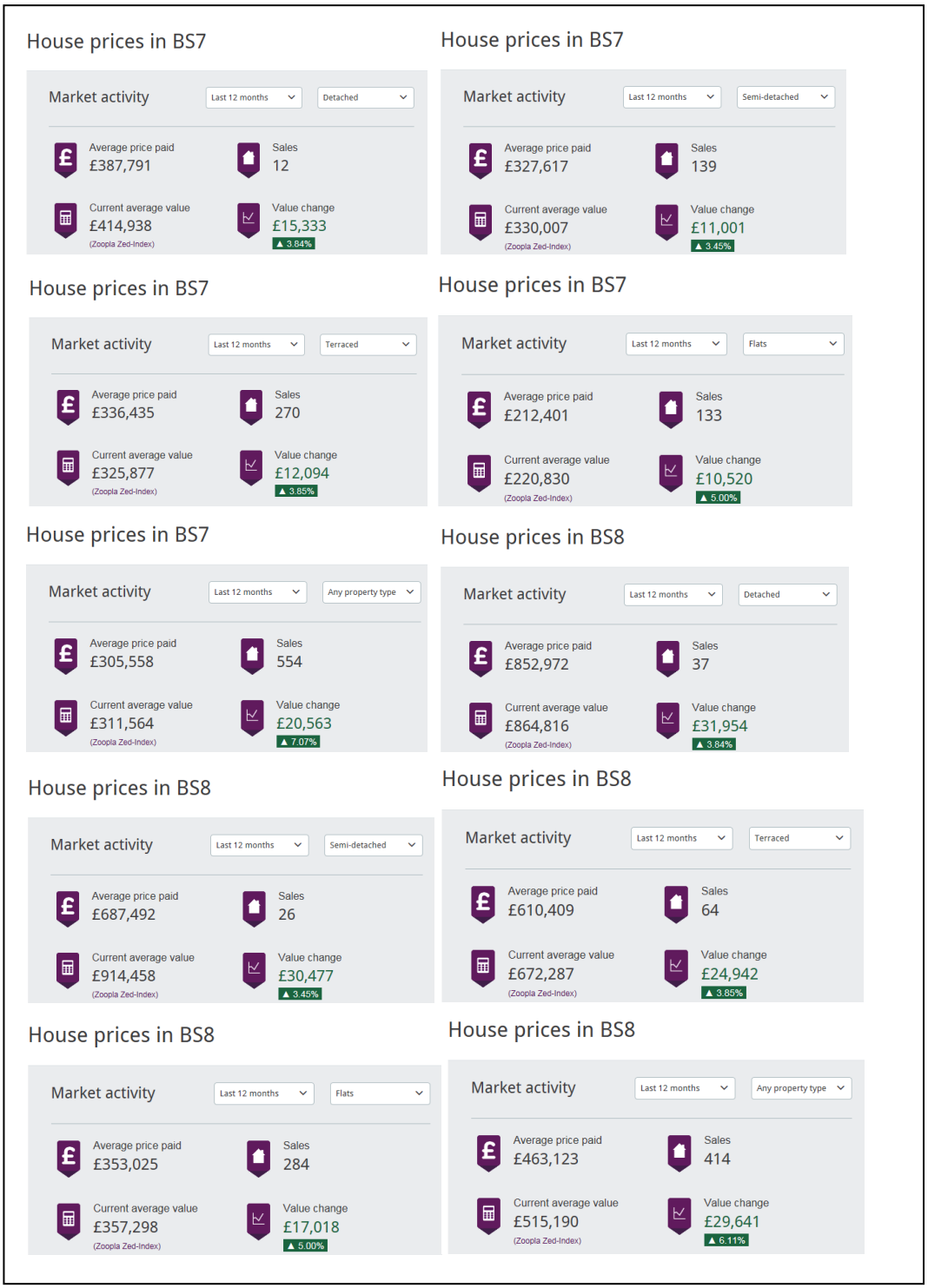
Property Type	BS1	BS2	BS3	BS4	BS5	BS6	BS7	BS8	BS9
Detached	572,000	286,666	297,876	279,764	268,322	576,106	387,791	852,972	669,449
Semi-detached	289,166	365,875	290,576	227,543	214,830	589,168	327,617	687,492	468,067
Terrace	363,743	305,704	290,980	241,953	210,686	509,615	336,435	610,409	366,108
Flat	266,862	190,951	170,138	146,582	133,857	272,200	212,401	353,025	252,474
Unclassified	270,464	231,141	254,875	223,900	196,671	388,312	305,558	463,123	454,183

The following figure shows the property value data as taken from Zoopla (2016) for the Bristol region.




House prices in BS3
Market activity
Last 12 months
Detached
Average price paid
£297,876
Sales
4
Current average value
£355,809
(Zoopla Zed-Index)
Value change
£13,150
▲ 3.84%
House prices in BS3
Market activity
Last 12 months
Semi-detached
Average price paid
£290,576
Sales
84
Current average value
£278,607
(Zoopla Zed-Index)
Value change
£9,288
▲ 3.45%
House prices in BS3
Market activity
Last 12 months
Terraced
Average price paid
£290,980
Sales
398
Current average value
£286,349
(Zoopla Zed-Index)
Value change
£10,628
▲ 3.85%
House prices in BS3
Market activity
Last 12 months
Flats
Average price paid
£170,138
Sales
207
Current average value
£193,801
(Zoopla Zed-Index)
Value change
£9,233
▲ 5.00%
House prices in BS3
Market activity
Last 12 months
Any property type
Average price paid
£254,875
Sales
693
Current average value
£266,860
(Zoopla Zed-Index)
Value change
£20,491
▲ 8.32%
House prices in BS4
Market activity
Last 12 months
Detached
Average price paid
£279,764
Sales
28
Current average value
£326,283
(Zoopla Zed-Index)
Value change
£12,060
▲ 3.84%
House prices in BS4
Market activity
Last 12 months
Semi-detached
Average price paid
£227,543
Sales
181
Current average value
£216,414
(Zoopla Zed-Index)
Value change
£7,990
▲ 3.83%
House prices in BS4
Market activity
Last 12 months
Terraced
Average price paid
£241,953
Sales
367
Current average value
£226,699
(Zoopla Zed-Index)
Value change
£8,413
▲ 3.85%
House prices in BS4
Market activity
Last 12 months
Flats
Average price paid
£146,582
Sales
114
Current average value
£152,863
(Zoopla Zed-Index)
Value change
£7,284
▲ 5.00%
House prices in BS4
Market activity
Last 12 months
Any property type
Average price paid
£223,900
Sales
691
Current average value
£219,059
(Zoopla Zed-Index)
Value change
£13,526
▲ 6.58%


House prices in BS5
Market activity
Last 12 months
Detached
Average price paid
£268,322
Sales
23
Current average value
£305,942
(Zoopla Zed-Index)
Value change
£11,307
▲ 3.84%
House prices in BS5
Market activity
Last 12 months
Semi-detached
Average price paid
£214,830
Sales
91
Current average value
£226,322
(Zoopla Zed-Index)
Value change
£8,358
▲ 3.83%
House prices in BS5
Market activity
Last 12 months
Terraced
Average price paid
£210,686
Sales
513
Current average value
£204,730
(Zoopla Zed-Index)
Value change
£7,599
▲ 3.85%
House prices in BS5
Market activity
Last 12 months
Flats
Average price paid
£133,857
Sales
167
Current average value
£145,172
(Zoopla Zed-Index)
Value change
£6,918
▲ 5.00%
House prices in BS5
Market activity
Last 12 months
Any property type
Average price paid
£196,671
Sales
794
Current average value
£200,858
(Zoopla Zed-Index)
Value change
£13,179
▲ 7.02%
House prices in BS6
Market activity
Last 12 months
Detached
Average price paid
£576,106
Sales
17
Current average value
£666,165
(Zoopla Zed-Index)
Value change
£24,615
▲ 3.84%
House prices in BS6
Market activity
Last 12 months
Semi-detached
Average price paid
£589,168
Sales
67
Current average value
£615,383
(Zoopla Zed-Index)
Value change
£20,511
▲ 3.45%
House prices in BS6
Market activity
Last 12 months
Terraced
Average price paid
£509,615
Sales
103
Current average value
£494,496
(Zoopla Zed-Index)
Value change
£18,349
▲ 3.85%
House prices in BS6
Market activity
Last 12 months
Flats
Average price paid
£272,200
Sales
251
Current average value
£282,594
(Zoopla Zed-Index)
Value change
£14,433
▲ 5.38%
House prices in BS6
Market activity
Last 12 months
Any property type
Average price paid
£388,312
Sales
438
Current average value
£446,716
(Zoopla Zed-Index)
Value change
£18,236
▲ 4.26%


House prices in BS7
Market activity
Last 12 months
Detached
Average price paid
£387,791
Sales
12
Current average value
£414,938
(Zoopla Zed-Index)
Value change
£15,333
▲ 3.84%
House prices in BS7
Market activity
Last 12 months
Semi-detached
Average price paid
£327,617
Sales
139
Current average value
£330,007
(Zoopla Zed-Index)
Value change
£11,001
▲ 3.45%
House prices in BS7
Market activity
Last 12 months
Terraced
Average price paid
£336,435
Sales
270
Current average value
£325,877
(Zoopla Zed-Index)
Value change
£12,094
▲ 3.85%
House prices in BS7
Market activity
Last 12 months
Flats
Average price paid
£212,401
Sales
133
Current average value
£220,830
(Zoopla Zed-Index)
Value change
£10,520
▲ 5.00%
House prices in BS7
Market activity
Last 12 months
Any property type
Average price paid
£305,558
Sales
554
Current average value
£311,564
(Zoopla Zed-Index)
Value change
£20,563
▲ 7.07%
House prices in BS8
Market activity
Last 12 months
Detached
Average price paid
£852,972
Sales
37
Current average value
£864,816
(Zoopla Zed-Index)
Value change
£31,954
▲ 3.84%
House prices in BS8
Market activity
Last 12 months
Semi-detached
Average price paid
£687,492
Sales
26
Current average value
£914,458
(Zoopla Zed-Index)
Value change
£30,477
▲ 3.45%
House prices in BS8
Market activity
Last 12 months
Terraced
Average price paid
£610,409
Sales
64
Current average value
£672,287
(Zoopla Zed-Index)
Value change
£24,942
▲ 3.85%
House prices in BS8
Market activity
Last 12 months
Flats
Average price paid
£353,025
Sales
284
Current average value
£357,298
(Zoopla Zed-Index)
Value change
£17,018
▲ 5.00%
House prices in BS8
Market activity
Last 12 months
Any property type
Average price paid
£463,123
Sales
414
Current average value
£515,190
(Zoopla Zed-Index)
Value change
£29,641
▲ 6.11%

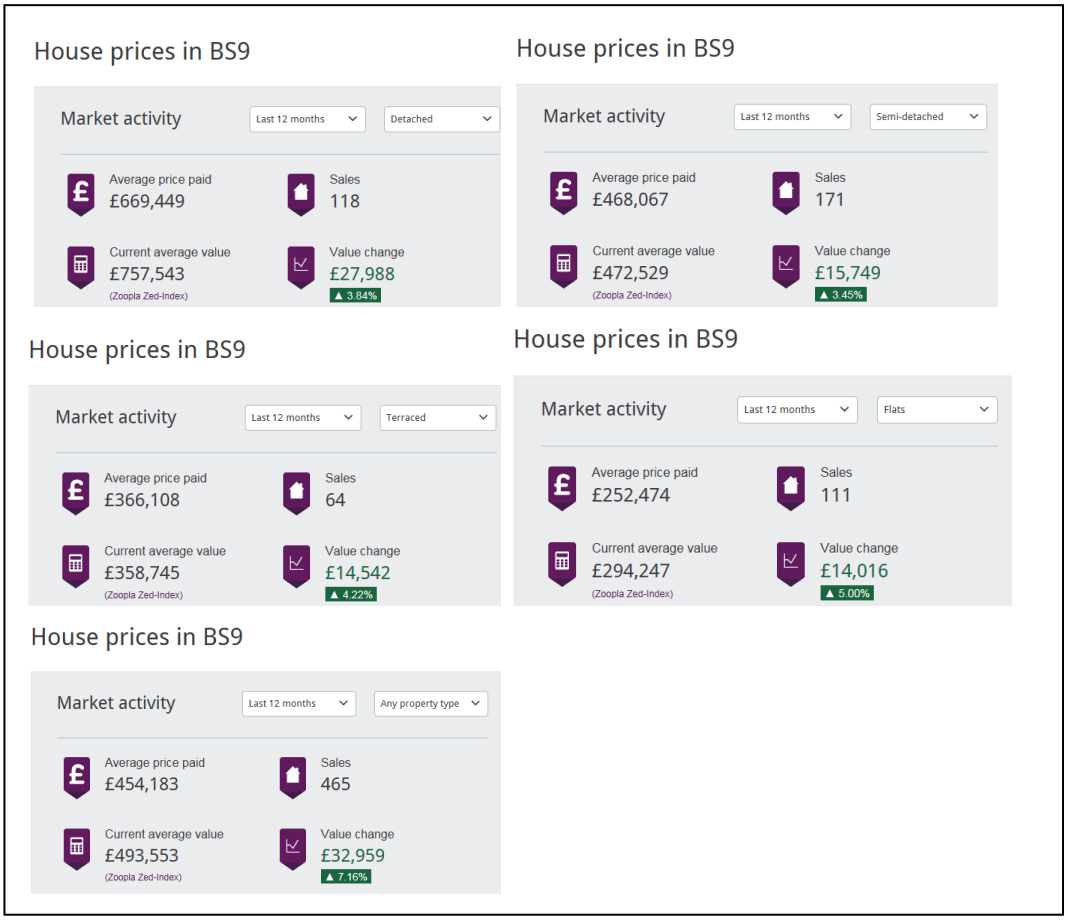


Figure 2-1 – Average property values for a range of postcodes within the Bristol region for a variety of property types (Zoopla 2016)

Figure 2-2 presents a breakdown of the types of residential property that will be at risk from flooding (1:200 year, 0.5% AEP event) over the next century across the Strategy area for the Do Nothing scenario.

