APPENDIX A

DAMAGE ASSESSMENT GUIDELINES AND METHODOLOGY

Damage Assessment Guidelines and Methodology

1. Damage Assessment Guidelines

The RPS methodology to damage assessments follows the guidance in “Flood and Coastal Erosion Risk Management: A Manual for Economic Appraisal" (Penning-Rowsell, *et al*., 2013). This book is a successor to and replacement of the highly respected manual and handbook “The Benefits of Flood and Coastal Defence: A Manual of Assessment Techniques" (Flood Hazard Research Centre, Middlesex University, UK, 2005). This document was often referred to as the ‘Multi-Coloured Manual’ (MCM).

The new manual draws on collaboration between the Flood Hazard Research Centre, the Environment Agency, Defra and other stakeholders. Its use, accompanied by the MCM-Online, has been recommended for benefit assessment as part of a flood and coastal erosion risk management appraisal.

The MCM is a result of research carried out by Middlesex University Flood Hazard Research Centre and provides data and techniques for assessing the benefits of flood risk management in the form of flood alleviation. The MCM has focused on the benefits that arise from protecting residential property, commercial property, and road disruption amongst other areas as experience has shown that these sectors constitute the vast majority of the potential benefits of capital investment.

Based on this research the MCM provides depth damage data for both residential and commercial properties. For certain depths of flood water, a monetary damage has been assigned to a property. This damage is a combination of the likely items within the building and the building structure itself. The damage to each property is dependent on the property type; as such the MCM has categorised both the residential and commercial properties. An example of depth damage data for residential properties is shown in Figure 7.1. Property damages are available for a number of different flood sources, including fluvial, coastal surge and wave overtopping. The appropriate datasets are sourced for the applicable flood mechanism/s which is assessed for the subject area.