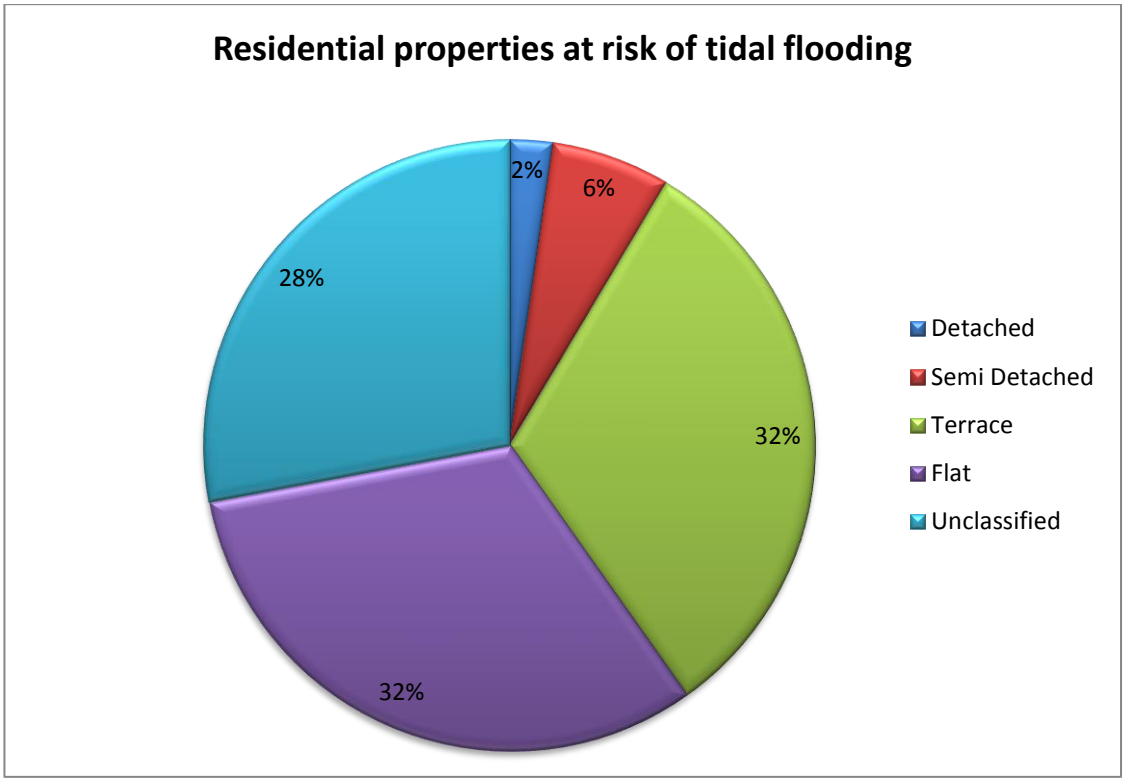


Figure 2-2 – Types of residential properties at risk across the Strategy frontage (1:200 year event, 2115)

A large portion of the data did not contain information regarding the type of dwelling being considered, i.e. detached, semi-detached, terrace or flat. As a result these properties were classed as dwellings only in the NRD and LPG datasets, which has an MCM code = 1. The average property price for each postcode was then applied, as outlined above, to estimate the potential damage value arising for each scenario.

2.3 Identifying properties at risk – commercial & critical infrastructure

Bristol City Council provided a commercial address point dataset (LPG, 2016) for the property address, post code, flood space (m^2), type (e.g. commercial – office, commercial – warehouse) and property coordinates for all assets within the strategy area.

A broad range of commercial properties are found in the strategy area. Table 2-3 presents a summary of the types of commercial property at risk of flooding over the coming century across the study area from a 1:1000 year event in 2115.

Table 2-3. Types of commercial property at risk of flooding (1:200, 2115)

Commercial Properties at Risk	
Property Type	**No. of Properties**
General Commercial	618
Warehouse	6
Factory	15
Office	114
Shopping	164
Supermarket	4
School / college / university	5
Industry	9
Other	678
Total	**1613**

Flood depths for each individual property were obtained by conducting point inspections in GIS using the property location and the flood modelling for each scenario (1:2, 1:20, 1:75, 1:200 and 1:1000 year events).

The commercial properties were valued on the rateable value for their business type (provided by the valuation office, see Table 2-4 below). Average values for retail, workshop, warehouses and offices between £60/m^2 and £90/m^2 were estimated and then multiplied by the building flood space to estimate the rentable value of the business. In accordance with the FCERM-AG guidance, the rentable values were then divided the business yield (~6%) to provide an estimate of the market value for flood damage capping and write off purposes.

Table 2-4. Commercial rateable values for various property types (www.voa.gov.uk)

Property Type	Rateable Value (£/m²)
Retail	90
Office	90
Warehouse	60
Public Building	60
Industry	60
Leisure	90
Playing Field	0
Sports Centre	90
Sports Stadium	90
Marina	70
Car Park	70
Substation	70

A manual check was carried out on the 100 properties with the largest floor areas to ensure that the property use designations were correctly assigned by the NRD and LPG data as these assets will generate the largest damages and would greatly affect the result if inaccurately designated.

2.4 Residential Flood depth damages

Direct damages

Flood damages were obtained from the Multi-Coloured Manual (MCM) (Penning-Rowsell 2015) which provided up to date damage costs for a range of properties. The value of flood damage was based on the residential property type (detached, semi, terrace, flat etc.) and the depth of flooding for each property for each flood scenario. Values for 'Short Duration, salt water, major flood, sewage' were used for this analysis. The short duration scenario is applicable when flooding occurs for less than 12 hours. The depth/damage data also includes an allowance for clean-up and drying of flooded properties.

Intangible health benefits were included in the appraisal at a rate of £290 per residential property at risk of flooding (in accordance with the MCM, 2013 and corrected to current prices). In order to account for damage to vehicles the MCM (2015) recommends the following approach:

"This method assumes that the total number of vehicles likely to be damaged during a flood occurring at any time of the day will equate to 28% of the total number of residential *and* commercial properties (see Chapter 5) at risk (from a flood of any depth)".

This is then multiplied by the average value for a typical vehicle, which for the UK is £3,100 (Penning-Roswell et al., 2013) in order to estimate the potential damages to vehicles as a result of flooding.

During a flood event 50% of those at risk of flooding were considered to require temporary accommodation and food for approximately 3 weeks at a cost of £900 per property (with the remainder able to reside in upper floor accommodation) (Penning-Roswell 2013).

Table 2-5. Flood damages adopted from the MCM (2015)

Short Duration, salt water, major flood, sewage, September 2015. Taken from MCM (2015)																	
Index	MCM Code	Property Type / Age / Social Grade	Component	0m	0.05m	0.1m	0.2m	0.3m	0.6m	0.9m	1.2m	1.5m	1.8m	2.1m	2.4m	2.7m	3m
2	11	Detached	Total Damage (£)	957	9,133	15,286	26,417	32,551	38,892	42,723	47,084	51,573	56,542	60,613	64,117	71,948	75,951
3	12	Semi-detached	Total Damage (£)	1,281	6,435	10,353	17,528	21,368	25,804	27,943	30,766	33,425	36,519	39,350	42,166	47,817	50,508
4	13	Terrace	Total Damage (£)	1,113	5,961	9,422	16,097	19,540	23,783	25,645	28,056	30,238	32,738	34,868	37,019	42,204	44,369
5	14	Bungalow	Total Damage (£)	894	9,726	15,697	25,373	30,517	36,894	40,823	45,267	49,883	55,087	59,464	63,530	71,580	75,578
6	15	Flat	Total Damage (£)	747	6,229	10,162	17,387	21,135	25,883	27,963	30,131	31,986	34,104	35,797	37,112	41,532	43,308

2.5 Commercial Flood damages

Commercial property damages were also obtained from the MCM (2015) based on the commercial property type, the footprint area (m^2) and the depth of flooding for each of the modelled water levels. Values for 'Short Duration, Yes Warning, No Cellar, salt water'. These costs are from the most up to date guidance. Emergency accommodation costs and intangible health benefits are not applicable to commercial properties.

As part of the sensitivity testing of the results the top 100 properties with the largest floor areas were manually inspected to ensure that the MCM codes used in the economic analysis were representative of the property use. This was an important check as these properties produced significant damages and as such were influential in estimating the resulting benefits.

A further manual check was also undertaken for 100 properties with the largest PV damages associated with them. This was undertaken in order to provide confidence in the results. Following this review a number of property MCM codes were updated in order to reflect their actual use. The main adjustment was a building identified adjacent to Bristol Temple Meads Station which was reclassified as being derelict following a manual inspection. This therefore has the effect of reducing the damages slightly. See Table 2-6 for the change in damages between the original estimation and following the manual property check.

Table 2-6. Updated Total PV Damages following sensitivity test on properties generating largest damages

	Total PV Damages (£k)	
Scenario	**Do Nothing**	**Do Minimum**
Original Estimation	1,872,851	469,888
Following Sensitivity Check	1,830,258	452,858
Following Pill / Shirehampton and Defacto Defence updates	1,650,522	334,776

As with residential properties (see section 2.4), vehicle damages associated with a flood event have been included as part of the damages estimation. The MCM (2015) guidance states that the total number of vehicles at risk equates to 28% of the total number of residential and commercial properties subject to flooding. Multiplying this property count by the average vehicle value for the UK, which is £3,100, gives the total vehicle damages associated with each flood event.

This economic assessment represents a conservative damage estimation as flooding of commercial properties can have a wider effect due to the disruption to trade and productivity for non-transferrable and bespoke industries such as those present within the strategy area. An example of this is Temple Meads station which is a key link in the regions transport network and wider supply chain. A more detailed study is required in order to fully capture the economic effects of flood disruption on the wider economy of the West of England. This matches the approach taken as part of the 'Avon Strategic Defences. First Phase Feasibility Study' (Arup 2014) which excludes the effects associated with loss of trade and wider regional disruption.

2.6 Write-off and capping damages

In accordance with FCERM-AG residential and commercial properties were defined as written off once flooded by an event of 1:3 year return period or less, as the property would be no longer habitable or functional. Once written off, these properties no longer accrue flooding or erosion damages. The guidance also requires that the property flood damages over the appraisal period must not exceed the

property market value. The cumulative damages were monitored for each property and once they exceeded the property value further flood damages were capped and the property was written off.

The occurrence of property write off for residential and commercial property is shown below (Figure 2-3 and Figure 2-4). With regard to commercial property, write off remains low between 2030 and 2065 before rising drastically in year 100 due to the impact of sea level rise leading to flooding on a 1:3 year return period or less. Both residential and commercial write-off peak in 2115.

Figure 2-3. Residential Write-off damages (£k) during the appraisal period

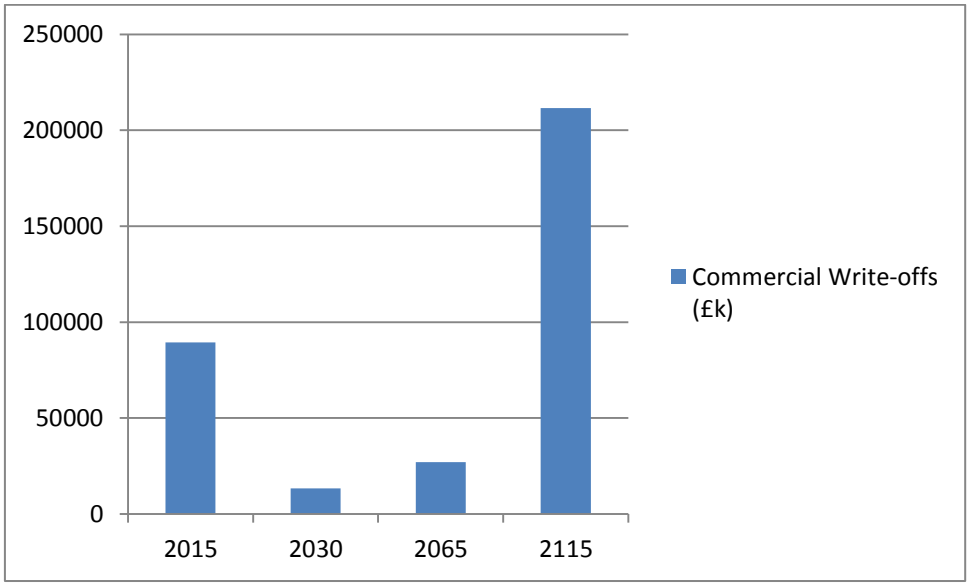


Figure 2-4. Commercial Write-off damages (£k) during the appraisal period

2.7 Other Indirect flood damages

In addition to direct flood damage to commercial and residential property, indirect flood losses have been considered. Indirect flood losses reflect deviations from the economic theory that suggests that in a perfectly competitive world, all sales or production would simply transfer to a competitor with no financial loss to the nation as a whole. In reality, deviations from the competitive model exist and trade cannot simply be transferred, leading to indirect flood damages.

With regard to the Strategy, the transport infrastructure was identified as an area likely to benefit from improved flood protection.

Travel disruption

The flooding of road and railways can cause significant disruption and damage. Travel disruption damages were based on the delay caused to road users as there is no easily accessible diversion route and the probability of flooding to estimate an Annual Average Damage. The MCM (2015) guidance notes that the additional costs incurred in a flood are a combination of the number of vehicles delayed, the additional cost per vehicle and the number of hours that the disruption lasts.

CH2M (2016) produced a 'Tidal Flood Risk Transport Modelling' report on behalf of Bristol City Council. The aim of the study was to assess the monetary impacts associated with the four flood risk scenarios assessed as part of this Tidal Flood Risk Management Strategy. This study provides monetary impacts for the following scenarios:

- Scenario 1: 1 in 5 year likelihood of flooding. Closures include sections of the A4 Portway, A369 Rownham Hill, limited roads around Cumberland Basin and Clarence Road.
- Scenario 2: 1 in 20 year likelihood of flooding. As above plus Albert Road.
- Scenario 3: 1 in 200 year likelihood of flooding. As above plus further closures in the vicinity of Cumberland basin, Cumberland Road, roads in the vicinity of Welshback and Redcliffe St, roads in the vicinity of Bedminster Parade and East St and further roads in the St Philip's Marsh area.
- Scenario 4: 1 in 200 year likelihood of flooding with flood walls in place. This scenario is the same likelihood as Scenario 3 but assumes flood walls are in place. Closures are as Scenario 3 but without some sections of Cumberland Road / Avon Crescent and Cattlemarket Road.