	Property-Type	MCM code	Property Type - Age	-0.3	0	0.05	0.1	0.2	0.3	0.6	0.9	1.2	1.5	1.8
4		111	pre-1919 Detached	1,606	1,606	15,018	26,224	43,860	54,476	64,439	71,559	78,045	85,808	94,353
5		112	1919-1944 Detached	1,009	1,009	7,046	11,355	19,934	24,468	29,727	32,245	36,222	40,039	44,545
6		113	1945-1964 Detached	884	884	8,637	13,957	23,791	28,777	34,509	37,624	41,590	45,092	49,433
7	Detached	114	1965-1974 Detached	754	754	7,117	11,402	19,934	24,427	29,758	32,315	36,033	39,049	42,763
8		115	1975-1985 Detached	792	792	7,879	12,541	21,976	27,465	33,745	37,601	41,446	44,805	48,761
9		117	utility Detached	641	641	2,485	3,606	5,154	6,410	7,305	8,599	10,442	12,473	14,903
10		118	post-1985 Detached	792	792	7,775	12,551	22,109	28,208	35,244	39,444	43,942	47,428	51,389
11		121	pre-1919 Semi-Detached	1,481	1,481	6,028	9,251	15,891	19,548	24,299	26,388	29,460	32,176	35,335
12		122	1919-1944 Semi-Detached	1,507	1,507	6,735	10,613	17,474	21,123	25,875	27,950	30,873	33,292	36,273
13		123	1945-1964 Semi-Detached	1,507	1,507	6,679	10,552	17,409	21,055	25,802	27,875	30,797	33,211	36,189
14	Semi-detached	124	1965-1974 Semi-Detached	661	661	5,381	8,745	15,229	18,690	23,313	25,222	28,329	30,994	34,375
15		125	1975-1985 Semi-Detached	629	629	5,110	8,393	14,985	18,734	23,642	25,973	28,750	30,916	33,610
16		127	utility Semi-Detached	643	643	2,434	3,583	5,092	6,385	7,330	8,530	10,030	11,727	13,648
17		128	post-1985 Semi-Detached	629	629	5,056	8,453	15,154	19,373	24,965	27,580	30,933	33,105	35,718
18		131	pre-1919 Terrace	1,419	1,419	6,280	9,419	16,030	19,806	24,776	26,812	29,332	31,660	34,348
19		132	1919-1944 Terrace	1,468	1,468	7,043	11,261	19,328	22,966	27,797	29,843	32,646	34,805	37,541
20		133	1945-1964 Terrace	934	934	4,118	6,068	9,030	10,101	12,482	13,653	15,851	17,094	18,808
21	Terrace	134	1965-1974 Terrace	723	723	5,925	9,636	16,504	20,089	24,778	26,833	29,843	32,149	35,060
22		135	1975-1985 Terrace	543	543	4,767	7,735	13,845	17,108	21,550	23,217	25,495	27,136	29,178
23		137	Utility Terrace	629	629	2,263	3,305	4,570	5,784	6,821	8,087	9,432	11,072	12,945
24		138	post-1985 Terrace	543	543	4,717	7,817	14,051	17,828	23,041	25,021	27,941	29,566	31,497
25		141	pre-1919 Bungalow	1,294	1,294	7,059	10,683	18,700	23,084	28,821	31,712	34,644	37,050	39,763
26		142	1919-1944 Bungalow	940	940	9,637	15,373	24,676	29,520	35,874	39,336	43,425	47,360	52,069
27	Bungalow	143	1945-1964 Bungalow	978	978	9,192	14,374	23,131	27,600	33,595	36,960	41,520	45,822	50,864
28		144	1965-1974 Bungalow	717	717	10,593	17,068	26,749	31,790	38,366	42,240	46,914	51,732	57,416
29		145	1975-1985 Bungalow	898	898	8,959	14,346	23,483	28,725	35,694	39,987	44,044	48,020	52,672
30		148	post 1985 Bungalow	898	898	8,844	14,538	24,117	30,630	39,452	44,548	50,161	54,181	58,656
31		151	pre-1919 Flat	1,294	1,294	5,517	8,512	14,203	17,084	21,490	22,940	24,871	26,231	27,914
32		152	1919-1944 Flat	765	765	8,362	13,632	22,101	26,319	31,905	34,431	37,142	39,560	42,437
33		153	1945-1964 Flat	765	765	4,935	7,668	13,807	16,816	21,006	22,633	24,783	26,140	27,873
34	Flat	154	1965-1974 Flat	543	543	7,232	11,859	19,519	23,411	28,735	30,987	33,642	35,849	38,565
35		155	1975-1985 Flat	543	543	5,468	8,891	15,674	19,303	24,514	26,769	28,973	30,534	32,481
36		157	utility Flat	616	616	2,058	2,987	3,967	5,038	6,096	7,369	8,553	10,145	11,971
37		158	post 1985 Flat	543	543	5,377	8,895	15,752	19,938	26,035	28,647	31,592	33,130	34,943