The daily monetary impacts associated with road disruption and closures for each of the scenarios are listed in Table 2-7 below.

Table 2-7. Daily monetary impacts (£ 2015 values and prices) (CH2M 2016)

Time Period	Scenario 1 1 in 5	Scenario 2 1 in 20	Scenario 3 1 in 200 (no flood walls)	Scenario 4 1 in 200 (flood walls)
AM	46,579	47,329	174,391	159,697
IP	82,448	90,843	252,894	246,219
PM	39,336	46,747	196,691	186,886
Total	**168,363**	**184,920**	**623,976**	**592,802**

These 2015 values, along with the 2036 data, were then extrapolated to cover the return periods considered as part flood modelling work (i.e. 2065 and 2115). The resulting daily monetary impacts are shown below (Table 2-8).

Table 2-8. Daily monetary impacts for each of the assessment scenarios

Time Period	Scenario	Daily Monetary Impacts (£)
2015	1 (1 in 5 year)	168,363
	2 (1 in 20 year)	184,920
	3 (1 in 200 year, no flood walls)	632,976
	4 (1 in 200 year, flood walls)	592,802
2036	1 (1 in 5 year)	355,773
	2 (1 in 20 year)	390,760
	3 (1 in 200 year, no flood walls)	1,318,543
	4 (1 in 200 year, flood walls)	1,252,669
2065	1 (1 in 5 year)	446,214
	2 (1 in 20 year)	490,095
	3 (1 in 200 year, no flood walls)	1,653,731
	4 (1 in 200 year, flood walls)	1,571,112
2115	1 (1 in 5 year)	892,429
	2 (1 in 20 year)	980,190
	3 (1 in 200 year, no flood walls)	3,307,462
	4 (1 in 200 year, flood walls)	3,142,224

These impacts were then incorporated as part on the intangible/indirect damages within the economic assessment.

Disruption to railway services was also considered as part of this study. The monetary impacts are based in passenger disruption along the main line east and west of Bristol Temple Meads Station.

The MCM (Penning-Roswell 2015) provides data regarding passenger numbers around the UK for all of the train operators along with a cost for the delay/cancellation of rail services. The MCM (2015) guidance recommends assuming a 40/60% split for delay/cancellations. The guidance also recommends that two methods be combined to estimate passenger disruptions; the compensation payments method and the value of time (VOT) approach. The MCM (2015) provides a breakdown of the trip purpose for the Bristol region which was used to estimate the cost associated with a flood event occurring.

- 63% Commute
- 13% Business
- 24% Leisure

Combining both the compensation payments and the VOT methods resulted in an approximate cost associated with railway disruption of £414,000 per flood event. This cost was included as part of the intangible/indirect damages.

Loss of Life

The indirect damages associated with potential loss of life from a flood event have been estimated for the entire study area by following the Defra *Flood and Coastal Defence appraisal guidance; Social Appraisal, Supplementary Notice to Operating Authorities – Assessing and Valuing the Risk to Life from Flooding for the Use in Appraisal of Risk Management Measures* (2008).

By utilising this guidance and following the 'Risks to people' method, the loss of life (£) per magnitude of flood event was estimated. This calculation was based upon a number of variables for the appraisal area that included the flood hazard rating (variables include the depth and flow of water, and the debris factor), the area vulnerability rating (variables include a flood warning system, speed of flood onset and the nature of the area), and the people vulnerability rating (age of the population, health of the population taken from the 2011 census data).

The loss of life (£) for each magnitude of flood event was then factored by the probability of the flood event occurring to determine an annual damage per year associated with the loss of life. The cash AAD damages associated with loss of life for the 2015 1:1000 year flood event was estimated as £531,000.

Heritage assets

A study was commissioned by Bristol City Council in conjunction with University College London (UCL) entitled 'Vulnerability of Historic Buildings to Tidal Flooding in Bristol due to Climate Change'. This research combined existing flood data and building analysis in order to model the vulnerability of historic buildings at years 2015, 2065 and 2115. It utilised field data and physical modelling in order to assess the vulnerability of Bristol's historic buildings to tidal flooding.

The results of this study were incorporated into the economics as many of the historic buildings suffered failure of the building facades and were therefore written off within the damage assessment. The Asset Annual Average Damage calculations were updated to manually write off any of the properties which were classified as failing as part of the modelling study. As a result some of the assets were written off sooner than the flood depths allowed for, resulting in a more realistic estimation of the resulting damages.

Tourism disruption

The potential loss of tourism benefits to the area was another key aspect which was considered as part of the Do Nothing economic analysis, given the local museums and cultural assets unique to Bristol. An economic impact report for the floating harbour (DC Research 2013) was undertaken which estimated the annual tourism benefits to the harbour of approximately £15 million. As part of the economic analysis it was assumed that on average a flood event lasts 7 days. This was used in conjunction with the probability of a flood occurring for each of the return periods considered in order to generate the potential damages associated with the loss of tourism to the Bristol area.

2.8 Discount rate

Discounting is a technique used to compare benefits (and costs) that occur at different points in time over the appraisal period (i.e. the next 100 years). Standard discount rates have been used to convert all cash damages to 'present values' (PV). This enables the whole life benefits of each management option to be compared and also leads to a realistic assessment of the cost implications of each option in today's terms. According to FCERM-AG, the following variable discount rates have been used within the economic appraisal; 3.5% for the years 0 to 30, 3% for the years 31 to 75, and 2.5% for the years 76 to 99 resulting in a PV factor over 100 years at 29.9 (HM Treasury Green Book, 2003)

The annual average (cash) damages were discounted over the appraisal period to calculate the discounted whole life PV damages. Cumulative PV damages across the entire strategy frontage are presented in Figure 2-5. The damages increase reasonably consistently across the 100 year appraisal period.

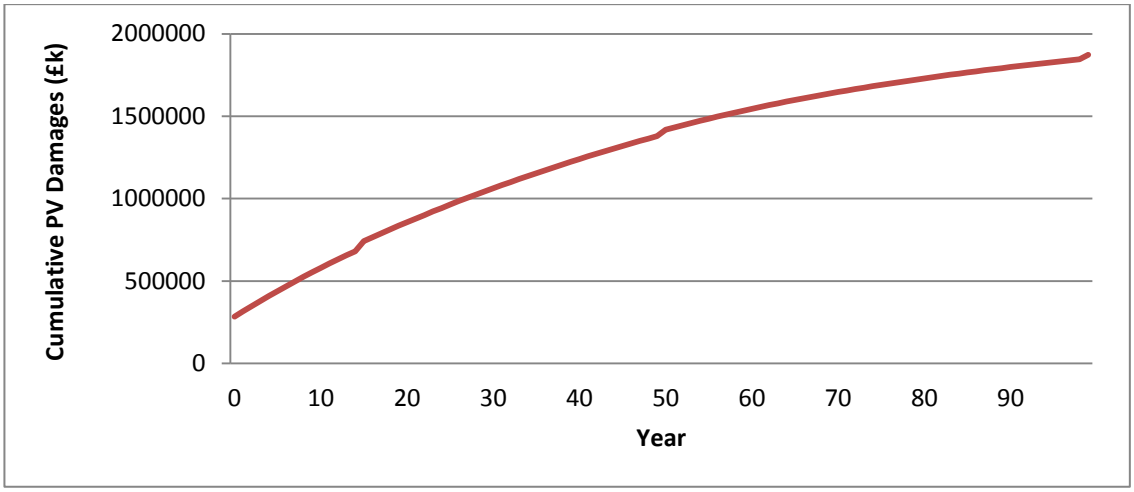


Figure 2-5. Cumulative PV damages (£k) across entire strategy frontage during the appraisal period for the Do Nothing scenario

3 'DO NOTHING' FLOOD DAMAGES

The number of properties (cumulative) expected to be at risk over the next 100 years from flooding under the baseline 'Do Nothing' scenario is presented in Table 3-1 below.

Table 3-1. Number of properties at risk from flooding for a range of return periods over the next 100 years

Return Period Event (years)	Year	Residential properties at risk of flooding	Commercial properties at risk of flooding	Total properties at risk of flooding
2	2015	422	179	601
	2030	572	210	782
	2065	794	422	1216
	2115	1314	731	2045
20	2015	895	458	1353
	2030	1003	569	1572
	2065	1306	706	2012
	2115	1864	995	2859
75	2015	1242	646	1888
	2030	1304	704	2008
	2065	1700	903	2603
	2115	2043	1193	3236
200	2015	1746	971	2717
	2030	1878	1057	2935
	2065	2278	1317	3595
	2115	2696	1613	4309
1000	2015	2276	1308	3584
	2030	2429	1375	3804
	2065	2431	1369	3800
	2115	3707	2005	5712

The PV damages for the study area under the baseline 'Do Nothing' scenario is presented below in Table 3-2.

Table 3-2. Present value damages expected the next 100 years (to 2115) under the baseline Do Nothing approach

PV Flood Damages –(£k)		PV Flood Damages – Write Off and Capping (£k)		PV Other (£k)	PV Total (£k)
Residential	Commercial	Residential	Commercial		
295,674	1,030,688	181,798	113,802	28,560	1,650,522

The flood damages to residential and commercial properties forms the most significant part of the total damages expected across the frontage under the 'Do Nothing' scenario.

4 'DO MINIMUM' FLOOD DAMAGES

The number of properties (cumulative) expected to be at risk over the next 100 years from flooding under the 'Do Minimum' scenario is presented in Table 4-1 below.

Table 4-1. Number of properties at risk from flooding for a range of return periods over the next 100 years

Return Period Event (years)	Year	Residential properties at risk of flooding	Commercial properties at risk of flooding	Total properties at risk of flooding
2	2015	49	7	56
	2030	52	20	72
	2065	91	111	202
	2115	131	245	376
20	2015	94	120	214
	2030	104	163	267
	2065	129	239	368
	2115	783	467	1250
75	2015	124	199	323
	2030	127	238	365
	2065	340	358	698
	2115	1499	820	2319
200	2015	488	486	974
	2030	579	497	1076
	2065	1673	964	2637
	2115	2342	1347	3689
1000	2015	1673	963	2636
	2030	2101	1074	3175
	2065	2128	1084	3212
	2115	3472	1896	5368

The PV damages for the study area under the baseline 'Do Minimum' scenario is presented below in Table 4-2.

Table 4-2. Present value damages expected the next 100 years (to 2115) under the baseline Do Minimum approach

PV Flood Damages –(£k)		PV Flood Damages – Write Off and Capping (£k)		PV Other (£k)	PV Total (£k)
Residential	Commercial	Residential	Commercial		
47,668	242,804	18,721	18,028	7,557	334,776

As with the 'Do Nothing' scenario, the flood damages to residential and commercial properties forms the most significant part of the total damages expected across the frontage under the 'Do Minimum' scenario.

5 STRATEGIC OPTION BENEFITS

To inform the selection of the preferred strategic option it has been necessary to determine the flood benefits that arise from the various strategic options.

The approach to determine the option benefits has been to calculate the residual damages of each option. This damage has then been compared to that of the Do Nothing scenario to derive the benefit of implementing the option.

Each strategic option is comprised of a sequence of measures spanning the three Strategy time epochs. The measures are:

- Property Level Protection / temporary defences
- Low Defences
- High Defences
- Tidal Barrier

The seven strategic options are:

- Option A: Property Level Protection (epoch 1, 2015), Low Defences (epoch 2, 2030), High Defences (epoch 3, 2065)
- Option B: Property Level Protection (epoch 1, 2015), High Defences (epoch 2, 2030), maintain High Defences (epoch 3, 2065)
- Option C: Property Level Protection (PLP) (epoch 1, 2015), Tidal Barrier (epoch 2, 2030), maintain Tidal Barrier (epoch 3, 2065)
- Option D: Low Defences (epoch 1, 2015), Low Defences (epoch 2, 2030), High Defences (epoch 3, 2065)
- Option E: Low Defences (epoch 1, 2015), Tidal Barrier (epoch 2, 2030), maintain Tidal Barrier (epoch 3, 2065)
- Option F: High Defences (epoch 1, 2015), maintain High Defences (epoch 2, 2030), maintain High Defences (epoch 3, 2065)
- Option G: Do Minimum (epoch 1, 2015), Do Minimum (epoch 2, 2030), High Defences (epoch 3, 2065)

A summary of the measures that comprise the strategic options is provided below. For more details, including a description and figures showing the areas protected by each measure, refer to the Preferred Options report.

In the economic assessment it has been assumed that the measures will be implemented at the start of each epoch and that flood risk benefits will be accrued from this point forward. This is consistent with the approach to option costing (i.e. the cost of capital works occurs at the start of each epoch) and allows for a fair comparison between options. In reality, it may take a number of years to construct an intervention measure (such as raised defences or a tidal barrier) and therefore the point at which flood risk benefits may start to occur could be delayed. However, for the purpose of comparing options in the Strategy the assumptions and approach taken are considered suitable.

A more detailed assessment of the residual risks and the potential deterioration of the options over time will be covered as part of the preferred option refinement stage of works.

5.1 Measure descriptions

Low Defences

The Low Defences measure consists of raised defences (walls, piles, embankments etc.) constructed to a 2030 1:200 year standard. The defences will be located at the following locations; Netham, Bath Road, Totterdown, Cattle Market Road, Clarence Road, Commercial Road, Cumberland Road, Entrance Lock, Pill and Shirehampton. The defences will be 'future proofed' in their design to allow for crest raising in the future in response to sea level rise.

Alignments for Low Defences were established for costing purposes during the preferred option appraisal. The alignments were used in this assessment to identify the properties along the frontage which would be protected following the construction of the defences. The damage associated with these properties was then removed from the Do Nothing damages in order to identify the benefits of the low defences measure. For the protected properties the residual damages from above design standard events were not included in the benefits (i.e. damages from events greater than the 1:200 year 2030 standard).

The Low Defence damages have been assessed for epoch 1 (2015-2030) and for epoch 2 (2030-2065) as part of the strategic options A, D and E.

High Defences

The High Defence measure consists of raised defences (walls, piles, embankments etc.) constructed to a 2115 1:200 year standard. The defences will be located in the same positions as the low defences (described above) but will be higher and also longer in some locations. For a strategic option it is envisaged that if low defences are already in place (i.e. from epochs 1 or 2), then the high defences will be constructed via crest raising and lengthening of the low defences rather than construction from scratch.

Alignments for High Defences were established for costing purposes during the preferred option appraisal. The alignments were used in this assessment to identify the properties along the frontage which would be protected following the construction of the defences. The damage associated with these properties was then removed from the Do Nothing damages in order to identify the benefits of the high defences measure. For the protected properties the residual damages from above design standard events were not included in the benefits (i.e. damages from events greater than the 1:200 year 2115 standard).

The High Defence damages have been assessed for epochs 1 (2015-2030), 2 (2030-2065) and 3 (2065-2115) as part of the strategic options A, B, D, F and G.

Property Level Protection / Temporary Defences

This option involves the use of temporary / demountable flood defences at either individual properties or in the form of community flood defences. PLP measures are typically retro-fitted to existing properties but can also be incorporated into new developments.

PLP measures typically only provide a low standard of protection as they are generally only effective up to flood depths of 600mm and therefore damages resulting from flood depths greater than this have been included in the assessment. In addition, MCM (2015) guidelines state that only 75% of PLP damages can be taken as a benefit given the potential risk of the measures not being implemented or installed correctly in the event of a flood occurring. This factor has been included within the PLP benefit assessment.

Zones for PLP measures were established for costing purposes during the preferred option appraisal. The properties within each zone were identified and for each property the benefits were accrued for flood events with depths less than 600mm.

Tidal Barrier

During the option appraisal phase of the Strategy a tidal barrier located at Ham Green – Nibley Road was identified as the preferred location for a barrier. This location was taken forward and considered during the preferred options phase of the appraisal. The barrier will protect to a 1:1000 year standard of protection to all the properties upstream of its location. Properties located downstream, notably at Pill and Shirehampton will not be protected from this measure.

5.2 Option benefits and damages

In the first instance the benefits associated with each measure for each relevant time epoch were determined. These were then combined to calculate the total benefits for each strategic option across the full appraisal period.

The benefits are presented in present value (PV) terms to allow for a representative comparison with the whole life option costs. **Table 5-1** presents the PV benefits for the strategic options. Also included are the Do Nothing and Do Minimum scenarios for comparison purposes.

Table 5-1 PV flood benefits and damages relative to Do Nothing

Strategic Option	Sequence of Measures	PV Flood Damages (£k)	PV Flood Benefits (£k)
Do Nothing	Do Nothing (2015) – Do Nothing (2030) – Do Nothing (2065)	1,650,522	0
Do Minimum	Do Minimum (2015) – Do Minimum (2030) – Do Minimum (2065)	334,776	1,315,746
A	PLP (2015) – Low Defences (2030) – High Defences (2065)	104,534	1,545,988
B	PLP (2015) – High Defences (2030) – High Defences (2065)	90,560	1,559,962
C	PLP (2015) – Tidal Barrier (2030) – Tidal Barrier (2065)	79,016	1,571,506
D	Low Defences (2015) – Low Defences (2030) – High Defences (2065)	74,590	1,575,932
E	Low Defences (2015) – Tidal Barrier (2030) – Tidal Barrier (2065)	51,733	1,598,749
F	High Defences (2015) – High Defences (2030) – High Defences (2065)	52,495	1,598,027
G	Do Minimum (2015) – Do Minimum (2030) – High Defences (2065)	220,754	1,429,768

The number of properties within the study site which benefit from each of the strategic options are presented in **Table 5-2**. These property numbers are presented relative to the **Do Minimum** scenario. It should be noted that the PLP measures are only effective for the protection of properties up to the 1:20 year risk scenario to a flood depth of 600mm. Above this risk threshold the benefits of PLP are unclear and therefore the number of properties protected by this measure for flood events is not defined in **Table 5-2**. For the 1:2 and 1:20yr flood events where PLP is considered effective (for flood depths <600mm), only 75% of the flood damages have been taken as a benefit in the economic assessment. This is in line with MCM recommendations to account for the residual risk of PLP measures not being operated or maintained correctly by the homeowner.

Table 5-2 Numbers of properties benefiting from strategic options relative to the Do Minimum scenario

Strategic Option	Epoch	Return period			
		1:2yr (50%)	1:20yr (5%)	1:75yr (1.33%)	1:200yr (0.5%)
A	2015	9	64	NA (PLP standard undefined)	NA (PLP standard undefined)
	2030	29	203	295	831
	2065	139	298	616	2211
	2115	306	1151	2210	3201
B	2015	9	64	NA (PLP standard undefined)	NA (PLP standard undefined)
	2030	29	203	295	831
	2065	139	298	616	2211
	2115	306	1151	2210	3201
C	2015	9	64	NA (PLP standard undefined)	NA (PLP standard undefined)
	2030	66	260	358	1014
	2065	195	361	636	2360
	2115	369	975	2014	3362
D	2015	16	150	254	668
	2030	29	203	295	831
	2065	139	298	616	2211
	2115	306	1151	2210	3201
E	2015	16	150	254	668
	2030	66	260	358	1014
	2065	195	361	636	2360
	2115	369	975	2014	3362
F	2015	16	150	254	670
	2030	29	203	295	831
	2065	139	298	616	2211
	2115	306	1151	2210	3201
G	2015	0	0	0	0
	2030	0	0	0	0
	2065	139	298	616	2211
	2115	306	1151	2210	3201

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5.3 Option costs

As part of the preferred option phase of the appraisal the cash and present value costs of each of the strategic options have been developed. For details on the costing methodology and the assumptions which have been made, refer to the preferred options report. The costs of the strategic options in present value terms are presented in **Table 5-3**.

Table 5-3 Present value costs of the strategic options

Strategic Option	Sequence of Measures	PV Cost (£k)
Do Minimum	Do Minimum (2015) – Do Minimum (2030) – Do Minimum (2065)	23,677
A	PLP (2015) – Low Defences (2030) – High Defences (2065)	112,666
B	PLP (2015) – High Defences (2030) – High Defences (2065)	130,297
C	PLP (2015) – Tidal Barrier (2030) – Tidal Barrier (2065)	471,133
D	Low Defences (2015) – Low Defences (2030) – High Defences (2065)	166,257
E	Low Defences (2015) – Tidal Barrier (2030) – Tidal Barrier (2065)	595,177
F	High Defences (2015) – High Defences (2030) – High Defences (2065)	201,994
G	Do Minimum (2015) – Do Minimum (2030) – High Defences (2065)	56,761

5.4 Option economic appraisal

To inform the selection of the preferred option, the average benefit cost ratio (ABCR) and incremental benefit cost ratio (IBCR) of the options has been calculated. For more details of how these ratios feed into the preferred option selection process, refer to the preferred options report.

The ABCR is the calculation whereby the benefits generated by the option are divided by the cost of implementing the option. The ABCR provides a basic marker as to whether an option is economically viable. If the ABCR is >1, it demonstrates that the option benefits outweigh the option costs. The ABCR's of the options are presented in **Table 5-4**. For comparison purposes the options have been ranked according to their PV cost.

Table 5-4 ABCRs of the strategic options. Options ranked by PV cost.

Strategic Option	Sequence of Measures	PV Cost (£k)	PV Benefit (£k)	ABCR
Do Minimum	Do Minimum (2015) – Do Minimum (2030) – Do Minimum (2065)	23,677	1,315,746	56:1
G	Do Minimum (2015) – Do Minimum (2030) – High Defences (2065)	56,761	1,429,768	25:1
A	PLP (2015) – Low Defences (2030) – High Defences (2065)	112,666	1,545,988	14:1
B	PLP (2015) – High Defences (2030) – High Defences (2065)	130,297	1,559,962	12:1
D	Low Defences (2015) – Low Defences (2030) – High Defences (2065)	166,257	1,575,932	9:1
F	High Defences (2015) – High Defences (2030) – High Defences (2065)	201,994	1,598,027	8:1
C	PLP (2015) – Tidal Barrier (2030) – Tidal Barrier (2065)	471,133	1,571,506	3:1
E	Low Defences (2015) – Tidal Barrier (2030) – Tidal Barrier (2065)	595,177	1,598,749	3:1

The IBCR is a calculation used to determine whether there is a strong economic case to invest in a higher cost option. In Flood and Coastal Risk Management appraisal guidance (FCERM-AG) the IBCR informs the cost effectiveness of different options. It is defined as the difference in benefit between two options, divided by the difference in cost. The ratio provides a measure of the return from the additional investment from one option to the next.

To determine the IBCR of the options it is necessary to rank the options in order of reduced probability of flooding. For simplicity, this has been done using the option costs and benefits (i.e. the option with the smallest costs and benefits at the top of the list, the option with the greatest costs and benefits at the base).

For details of how the IBCR has been used to inform the selection of the preferred option, refer to the preferred options report.

Table 5-5 presents the IBCRs of the strategic options.

Table 5-5 IBCRs of the strategic options. Options ranked by PV costs and benefits

Strategic Option	Sequence of Measures	PV Cost (£k)	PV Benefit (£k)	BBCR
Do Minimum	Do Minimum (2015) – Do Minimum (2030) – Do Minimum (2065)	23,677	1,315,746	NA
G	Do Minimum (2015) – Do Minimum (2030) – High Defences (2065)	56,761	1,429,768	3.45
A	PLP (2015) – Low Defences (2030) – High Defences (2065)	112,666	1,545,988	2.08
B	PLP (2015) – High Defences (2030) – High Defences (2065)	130,297	1,559,962	0.79
D	Low Defences (2015) – Low Defences (2030) – High Defences (2065)	166,257	1,575,932	0.44
F	High Defences (2015) – High Defences (2030) – High Defences (2065)	201,994	1,598,027	0.62
C	PLP (2015) – Tidal Barrier (2030) – Tidal Barrier (2065)	471,133	1,571,506	(-ve)
E	Low Defences (2015) – Tidal Barrier (2030) – Tidal Barrier (2065)	595,177	1,598,749	0.22

The IBCRs presented in **Table 5-5** range between 0.22 and 3.45. If the IBCR between options is >1, it demonstrates that there is a strong economic case to invest in the more costly option. Observations from the IBCRs presented include:

- A strong economic case to invest in option A rather than option G with an IBCR of 2.08
- No economic case to invest in options C or E (the barrier options) with a negative IBCR relative to option F
- Very similar costs and benefits for options A, B, D and F with IBCRs ranging between 0.62 and 2.08. Economically viable to invest in each of these options given the similarities.

The choice of the preferred option has not been made on economics grounds alone. Wider strategy objectives, funding and uncertainty have also been considered. For more details of how the economic appraisal has fed into the preferred option selection, refer to the preferred options report.

6 PARTNERSHIP FUNDING ASSESSMENT OF STRATEGIC OPTIONS

6.1 Context

In the past, flood defence projects were largely funded from a national budget. Funding for coastal management schemes was allocated on an 'all or nothing' basis. In May 2011 the Government announced changes to the system to encourage more local contributions to flood defence schemes. This was a recommendation of the Pitt Review and it generally has widespread support.

In the current 'Partnership Funding' system, public money (Grant in Aid or 'GiA') is made available to part fund justifiable schemes, while any shortfall in funding is made up by other parties with a vested interest in seeing the project go ahead. The levels of funding made available by the government through GiA are based on the economic, social and environmental benefits that the project will bring.

Partnership Funding is therefore an effective way of making the FCRM GiA go further. With the Partnership Funding system, if sufficient contributions can be attracted, any project could proceed so long as it is economically, socially and environmentally viable. The Strategy, once approved and adopted, will also support the business case for these projects.

Although the Avon TFRMS is not strictly following FCERM-AG it is highly likely that the preferred option (or the schemes required to deliver them) will be funded via a partnership approach, with potential GiA applications forming part of the funding packages. Therefore to gain an appreciation of the potential affordability of options, and the scale of funding gaps or shortfalls, provisional partnership funding assessments were carried out.

For the strategic options which include PLP, it is important to note that there are limitations associated with partnership funding for the options. For instance commercial properties protected by these measures will not be eligible for Grant in Aid funding.

6.2 Approach

Some of the shortlisted strategic options comprise packages of measures phased in time; where this is the case a PF calculation has been carried out to assess the likely GiA % (and contribution required) only for the first intervention, as a GiA application will only be relevant to first scheme. Follow on schemes in the future are subject to too much uncertainty (e.g. funding system, climate change, baseline condition) etc to make the assessment meaningful. Where the first scheme is delayed (e.g. 2030) PF assessment has been carried out on the basis that current funding rules apply and that the baseline is 2030 as if it were the present day. This gives a relative and fair indicative comparison of funding potential for schemes, even if in reality the current funding rules and system is likely to change before 2030.

The partnership funding assessment was carried out in accordance with the Environment Agency funding guidance for flood and coastal protection schemes. The Defra Flood and Coastal Resilience Partnership Funding arrangement defines the level of Flood Defence Grant Aid (GiA) a project could achieve based on a series of Defra Outcome Measure (OM) targets.

There are four outcome measures under which projects can attract FDGiA. These are:

1. All benefits arising as a result of the investment, less than those valued under the other outcome measures (outcome measure 1).
2. Households moved from one category of flood risk to a lower category (outcome measure 2).
3. Households better protected against coastal erosion (outcome measure 3).
4. Statutory environmental obligations met through flood and erosion risk management (outcome measure 4).

The first two outcome measures are most relevant to the Strategy, although there is potential for OM4 benefits to be included subject to specific scheme details (although these benefits have not been included at present in these initial PF assessments). A full table of the outcome measures (OMs) and benefits under each that will qualify for national funding is provided in the latest DEFRA FDGiA guidance. The table is reproduced below in

Table 6-1. Summary of outcome measures (DEFRA, 2011).