Figure 7.1 – Example of MCM's Depth Damage Data for Residential Properties

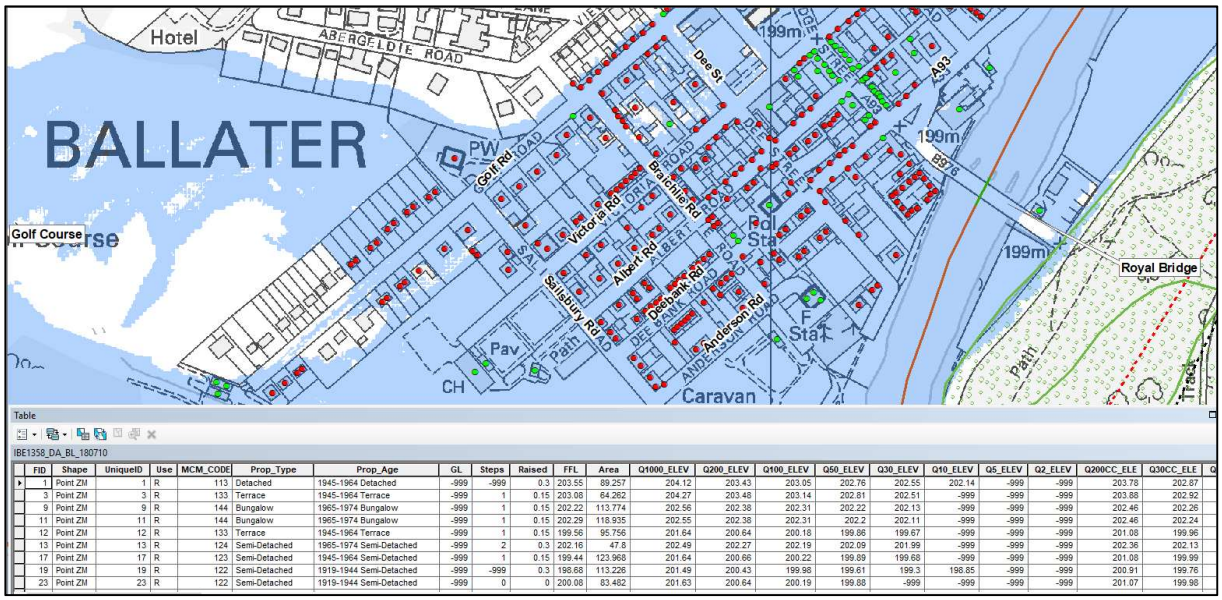
2. Recording Damage Assessment Data

Damage assessments are carried out in order to quantify the economic risk to the study area. This requires many details to be recorded such as background data, interim calculations and final damage results. RPS creates geo-referenced shapefiles with relevant data recorded in their attribute tables, an example of which is shown in Figure 7.2. Each flood mechanism to be assessed requires a building polygon shapefile and a damage assessment point file.

Building polygon shapefiles are created to contain background data for building polygons including building use and area. These commonly originate from datasets provided by the relevant local authority.

Damage assessment point files are created to contain all information needed to complete the damage assessment. Information such as building area, finished floor level (FFL) and water elevations from the modelled flood events are combined into this shapefile to give depths referenced to finished floor level for each flood event. For buildings with multiple water elevation entries, the maximum level of water above FFL is taken. These shapefiles can be used to show economic risk of properties relating to a range of flood events.

The following sections detail how damage assessments are carried out and the data that is recorded during various processes.



FID	Shape	UniqueID	Use	MCM_CODE	Prop_Type	Prop_Age	GL	Steps	Raised	FFL	Area	Q1000_ELEV	Q200_ELEV	Q100_ELEV	Q50_ELEV	Q30_ELEV	Q10_ELEV	Q5_ELEV	Q2_ELEV	Q200CC_ELE	Q30CC_ELE
1	Point ZM	1	R	113	Detached	1945-1964 Detached	-999	-999	0.3	203.55	89.257	204.12	203.43	203.05	202.76	202.55	202.14	-999	-999	203.78	202.87
3	Point ZM	3	R	133	Terrace	1945-1964 Terrace	-999	1	0.15	203.08	64.262	204.27	203.48	203.14	202.81	202.51	-999	-999	-999	203.88	202.92
9	Point ZM	9	R	144	Bungalow	1965-1974 Bungalow	-999	1	0.15	202.22	113.774	202.56	202.38	202.31	202.22	202.13	-999	-999	-999	202.46	202.26
11	Point ZM	11	R	144	Bungalow	1965-1974 Bungalow	-999	1	0.15	202.29	118.935	202.55	202.38	202.31	202.2	202.11	-999	-999	-999	202.46	202.24
12	Point ZM	12	R	133	Terrace	1945-1964 Terrace	-999	1	0.15	199.56	95.756	201.64	200.64	200.18	199.86	199.67	-999	-999	-999	201.08	199.96
13	Point ZM	13	R	124	Semi-Detached	1965-1974 Semi-Detached	-999	2	0.3	202.16	47.8	202.49	202.27	202.19	202.09	201.99	-999	-999	-999	202.36	202.13
17	Point ZM	17	R	123	Semi-Detached	1945-1964 Semi-Detached	-999	1	0.15	199.44	123.968	201.64	200.66	200.22	199.89	199.68	-999	-999	-999	201.08	199.99
19	Point ZM	19	R	122	Semi-Detached	1919-1944 Semi-Detached	-999	-999	0.3	198.68	113.226	201.49	200.43	199.98	199.61	199.3	198.85	-999	-999	200.91	199.76
23	Point ZM	23	R	122	Semi-Detached	1919-1944 Semi-Detached	-999	0	0	200.08	83.482	201.63	200.64	200.19	199.88	-999	-999	-999	-999	201.07	199.98

Figure 7.2 - Ballater Damage Assessment Building Polygon Shapefile with Attributes