OM no.	Outcome Measure definition	Benefits and outcomes qualifying for national funding	Payment rate	Examples of funding levels from Government
OM1	Average benefit to cost ratio of schemes delivering OMs	Under OM1, present value of whole-life benefits of the current investment, less benefits paid for or payments made under the other outcome measures.	5.56p per £1 of qualifying benefit (i.e. seeking an 18 to 1 return from national investment)	These include avoidance of damages to e.g. business, agriculture, local government, communications, infrastructure, utilities and public health
OM 1a	*Present value of whole-life benefits per £1 of GiA*			
OM2	Households moved from one category of flood risk to a lower category Households must be at direct risk of flood damage and have been built or converted into housing before January 2012 to counted	Under OM2, present value of direct damages to residential properties and their contents avoided, in the: -20% most deprived areas -21-40% most deprived areas -60% least deprived areas	 45p per £1 30p per £1 20p per £1	Based on moving a single household from a very significant risk to a low risk for a duration of 50 years £15,399 per household protected £10,266 £6,844
	Households better protected against coastal	Under OM3, present value of the reduction in direct damages to		Based on protecting a single household at risk of loss within 20

OM3	erosion Households against must be direct risk of damage from coastal erosion and have been built or converted into housing before January 2012 to qualify	residential properties, in the: - 20% most deprived areas - 21-40% most deprived areas - 60% least deprived areas	 45p per £1 30p per £1 20p per £1	years, for a period of 50 years £35,601 per household protected £23, 734 £15,822
OM4	Statutory environmental obligations fully met through flood and coastal erosion risk management	Outcomes specifically funded under OM4:		
OM 4a	Hectares of water-dependent habitat created or improved to help meet the objectives of the Water Framework Directive	Water-dependent habitat created or improved	£15,000 per hectare	
OM 4b	Hectares of inter-tidal habitat created to help meet the objectives of the Water Framework Directive for areas protected under the EA Habitats or Birds Directive	Inter-tidal habitat created	£50,000 per hectare	
OM 4c	Kilometers of river protected under the EU Habitats or Birds Directive improved to help meet the objectives of the Water Framework Directive	Protected rivers improved	£80,000 per km of river bed	

Table 6-2. Flood risk categories (Defra, 2011).

Risk category	Annual chance of flooding
Very significant	5% or greater 1 in 20
Significant risk	Greater than 1.33% (1in 75) but less than 5%
Moderate risk	Greater than 0.5 % (1in200) but less than or equal to 1.3%
Low risk	0.5% or less

To consider the households protected against flood risk over the duration of the investment, flood inundation mapping before and after scheme implementation was inspected to calculate the number of households within each flood risk category (as defined in Table 6-2). To complete the full analysis and enable the level of deprivation to be considered in the OM score calculation, the Multiple Index for Deprivation Rank for each property can be determined.

At this initial stage, the properties at risk were all assumed to fall in the mid deprivation band (as an average). Although this provides a limitation, sensitivity testing shows it is likely to make a marginal difference to the PF %. A more detailed PF assessment on the preferred option will be undertaken during the next phase. This will involve identifying the IMD rank for each property and accurately applying it to the PF calculation.

6.3 Contributions and Partnership Funding for shortlisted options

Funding of any of the strategic options is challenging. None of the options generates a high Partnership Funding score, so all will require a significant degree of contributions.

Partnership Funding scores are set out below for the works that the Options would require in Epoch 1 or 2. Two calculations have been undertaken, one assuming Do Nothing as a baseline, and one assuming Do Minimum.

The Do Nothing scenario is considered an appropriate baseline for the PF calculations given the importance of the continued operation of the Floating Harbour to the total flood damages within the study area and the reliance on human interaction to operate the water level control structures within the harbour. However, small changes in the assumptions which comprise the Do Nothing scenario could create large difference in the flood damages and therefore there is uncertainty in this approach. There are also concerns that the Environment Agency and Defra may see the Do Minimum baseline as the more appropriate.

Table 6-3. Partnership Funding scores for the strategic options. Do Nothing baseline

Strategic option	Sequence of measures	Scheme Assessed for PF	Capital cost (cash £)	Raw PF Score	GiA (cash £)	Shortfall (cash £)
G	Do Min – Do Min – High Def	-		-	-	-
A	PLP – Low Def – High Def	Low defences from 2030 with 50 year design life	£128m	64%	£82m	£46m
B	PLP – High Def – High Def	High defences at 2030 with 85 year design life	£165m	60%	£99	£66m
D	Low Def – High Def- High Def	Low defences 2015 with 50 year design life	£128m	59%	£75m	£53m
F	High Def – High Def – High Def	High defences, 2015 with 100 year design life	£165m	51%	£84m	£81m
C	PLP – Tidal Barrier – Tidal Barrier	Tidal barrier from 2030 with 85 year design life.	£683m	16%	£108m	£575m
E	Low Def – Tidal Barrier – Tidal Barrier	See D for low wall in Epoch 1 and C for Tidal Barrier in Epoch 2.				

Table 6-4 . Partnership Funding scores for the strategic options. Do Minimum baseline

Strategic option	Sequence of measures	Scheme Assessed for PF	Capital cost (cash £)	Raw PF Score	GiA (cash £)	Shortfall (cash £)
G	Do Min – Do Min – High Def	-		-	-	-
A	PLP – Low Def – High Def	Low defences from 2030 with 50 year design life	£128m	10%	£13m	£115m
B	PLP – High Def – High Def	High defences at 2030 with 85 year design life	£165m	9%	£15m	£150m
D	Low Def – High Def- High Def	Low defences 2015 with 50 year design life	£128m	6%	£8m	£120m
F	High Def – High Def – High Def	High defences, 2015 with 100 year design life	£165m	8%	£14m	£151m
C	PLP – Tidal Barrier – Tidal Barrier	Tidal barrier from 2030 with 85 year design life.	£683m	3%	£22m	£661m
E	Low Def – Tidal Barrier – Tidal Barrier	See D for low wall in Epoch 1 and C for Tidal Barrier in Epoch 2.				

As shown in Table 6-3 and Table 6-4 the funding gap for Low Defences in Epoch 1 is £53m (best case via Do Nothing scenario) to £120m (worst case via Do Nothing scenario). To implement these works, this gap would need to be filled by contributions from BCC, LEP, other public funding sources and beneficiaries from the defences.

In some areas there is an opportunity to integrate the defence works with site raising and redevelopment, potentially gaining contributions from developers (in cash or in kind) and reducing costs.

Nonetheless, it is very unlikely that the works could go ahead without a substantial contribution from BCC. Before the Preferred Option is confirmed BCC's appetite for funding the shortfall will need to be ascertained.

7 GVA ASSESSMENT

7.1 Wider economic impacts of Do Nothing

The Environment Agency currently has detailed guidance for appraising the economic, environmental and social impacts of FCERM interventions. Some economic impacts are assessed within that framework such as the expected annual damage to properties. These assessments relate specifically to impacts in the short term post-flood. These are termed 'First Round Impacts' and include losses which are applicable to the economy in a national context.

7.2 First Round impacts

The estimated 'first round 'damages for a Do Nothing scenario (Table 3-2) include the following aspects:

- Expected damage to residential and commercial properties (premises, inventories, machinery etc.);
- Damage to public infrastructure (utilities, for example);
- Education and Schools;
- Vehicle damage;
- Risk to life;
- Emergency clean up and response;
- Accommodation and subsistence ;
- Traffic and business travel disruption;
- Heritage and tourism loss from impacts on bespoke features (e.g. There is no equivalent feature elsewhere, or there is no potential for displacement or transfer of this related tourism).

Where FCERM interventions prevent some or all of these first round impacts, these benefits are included in Partnership funding and Grant in Aid assessments. However, in addition these direct impacts can trigger business responses and in turn, dynamic impacts. The scale and significance of these dynamic impacts on the local economy, in part depends on the geographical area under consideration. The relationship of GVA and FCERM-AG impacts, and the categorisation of first round and dynamic impacts, is shown in Figure 7-1.

7.3 Dynamic Impacts

Dynamic impacts reflect the outcomes for a local economy over time as businesses respond to changes in flood risk. Strategic tidal flood risk management intervention is likely to:

- Support business continuity and sustainability of business activity in an area;
- 'Unlock' investments that might otherwise have been constrained or unattractive given the flood risk; and,
- Lead to 'spill over' impacts which reflect interdependencies or other intangible impacts on economic activity.

By evaluating the potential contribution to the local economy of investing in flood risk management measures it helps build an understanding of their potential impacts on the local economy. This would be expected to increase the propensity for local partners to contribute funding to FCERM as part of the government's Partnership Funding approach.

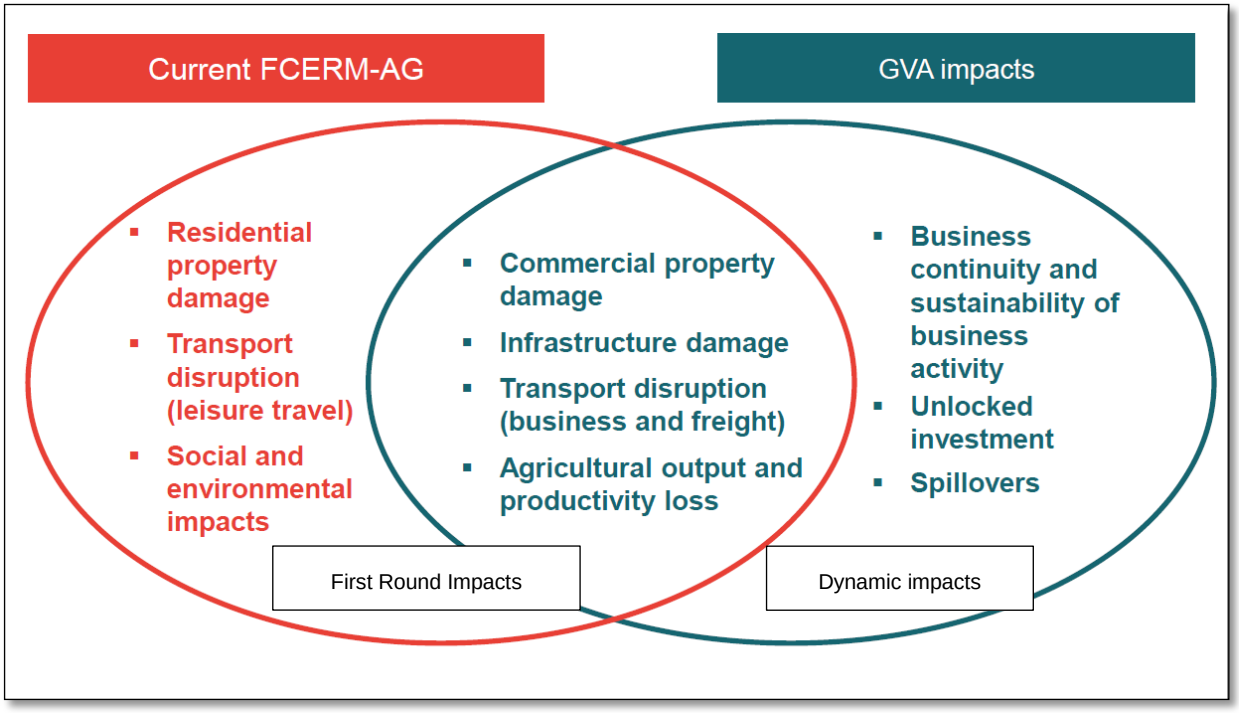

Figure 7-1. Overlap of current FCERM-AG economic impacts and additional impacts on the local economy.

7.4 Overview of approach to GVA Assessment

The contribution to the economy is quantified where possible and measured as Gross Value Added, GVA. This is complemented with qualitative assessments. The full method is described in "TOOLKIT for assessing the impacts of flood and coastal erosion risk management on the local economy".

The primary focus is on local GVA, and associated key drivers of the impacts on the local economy. As the methodology for assessing GVA impacts of FCERM, and its application, are in their infancy, it is likely that the approach, data and assumptions will need to be reviewed and updated over time as a richer evidence base comes to light.

A high level proportionate GVA assessment was applied in this study estimate the wider impacts on economic activity by explicitly considering businesses' likely responses to flood risk. The assessment has drawn upon a range of available data including:

- GVA toolkit and annexes
- Business size and sector distribution statistics for Bristol (Office of National Statistics)
- Average salaries for different business sizes and categories in Bristol (ww.payscale.com)
- Local Plan (development and employment projections)
- National Receptor Database 2011
- Derived data from Strategic City Planning (Sept 2015)
- Economic Development Needs Assessment (2015)

Typically, a GVA assessment is undertaken using a 10 year period, as this period reflects that where direct impacts can be reasonably attributed or linked to specific interventions. Beyond that the envelope of uncertainty grows significantly and other factors may become more influential in determining the futures experienced. However, in this study a 23 year period from 2015 – 2038 was considered, as estimates of development and employment projections are available or can be extrapolated. The GVA estimations are based on an average annual figure for the period which is then presented as a discounted (Present Value) total for the whole period.

The dynamic impacts focussed on in the quantitative estimations in the assessment included:

- **Disruption to existing businesses.** A valuation of potential losses from flood risk detrimentally impacting on business continuity and operation.
- **Opportunity lost.** An estimation of potential development and investment lost out on in a Do Nothing case. Without FRM intervention the development plans and employment increases will not be enabled and therefore the locally economy will not benefit from the investment that could be unlocked by FRM intervention**.**

It should be noted that this high level GVA assessment, which is suitable for a strategic level appraisal, provides ballpark estimates of dynamic impacts but is underpinned by significant assumptions and uncertainties in the data. Further more detailed assessment and valuation of GVA impacts is recommended in future more detailed appraisals to support potential schemes.

Business responses to flood risk

Using the estimated range of business responses, we can explore the likely dynamic impacts of flooding and FRM. In the absence of FCERM intervention, evidence suggests that disruption to business activity could last many weeks. Based on a review of available evidence, we assume that without the intervention, a business could be disrupted for around 16-24 weeks because of flooding, and 2-4 weeks with the FRM intervention.

Businesses operate in the context of uncertainty about when, how, what scale, how long and how often they may experience flooding. They have to make business decisions to manage the risks they face. In response to flood risk, businesses respond in one of 4 ways:

- stay and do nothing
- stay and adapt
- move
- shut down

In Bristol, many premises within the City Centre are national or Regional Headquarters who provide specialist knowledge-intensive, creative or financial services which are not easily transferrable. With this in mind, and without detailed data to underpin an assessment of potential business behaviours (with respect to flood risk) it has been assumed in the valuation of impacts that all businesses will 'Stay and Do Nothing.'

Impacts of Do Nothing on Planned Development and Investment

Development Control and Planning Policy in in place to ensure that new development is safe and appropriate with respect to potential flood risk. A Do Nothing Scenario will lead to an unmitigated increase in tidal flood risk which will become increasingly significant over time. As such this scenario would inhibit planned development within the flood plain, such as the Temple Quay Enterprise Zone. This would lead to lost opportunities and the added investment benefiting the locally economy would be missed. Therefore in the valuation this lost opportunity it was assumed that the Do Nothing Scenario would lead to none of the planned development and employment being realised, thus representing 'worst case' estimation.

7.5 Headlines from GVA Assessment

The analysis shows that the true potential cost of flooding for the local economy is over £2.75bn (present value) over the next 23 years. Within this figure nearly £830m (PV) can be counted under FCERM-AG as a national economic loss. The remaining £1.9bn is comprised of GVA impacts to the local economy. This total economic loss (£2.75bn PV) relates to total annual loss £171m (in cash terms) over the period.

Just over £52m of this annual cash loss figure comes from first round impacts which can be valued and counted under FCERM-AG. A key component of this valuation comprises annual damage and write off of properties due to increasingly frequent flood events as well as significant infrastructure and transport disruption. Other associated or indirect damages, as described in Chapter 2.7 above, are also included in this sum.

The remaining £121m comes from dynamic impacts (those felt by the local economy but not necessarily on a national level; i.e. the impacts have the potential to be displaced or transferred to another area).

A significant proportion (over 90%) of the dynamic impacts (over £1.75bn pv) stem from the likely lost opportunity (development, employment and investment) which would otherwise bring benefit to the local economy if it were not to be inhibited by the unmitigated tidal flood risk. As a worst case scenario it has been assumed that without flood risk management infrastructure to adequately mitigate flood risk to these developments, the future projected jobs and employment both within the Temple Quay Enterprise Zone and in the Wider City area within the floodplain would not occur.

There would also be significant disruption to commercial activity already currently located within the floodplain, meaning £10m annual cash loss from business discontinuity and loss of earnings. Without flood risk management intervention this total dynamic impact on existing commercial activity within the floodplain could total over £273m pv by 2038).

A summary graphic from the GVA assessment findings is provided in Figure 7-2.

2016 - 2038

Key findings from the GVA assessment
a) First round impacts nearly £505m (PV) in next 23 years.
b) Tidal flood risk unmanaged leading to >£2bn (PV) dynamic impacts (local economic loss) in next 23 years.
c) Unlocked investment exceeding £1.75bn (PV) would not materialise.
d) Impacts on existing business (disconituiy etc.) totalling £273m (pv) over next 23 years)
e) Over 4,000 pipeline jobs would not materialise over the next 10 years.
f) GVA dynamic impacts nearly 4x first round impacts, with total £2.5bn (PV) economic loss over 23 year period.
g) £170m average annual cash damage (first round + dynamic impacts) over the period under Do Nothing.

	Estimated undiscounted annual average (cash £k)	**Estimated 23-year GVA impact (£k PV)**	**Qualitative assessment**
First Round impacts	**29,439**	**504,735**	Significant write off of commercial and residential properties likely due to very high levels of flood risk. Regular and frequent flooding of key enterprise and commercial zones, including financial hub Significant tourism loss due to flooding of key assets and Floating Harbour area. Large areas become unihabitable due to flood risk. Critical Infrastrcuture significantly damage, disrupted or lost.
Dynamic impacts	**110,353**	**2,030,067**	Area blighted by unmanaged, very significant flood risk. New development currently in the pipeline does not proceed due to level of flood risk. Much of the commercial sector around the Floating Harbour becomes unviable and future pipeline jobs are not created. Wider spillover impacts on regional economy also likely.

Limitations
Estimates based on a Do Nothing Scenario.
Estimates based on Defra GVA toolkit 2014 methodologies.
Estimates of dynamic impacts beyond 2025 extropolated from data and employment targets up to 2025.
Assumptions that all businesses 'Stay and Do Nothing' and are unable to operate for 20 weeks following a flood with no FRM in place.
Figures based on statistics for Bristol (e.g. average salaries, sector distribution, business sizes etc).

Figure 7-2. Summary of GVA Assessment – Do Nothing Scenario

7.6 Likely GVA benefits of preferred option

The recommended preferred option will maximise the opportunity to turn the GVA impacts (damages) estimated for a Do Nothing Scenario into benefits. By providing a strategic FRM intervention which delivers a high standard of protection to Bristol, the impacts valued under Do Nothing will almost entirely be claimed as a benefit through significantly improved protection against tidal flooding. Such intervention will also maximise the opportunity to unlock investment through enabling and supporting potential development and regeneration within the current floodplain, also reducing site specific flood risk measures.

The GVA assessment also identifies significant potential spill over impacts for the regional economy, and improve strategic defence could also enhance the potential for additional development over that currently planned, or may facilitate different uses e.g. housing. The GVA assessment demonstrates significant local value (beyond simply traditional FCERM valuation of benefits) of the proposed FRM intervention, and this provides a more comprehensive evidence base and greater justification to seek partner funding from the potential beneficiaries thus helping to enable the schemes required.

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APPENDIX 1 – FCERM-AG CALCULATION SHEETS

Do Nothing flood damages:

Damage Cost Calculation Sheet - Do Nothing (Linear)

Sheet Nr.

Client/Authority: Bristol City Council
Project name: River Avon TFRMS
Option: Do Nothing
Project reference: 60478613
Base date for estimates (year 0): 2015
Scaling factor (e.g. £m, £k, £): £k
Initial discount rate: 3.5% | 3.0% | 2.5%

Prepared (date): 03/05/2016
Printed: 05/07/2016
Prepared by: NC
Checked by: 00/01/1900
Checked date: 00/01/1900

PV breach/failure: £k
Ave Annual Damage (overtopping) - yr 0: £k N/A /yr
PV Total Damage: £k 1,676,225 (calculated below)

Year	0	15	50	99
Breach pb	0.100	1.000	1.000	1.000

Year	Discount factor	Prob of a breach / failure	Prob that breach / failure: occurs in year	Prob that breach / failure: has not occurred	Breach	Resi PV Damage	Comm PV Damage	Other damages Risk to life & intangible / indirect	Write off & Capping Residential	Write off & Capping Commercial	PV total damage
0	1.000	1.000	1.000	0.000	0.00	6939.9	23024.4	1321.0	122286.3	89410	242961.7
1	0.966	1.000	1.000	0.000	0.00	6796.9	22557.2	1293.3	0.0	0	30647.3
2	0.934	1.000	1.000	0.000	0.00	6655.6	22095.2	1265.9	0.0	0	30016.7
3	0.902	1.000	1.000	0.000	0.00	6516.1	21638.7	1238.9	0.0	0	29393.7
4	0.871	1.000	1.000	0.000	0.00	6378.4	21187.8	1212.2	0.0	0	28778.5
5	0.842	1.000	1.000	0.000	0.00	6242.6	20742.7	1186.0	0.0	0	28171.3
6	0.814	1.000	1.000	0.000	0.00	6108.7	20303.4	1160.1	0.0	0	27572.2
7	0.786	1.000	1.000	0.000	0.00	5976.7	19870.1	1134.6	0.0	0	26981.5
8	0.759	1.000	1.000	0.000	0.00	5846.7	19442.9	1109.6	0.0	0	26399.2
9	0.734	1.000	1.000	0.000	0.00	5718.6	19021.9	1084.9	0.0	0	25825.4
10	0.709	1.000	1.000	0.000	0.00	5592.5	18607.1	1060.6	0.0	0	25260.2
11	0.685	1.000	1.000	0.000	0.00	5468.3	18198.6	1036.7	0.0	0	24703.7
12	0.662	1.000	1.000	0.000	0.00	5346.2	17796.5	1013.2	0.0	0	24156.0
13	0.639	1.000	1.000	0.000	0.00	5226.1	17400.8	990.2	0.0	0	23617.0
14	0.618	1.000	1.000	0.000	0.00	5108.0	17011.4	967.5	0.0	0	23086.9
15	0.597	1.000	1.000	0.000	0.00	4991.9	16628.5	945.2	26998.6	8015.345672	57579.6
16	0.577	1.000	1.000	0.000	0.00	4887.3	16322.7	922.4	0.0	0	22132.4
17	0.557	1.000	1.000	0.000	0.00	4764.2	16018.5	900.0	0.0	0	21702.7
18	0.538	1.000	1.000	0.000	0.00	4682.4	15716.3	878.1	0.0	0	21276.7
19	0.520	1.000	1.000	0.000	0.00	4582.0	15416.1	856.6	0.0	0	20854.7
20	0.503	1.000	1.000	0.000	0.00	4483.1	15118.3	835.6	0.0	0	20436.9
21	0.486	1.000	1.000	0.000	0.00	4385.6	14823.0	815.0	0.0	0	20023.6
22	0.469	1.000	1.000	0.000	0.00	4289.5	14530.4	794.9	0.0	0	19614.8
23	0.453	1.000	1.000	0.000	0.00	4196.0	14240.6	775.1	0.0	0	19210.7
24	0.438	1.000	1.000	0.000	0.00	4101.9	13953.8	755.9	0.0	0	18811.6
25	0.423	1.000	1.000	0.000	0.00	4010.4	13670.1	737.0	0.0	0	18417.5
26	0.409	1.000	1.000	0.000	0.00	3920.3	13389.7	718.5	0.0	0	18028.5
27	0.395	1.000	1.000	0.000	0.00	3831.8	13112.6	700.5	0.0	0	17644.8
28	0.382	1.000	1.000	0.000	0.00	3744.7	12838.9	682.8	0.0	0	17266.4
29	0.369	1.000	1.000	0.000	0.00	3659.2	12568.7	665.5	0.0	0	16893.4
30	0.356	1.000	1.000	0.000	0.00	3575.1	12302.1	648.7	0.0	0	16525.9
31	0.346	1.000	1.000	0.000	0.00	3509.5	12097.7	635.2	0.0	0	16242.4
32	0.336	1.000	1.000	0.000	0.00	3444.7	11894.7	622.1	0.0	0	15961.5
33	0.326	1.000	1.000	0.000	0.00	3380.7	11693.2	609.1	0.0	0	15683.0
34	0.317	1.000	1.000	0.000	0.00	3317.5	11493.4	596.4	0.0	0	15407.3
35	0.307	1.000	1.000	0.000	0.00	3256.2	11295.3	583.8	0.0	0	15134.3
36	0.298	1.000	1.000	0.000	0.00	3193.6	11099.0	571.6	0.0	0	14864.2
37	0.290	1.000	1.000	0.000	0.00	3132.9	10904.6	559.5	0.0	0	14597.0
38	0.281	1.000	1.000	0.000	0.00	3073.0	10712.1	547.6	0.0	0	14332.7
39	0.273	1.000	1.000	0.000	0.00	3013.9	10521.5	536.0	0.0	0	14071.4
40	0.265	1.000	1.000	0.000	0.00	2955.6	10333.0	524.6	0.0	0	13813.2
41	0.257	1.000	1.000	0.000	0.00	2898.2	10146.5	513.4	0.0	0	13558.1
42	0.250	1.000	1.000	0.000	0.00	2841.7	9962.1	502.4	0.0	0	13306.1
43	0.243	1.000	1.000	0.000	0.00	2786.9	9779.8	491.6	0.0	0	13057.3
44	0.236	1.000	1.000	0.000	0.00	2731.0	9599.7	481.0	0.0	0	12811.7
45	0.229	1.000	1.000	0.000	0.00	2677.0	9421.8	470.6	0.0	0	12569.4
46	0.222	1.000	1.000	0.000	0.00	2623.7	9246.1	460.4	0.0	0	12330.3
47	0.216	1.000	1.000	0.000	0.00	2571.3	9072.7	450.4	0.0	0	12094.4
48	0.209	1.000	1.000	0.000	0.00	2519.8	8901.5	440.6	0.0	0	11861.8
49	0.203	1.000	1.000	0.000	0.00	2469.0	8732.6	431.0	0.0	0	11632.6
50	0.197	1.000	1.000	0.000	0.00	2419.1	8566.0	421.5	21704.6	5354.696472	38465.8
51	0.192	1.000	1.000	0.000	0.00	2379.1	8456.1	415.3	0.0	0	11250.5
52	0.186	1.000	1.000	0.000	0.00	2339.5	8345.3	409.0	0.0	0	11093.7
53	0.181	1.000	1.000	0.000	0.00	2300.1	8233.8	402.8	0.0	0	10936.6
54	0.175	1.000	1.000	0.000	0.00	2261.0	8121.7	396.6	0.0	0	10779.2

Cash AAD Damages for Interpolation

Yr	Res AAD	Com AAD	Res WO/Cap	Com WO/Cap	Loss of Life	Other
0	6940	23024	122286	89410	13	1308
15	8363	27859	45232	13429	13	1571
50	12263	43424	110029	27145	46	2091
99	20067	79134	207510	211618	551	3128

Yr	res £k	com £k	WO/CAP res	WO/CAP com	Other
0	6940	23024	122286	89410	13	1308
1	7035	23347			13	1326
2	7130	23669			13	1343
3	7225	23991			13	1361
4	7319	24314			13	1378
5	7414	24636			13	1396
6	7509	24958			13	1413
7	7604	25280			13	1431
8	7699	25603			13	1448
9	7794	25925			13	1466
10	7889	26247			13	1483
11	7984	26569			13	1501
12	8079	26892			13	1518
13	8173	27214			13	1536
14	8268	27536			13	1553
15	8363	27859	45232	13429	13	1571
16	8475	28303			14	1586
17	8586	28748			15	1601
18	8697	29193			16	1615
19	8809	29638			17	1630
20	8920	30082			17	1645
21	9032	30527			18	1660
22	9143	30972			19	1675
23	9255	31416			20	1690
24	9366	31861			21	1705
25	9477	32306			22	1720
26	9589	32751			23	1734
27	9700	33195			24	1749
28	9812	33640			25	1764
29	9923	34085			26	1779
30	10035	34530			27	1794
31	10146	34974			28	1809
32	10258	35419			29	1824
33	10369	35864			30	1838
34	10480	36309			31	1853
35	10592	36753			32	1868
36	10703	37198			32	1883
37	10815	37643			33	1898
38	10926	38087			34	1913
39	11038	38532			35	1928
40	11149	38977			36	1943
41	11260	39422			37	1957
42	11372	39866			38	1972
43	11483	40311			39	1987
44	11595	40756			40	2002
45	11706	41201			41	2017
46	11818	41645			42	2032
47	11929	42090			43	2047
48	12040	42535			44	2061
49	12152	42979			45	2076
50	12263	43424	110029	27145	46	2091
51	12423	44153			56	2112
52	12582	44882			66	2134
53	12741	45611			77	2155
54	12900	46339			87	2176

Year	Discount factor	Prob of a breach / failure	Prob that breach / failure: occurs in year	Prob that breach / failure: has not occurred	Breach	Resi PV Damage	Comm PV Damage	Other damages Risk to life & intangible / indirect	Write off & Capping Residential	Write off & Capping Commercial	PV total damage	
55	0.170	1.000	1.000	0.000	0.00	2222.2	8009.1	390.4	0.0	0	10621.7	
56	0.165	1.000	1.000	0.000	0.00	2183.8	7896.2	384.2	0.0	0	10464.3	
57	0.160	1.000	1.000	0.000	0.00	2145.8	7783.1	378.1	0.0	0	10307.0	
58	0.156	1.000	1.000	0.000	0.00	2108.1	7669.9	371.9	0.0	0	10149.9	
59	0.151	1.000	1.000	0.000	0.00	2070.7	7556.7	365.9	0.0	0	9993.3	1361402.5
60	0.147	1.000	1.000	0.000	0.00	2033.8	7443.6	359.8	0.0	0	9837.2	
61	0.143	1.000	1.000	0.000	0.00	1997.3	7330.6	353.8	0.0	0	9681.7	
62	0.138	1.000	1.000	0.000	0.00	1961.1	7218.0	347.9	0.0	0	9527.0	
63	0.134	1.000	1.000	0.000	0.00	1925.4	7105.6	342.0	0.0	0	9373.0	
64	0.130	1.000	1.000	0.000	0.00	1890.1	6993.7	336.1	0.0	0	9219.9	
65	0.127	1.000	1.000	0.000	0.00	1855.2	6882.3	330.3	0.0	0	9067.8	
66	0.123	1.000	1.000	0.000	0.00	1820.8	6771.4	324.6	0.0	0	8916.7	
67	0.119	1.000	1.000	0.000	0.00	1786.7	6661.1	318.9	0.0	0	8766.7	
68	0.116	1.000	1.000	0.000	0.00	1753.1	6551.6	313.2	0.0	0	8617.9	
69	0.112	1.000	1.000	0.000	0.00	1720.0	6442.7	307.6	0.0	0	8470.4	
70	0.109	1.000	1.000	0.000	0.00	1687.3	6334.7	302.1	0.0	0	8324.1	
71	0.106	1.000	1.000	0.000	0.00	1655.0	6227.4	296.7	0.0	0	8179.1	
72	0.103	1.000	1.000	0.000	0.00	1623.2	6121.1	291.3	0.0	0	8035.6	
73	0.100	1.000	1.000	0.000	0.00	1591.9	6015.6	285.9	0.0	0	7893.4	
74	0.097	1.000	1.000	0.000	0.00	1561.0	5911.2	280.6	0.0	0	7752.8	
75	0.094	1.000	1.000	0.000	0.00	1530.5	5807.6	275.4	0.0	0	7613.6	
76	0.092	1.000	1.000	0.000	0.00	1507.8	5733.0	271.6	0.0	0	7512.4	
77	0.090	1.000	1.000	0.000	0.00	1485.3	5658.5	267.8	0.0	0	7411.6	
78	0.087	1.000	1.000	0.000	0.00	1463.0	5584.2	264.0	0.0	0	7311.3	
79	0.085	1.000	1.000	0.000	0.00	1440.9	5510.2	260.3	0.0	0	7211.5	
80	0.083	1.000	1.000	0.000	0.00	1419.1	5436.5	256.5	0.0	0	7112.1	
81	0.081	1.000	1.000	0.000	0.00	1397.4	5363.1	252.8	0.0	0	7013.4	
82	0.079	1.000	1.000	0.000	0.00	1375.9	5290.1	249.2	0.0	0	6915.2	
83	0.077	1.000	1.000	0.000	0.00	1354.7	5217.4	245.5	0.0	0	6817.6	
84	0.075	1.000	1.000	0.000	0.00	1333.7	5145.1	241.9	0.0	0	6720.7	
85	0.074	1.000	1.000	0.000	0.00	1312.9	5073.3	238.3	0.0	0	6624.5	
86	0.072	1.000	1.000	0.000	0.00	1292.3	5001.9	234.8	0.0	0	6528.9	
87	0.070	1.000	1.000	0.000	0.00	1271.9	4930.9	231.3	0.0	0	6434.1	
88	0.068	1.000	1.000	0.000	0.00	1251.8	4860.5	227.8	0.0	0	6340.0	
89	0.067	1.000	1.000	0.000	0.00	1231.9	4790.5	224.3	0.0	0	6246.7	
90	0.065	1.000	1.000	0.000	0.00	1212.2	4721.1	220.9	0.0	0	6154.1	
91	0.063	1.000	1.000	0.000	0.00	1192.7	4652.2	217.5	0.0	0	6062.4	
92	0.062	1.000	1.000	0.000	0.00	1173.5	4583.8	214.1	0.0	0	5971.5	
93	0.060	1.000	1.000	0.000	0.00	1154.5	4516.1	210.8	0.0	0	5881.4	
94	0.059	1.000	1.000	0.000	0.00	1135.7	4448.9	207.5	0.0	0	5792.1	
95	0.057	1.000	1.000	0.000	0.00	1117.2	4382.3	204.3	0.0	0	5703.7	
96	0.056	1.000	1.000	0.000	0.00	1098.9	4316.2	201.1	0.0	0	5616.2	
97	0.055	1.000	1.000	0.000	0.00	1080.8	4250.9	197.9	0.0	0	5529.5	
98	0.053	1.000	1.000	0.000	0.00	1062.9	4186.1	194.7	0.0	0	5443.7	
99	0.052	1.000	1.000	0.000	0.00	1045.3	4121.9	191.6	10808.9	11022.83241	27190.6	
Total					0.00	295673.9	1030687.6	54251.8	181798.4	113802.8746	1676224.57	

Notes

Complete one spreadsheet for the 'do nothing' option
The formulae assume that breach probability will be constant to the first year entered and after the last year with linear variation between
It is assumed that breaches are not repaired and that once breach damage has occurred it will not recur.
A separate check should be made to ensure that overtopping damages do not exceed write off values.
These damage calculations assume that overtopping damage can reasonably be ignored once a breach has occurred.
If these assumptions are not valid then appropriate adjustments need to be made. In this case the total damage is calculated as:
PV damage in year=disc factor*((prob no breach damage in year*annual overtop damage)+(prob breach damage in year*breach damage))

Yr	res £k	com £k	WO/CAP res	WO/CAP com	Other	
55	13060	47068			97	2197
56	13219	47797			107	2218
57	13378	48526			118	2239
58	13537	49254			128	2260
59	13697	49983			138	2282
60	13856	50712			149	2303
61	14015	51441			159	2324
62	14175	52169			169	2345
63	14334	52898			180	2366
64	14493	53627			190	2387
65	14652	54356			200	2408
66	14812	55084			211	2430
67	14971	55813			221	2451
68	15130	56542			231	2472
69	15289	57271			242	2493
70	15449	57999			252	2514
71	15608	58728			262	2535
72	15767	59457			273	2557
73	15926	60186			283	2578
74	16086	60915			293	2599
75	16245	61643			303	2620
76	16404	62372			314	2641
77	16564	63101			324	2662
78	16723	63830			334	2683
79	16882	64558			345	2705
80	17041	65287			355	2726
81	17201	66016			365	2747
82	17360	66745			376	2768
83	17519	67473			386	2789
84	17678	68202			396	2810
85	17838	68931			407	2831
86	17997	69660			417	2853
87	18156	70388			427	2874
88	18316	71117			438	2895
89	18475	71846			448	2916
90	18634	72575			458	2937
91	18793	73303			469	2958
92	18953	74032			479	2980
93	19112	74761			489	3001
94	19271	75490			499	3022
95	19430	76219			510	3043
96	19590	76947			520	3064
97	19749	77676			530	3085
98	19908	78405			541	3106
99	20067	79134	207510	211618	551	3128

Do Minimum flood damages:

Damage Cost Calculation Sheet - Do Minimum (Linear)

Sheet Nr.

Client/Authority: Bristol City Council
Project name: River Avon TFRMS
Project reference: 60478613
Base date for estimates (year 0): 2015
Scaling factor (e.g. £m, £k, £): £k
Initial discount rate: 3.5% 3.0% 2.5%
Option: Do Nothing

Prepared (date): 03/05/2016
Printed: 05/07/2016
Prepared by: NC
Checked by: 00/01/1900
Checked date: 00/01/1900

	<			>
Year	0	15	50	99
Breach pb	0.100	1.000	1.000	1.000

PV breach/failure £k
Ave Annual Damage
(overtopping) - yr 0 £k N/A /yr
PV Total Damage £k 342,016 (calculated below)

Year	Discount factor	Prob of a breach / failure	Prob that breach / failure: occurs in year	Prob that breach / failure: has not occurred	Breach	Reel PV Damage	Comm PV Damage	Other damages Risk to life & intangible / indirect	Write off & Capping Residential	Write off & Capping Commercial	PV total damage
0	1.000	1.000	1.000	0.000	0.00	1047.6	4039.7	268.4	14563.0	697	20615.8
1	0.966	1.000	1.000	0.000	0.00	1019.0	3992.1	265.2	0.0	0	5276.3
2	0.934	1.000	1.000	0.000	0.00	991.1	3943.0	262.0	0.0	0	5196.1
3	0.902	1.000	1.000	0.000	0.00	964.0	3892.7	258.6	0.0	0	5115.3
4	0.871	1.000	1.000	0.000	0.00	937.5	3841.3	255.2	0.0	0	5034.0
5	0.842	1.000	1.000	0.000	0.00	911.8	3788.9	251.7	0.0	0	4952.4
6	0.814	1.000	1.000	0.000	0.00	886.7	3735.7	248.2	0.0	0	4870.5
7	0.786	1.000	1.000	0.000	0.00	862.2	3681.7	244.6	0.0	0	4788.5
8	0.759	1.000	1.000	0.000	0.00	838.4	3627.1	240.9	0.0	0	4706.5
9	0.734	1.000	1.000	0.000	0.00	815.2	3572.0	237.3	0.0	0	4624.5
10	0.709	1.000	1.000	0.000	0.00	792.7	3516.5	233.6	0.0	0	4542.7
11	0.685	1.000	1.000	0.000	0.00	770.7	3460.6	229.8	0.0	0	4461.2
12	0.662	1.000	1.000	0.000	0.00	749.3	3404.5	226.1	0.0	0	4379.9
13	0.639	1.000	1.000	0.000	0.00	728.5	3348.3	222.4	0.0	0	4299.1
14	0.618	1.000	1.000	0.000	0.00	708.2	3291.9	218.6	0.0	0	4218.7
15	0.597	1.000	1.000	0.000	0.00	688.4	3235.6	214.9	661.6	4095.27	8895.7
16	0.577	1.000	1.000	0.000	0.00	674.1	3222.2	210.7	0.0	0	4107.0
17	0.557	1.000	1.000	0.000	0.00	659.9	3206.1	206.6	0.0	0	4072.6
18	0.538	1.000	1.000	0.000	0.00	645.9	3187.3	202.6	0.0	0	4035.9
19	0.520	1.000	1.000	0.000	0.00	632.1	3166.2	198.6	0.0	0	3996.9
20	0.503	1.000	1.000	0.000	0.00	618.5	3142.9	194.6	0.0	0	3956.0
21	0.486	1.000	1.000	0.000	0.00	605.1	3117.5	190.7	0.0	0	3913.2
22	0.469	1.000	1.000	0.000	0.00	591.9	3090.2	186.8	0.0	0	3868.9
23	0.453	1.000	1.000	0.000	0.00	578.9	3061.2	182.9	0.0	0	3823.0
24	0.438	1.000	1.000	0.000	0.00	566.1	3030.7	179.1	0.0	0	3775.9
25	0.423	1.000	1.000	0.000	0.00	553.5	2998.7	175.4	0.0	0	3727.5
26	0.409	1.000	1.000	0.000	0.00	541.1	2965.4	171.7	0.0	0	3678.1
27	0.395	1.000	1.000	0.000	0.00	528.9	2930.9	168.0	0.0	0	3627.8
28	0.382	1.000	1.000	0.000	0.00	516.9	2895.4	164.4	0.0	0	3576.7
29	0.369	1.000	1.000	0.000	0.00	505.1	2858.9	160.9	0.0	0	3524.9
30	0.356	1.000	1.000	0.000	0.00	493.6	2821.6	157.4	0.0	0	3472.5
31	0.345	1.000	1.000	0.000	0.00	484.5	2797.0	154.7	0.0	0	3436.2
32	0.336	1.000	1.000	0.000	0.00	475.6	2771.5	152.0	0.0	0	3399.1
33	0.326	1.000	1.000	0.000	0.00	466.8	2745.1	149.3	0.0	0	3361.2
34	0.317	1.000	1.000	0.000	0.00	458.1	2717.9	146.7	0.0	0	3322.7
35	0.307	1.000	1.000	0.000	0.00	449.5	2689.9	144.1	0.0	0	3283.5
36	0.298	1.000	1.000	0.000	0.00	441.0	2661.3	141.5	0.0	0	3243.9
37	0.290	1.000	1.000	0.000	0.00	432.7	2632.0	139.0	0.0	0	3203.7
38	0.281	1.000	1.000	0.000	0.00	424.4	2602.2	136.5	0.0	0	3163.1
39	0.273	1.000	1.000	0.000	0.00	416.3	2571.9	134.0	0.0	0	3122.2
40	0.265	1.000	1.000	0.000	0.00	408.3	2541.2	131.5	0.0	0	3081.0
41	0.257	1.000	1.000	0.000	0.00	400.4	2510.0	129.1	0.0	0	3039.5
42	0.250	1.000	1.000	0.000	0.00	392.6	2478.5	126.7	0.0	0	2997.8
43	0.243	1.000	1.000	0.000	0.00	384.9	2446.8	124.3	0.0	0	2956.0
44	0.236	1.000	1.000	0.000	0.00	377.3	2414.7	122.0	0.0	0	2914.1
45	0.229	1.000	1.000	0.000	0.00	369.9	2382.5	119.7	0.0	0	2872.1
46	0.222	1.000	1.000	0.000	0.00	362.5	2350.1	117.4	0.0	0	2830.0
47	0.216	1.000	1.000	0.000	0.00	355.3	2317.6	115.2	0.0	0	2788.0
48	0.209	1.000	1.000	0.000	0.00	348.2	2284.9	113.0	0.0	0	2746.1
49	0.203	1.000	1.000	0.000	0.00	341.2	2252.2	110.8	0.0	0	2704.2
50	0.197	1.000	1.000	0.000	0.00	334.3	2219.5	108.6	2257.1	6470.02	11389.5
51	0.192	1.000	1.000	0.000	0.00	340.6	2213.4	110.7	0.0	0	2664.6
52	0.186	1.000	1.000	0.000	0.00	346.3	2205.7	112.5	0.0	0	2664.5
53	0.181	1.000	1.000	0.000	0.00	351.4	2196.6	114.1	0.0	0	2662.1
54	0.175	1.000	1.000	0.000	0.00	355.8	2186.2	115.6	0.0	0	2657.6

Cash AAD Damages for Interpolation

Yr	Res AAD	Com AAD	Res WO/Cap	Com WO/Cap	Loss of Life	Other
0	1048	4040	14563	697	13	256
15	1153	5421	1108	6861	13	347
50	1695	11251	11442	32799	46	505
99	5806	26221	23784	129884	551	1331

Yr	res £k	com £k	WO/CAP res	WO/CAP com	Other
0	1048	4040	14563	697	13	256
1	1055	4132			13	262
2	1062	4224			13	268
3	1069	4316			13	274
4	1076	4408			13	280
5	1083	4500			13	286
6	1090	4592			13	292
7	1097	4684			13	298
8	1104	4776			13	304
9	1111	4868			13	311
10	1118	4960			13	317
11	1125	5052			13	323
12	1132	5144			13	329
13	1139	5237			13	335
14	1146	5329			13	341
15	1153	5421	1108	6861	13	347
16	1169	5587			14	352
17	1184	5754			15	356
18	1200	5920			16	361
19	1215	6087			17	365
20	1231	6254			17	370
21	1246	6420			18	374
22	1262	6587			19	379
23	1277	6753			20	383
24	1293	6920			21	388
25	1308	7087			22	392
26	1324	7253			23	397
27	1339	7420			24	401
28	1354	7586			25	406
29	1370	7753			26	410
30	1385	7920			27	415
31	1401	8086			28	419
32	1416	8253			29	424
33	1432	8419			30	428
34	1447	8586			31	433
35	1463	8753			32	437
36	1478	8919			32	442
37	1494	9086			33	446
38	1509	9252			34	451
39	1525	9419			35	455
40	1540	9585			36	460
41	1555	9752			37	464
42	1571	9919			38	469
43	1586	10085			39	473
44	1602	10252			40	478
45	1617	10418			41	482
46	1633	10585			42	487
47	1648	10752			43	492
48	1664	10918			44	496
49	1679	11085			45	501
50	1695	11251	11442	32799	46	505
51	1779	11557			56	522
52	1863	11862			66	539
53	1946	12168			77	556
54	2030	12473			87	572

Year	Discount factor	Prob of a breach / failure	Prob that breach / failure: occurs in year	Prob that breach / failure: has not occurred	Breach	Resi PV Damage	Comm PV Damage	Other damages Risk to life & intangible / indirect	Write off & Capping Residential	Write off & Capping Commercial	PV total damage	
55	0.170	1.000	1.000	0.000	0.00	359.8	2174.5	116.8	0.0	0	2651.0	
56	0.165	1.000	1.000	0.000	0.00	363.1	2161.6	117.9	0.0	0	2642.7	
57	0.160	1.000	1.000	0.000	0.00	366.0	2147.7	118.8	0.0	0	2632.5	
58	0.156	1.000	1.000	0.000	0.00	368.4	2132.7	119.6	0.0	0	2620.7	
59	0.151	1.000	1.000	0.000	0.00	370.4	2116.7	120.2	0.0	0	2607.3	246791.3
60	0.147	1.000	1.000	0.000	0.00	371.9	2099.9	120.7	0.0	0	2592.6	
61	0.143	1.000	1.000	0.000	0.00	373.0	2082.3	121.0	0.0	0	2576.4	
62	0.138	1.000	1.000	0.000	0.00	373.8	2063.9	121.3	0.0	0	2559.0	
63	0.134	1.000	1.000	0.000	0.00	374.2	2044.9	121.4	0.0	0	2540.4	
64	0.130	1.000	1.000	0.000	0.00	374.2	2025.1	121.4	0.0	0	2520.8	
65	0.127	1.000	1.000	0.000	0.00	373.9	2004.8	121.3	0.0	0	2500.1	
66	0.123	1.000	1.000	0.000	0.00	373.4	1984.0	121.1	0.0	0	2478.5	
67	0.119	1.000	1.000	0.000	0.00	372.5	1962.7	120.8	0.0	0	2456.0	
68	0.116	1.000	1.000	0.000	0.00	371.4	1940.9	120.5	0.0	0	2432.7	
69	0.112	1.000	1.000	0.000	0.00	370.0	1918.7	120.0	0.0	0	2408.8	
70	0.109	1.000	1.000	0.000	0.00	368.4	1896.2	119.5	0.0	0	2384.1	
71	0.106	1.000	1.000	0.000	0.00	366.6	1873.4	118.9	0.0	0	2358.8	
72	0.103	1.000	1.000	0.000	0.00	364.5	1850.3	118.2	0.0	0	2333.0	
73	0.100	1.000	1.000	0.000	0.00	362.3	1826.9	117.5	0.0	0	2306.7	
74	0.097	1.000	1.000	0.000	0.00	359.9	1803.4	116.7	0.0	0	2279.9	
75	0.094	1.000	1.000	0.000	0.00	357.3	1779.6	115.9	0.0	0	2252.8	
76	0.092	1.000	1.000	0.000	0.00	356.3	1764.3	115.5	0.0	0	2236.1	
77	0.090	1.000	1.000	0.000	0.00	355.1	1748.7	115.1	0.0	0	2218.9	
78	0.087	1.000	1.000	0.000	0.00	353.8	1732.7	114.7	0.0	0	2201.3	
79	0.085	1.000	1.000	0.000	0.00	352.4	1716.6	114.2	0.0	0	2183.1	
80	0.083	1.000	1.000	0.000	0.00	350.7	1700.1	113.7	0.0	0	2164.6	
81	0.081	1.000	1.000	0.000	0.00	349.0	1683.5	113.1	0.0	0	2145.6	
82	0.079	1.000	1.000	0.000	0.00	347.1	1666.6	112.5	0.0	0	2126.3	
83	0.077	1.000	1.000	0.000	0.00	345.2	1649.6	111.9	0.0	0	2106.7	
84	0.075	1.000	1.000	0.000	0.00	343.1	1632.4	111.2	0.0	0	2086.7	
85	0.074	1.000	1.000	0.000	0.00	340.9	1615.1	110.5	0.0	0	2066.5	
86	0.072	1.000	1.000	0.000	0.00	338.6	1597.6	109.8	0.0	0	2046.0	
87	0.070	1.000	1.000	0.000	0.00	336.2	1580.1	109.0	0.0	0	2025.3	
88	0.068	1.000	1.000	0.000	0.00	333.8	1562.4	108.2	0.0	0	2004.3	
89	0.067	1.000	1.000	0.000	0.00	331.2	1544.7	107.4	0.0	0	1983.2	
90	0.065	1.000	1.000	0.000	0.00	328.6	1526.9	106.5	0.0	0	1962.0	
91	0.063	1.000	1.000	0.000	0.00	325.9	1509.0	105.6	0.0	0	1940.5	
92	0.062	1.000	1.000	0.000	0.00	323.1	1491.1	104.7	0.0	0	1919.0	
93	0.060	1.000	1.000	0.000	0.00	320.3	1473.2	103.8	0.0	0	1897.4	
94	0.059	1.000	1.000	0.000	0.00	317.5	1455.3	102.9	0.0	0	1875.6	
95	0.057	1.000	1.000	0.000	0.00	314.5	1437.4	101.9	0.0	0	1853.8	
96	0.056	1.000	1.000	0.000	0.00	311.6	1419.4	101.0	0.0	0	1832.0	
97	0.055	1.000	1.000	0.000	0.00	308.6	1401.5	100.0	0.0	0	1810.1	
98	0.053	1.000	1.000	0.000	0.00	305.5	1383.7	99.0	0.0	0	1788.2	
99	0.052	1.000	1.000	0.000	0.00	302.5	1365.8	98.0	1238.9	6765.43	9770.6	
Total					0.00	47667.6	242803.5	14796.5	18720.5	18027.71958	342015.86	

Notes

Complete one spreadsheet for the 'do nothing' option
The formulae assume that breach probability will be constant to the first year entered and after the last year with linear variation between
It is assumed that breaches are not repaired and that once breach damage has occurred it will not recur.
A separate check should be made to ensure that overtopping damages do not exceed write off values.
These damage calculations assume that overtopping damage can reasonably be ignored once a breach has occurred.
If these assumptions are not valid then appropriate adjustments need to be made. In this case the total damage is calculated as:
PV damage in year=disc factor*((prob no breach damage in year*annual overtop damage)+(prob breach damage in year*breach damage))

Yr	res £k	com £k	WO/CAP res	WO/CAP com	Other	
55	2114	12779			97	589
56	2198	13084			107	606
57	2282	13390			118	623
58	2366	13695			128	640
59	2450	14001			138	657
60	2534	14307			149	674
61	2618	14612			159	690
62	2702	14918			169	707
63	2786	15223			180	724
64	2869	15529			190	741
65	2953	15834			200	758
66	3037	16140			211	775
67	3121	16445			221	791
68	3205	16751			231	808
69	3289	17056			242	825
70	3373	17362			252	842
71	3457	17667			262	859
72	3541	17973			273	876
73	3625	18278			283	893
74	3709	18584			293	909
75	3793	18889			303	926
76	3876	19195			314	943
77	3960	19500			324	960
78	4044	19806			334	977
79	4128	20111			345	994
80	4212	20417			355	1010
81	4296	20722			365	1027
82	4380	21028			376	1044
83	4464	21333			386	1061
84	4548	21639			396	1078
85	4632	21944			407	1095
86	4716	22250			417	1112
87	4800	22555			427	1128
88	4883	22861			438	1145
89	4967	23166			448	1162
90	5051	23472			458	1179
91	5135	23777			469	1196
92	5219	24083			479	1213
93	5303	24388			489	1229
94	5387	24694			499	1246
95	5471	24999			510	1263
96	5555	25305			520	1280
97	5639	25610			530	1297
98	5723	25916			541	1314
99	5806	26221	23784	129884	551	1331

Summary Sheet:

Project Summary Sheet

Client/Authority				Prepared (date)		03/05/2016
Bristol City Council				Printed		05/07/2016
Project name				Prepared by		NC
River Avon TFRMS				Checked by		
Project reference	60478613			Checked date		
Base date for estimates (year 0)	2015					
Scaling factor (e.g. £m, £k, £)	£k	(used for all costs, losses and benefits)				
Year	0	30	75			
Discount Rate	3.5%	3.00%	2.50%			
Optimism bias adjustment factor	60%					

Costs and benefits of options

Option number	Costs and benefits £k					
	Option 1	Option 2	Option 3	Option 4	Option 5	Option 6
Option name	Do Nothing	Do Minimum				
AEP or SoP (where relevant)						
COSTS:						
PV capital costs						
PV operation and maintenance costs						
PV other						
Optimism bias adjustment	0	0				
PV negative costs (e.g. sales)	0	0				
PV contributions						
Total PV Costs £k excluding contributions	0	0				
Total PV Costs £k taking contributions into account	0	0				
BENEFITS:						
PV monetised flood damages	1,676,225	342,016				
PV monetised flood damages avoided						
PV monetised erosion damages	0	0				
PV monetised erosion damages avoided (protected)						
Total monetised PV damages £k	1,676,225	342,016				
Total monetised PV benefits £k		1,334,209				
PV damages (from scoring and weighting)						
PV damages avoided/benefits (from scoring and weighting)						
PV benefits from ecosystem services						
Total PV damages £k	1,676,225	342,016				
Total PV benefits £k		1,334,209				
DECISION-MAKING CRITERIA:						
excluding contributions						
Based on total PV benefits (includes benefits from scoring and weighting and ecosystem services)						
Net Present Value **NPV**		1,334,209				
Average benefit/cost ratio **BCR**						
Incremental benefit/cost ratio **IBCR**						
Based on monetised PV benefits (excludes benefits from scoring and weighting and ecosystem services)						
Net Present Value **NPV**		1,334,209				
Average benefit/cost ratio **BCR**						
Incremental benefit/cost ratio **IBCR**						
including contributions						
Taking account of contributions (includes benefits from scoring and weighting and ecosystem services)						
Net Present Value **NPV**		1,334,209				
Average benefit/cost ratio **BCR**						
Incremental benefit/cost ratio **IBCR**						
Based on monetised PV benefits (excludes benefits from scoring and weighting and ecosystem services)						
Net Present Value **NPV**		1,334,209				
Average benefit/cost ratio **BCR**						
Incremental benefit/cost ratio **IBCR**						
Best practicable environmental option (WFD)						

Brief description of options:

Option 1	Do Nothing
Option 2	Do Minimum
Option 3	
Option 4	
Option 5	
Option 6	

Comments and assumptions: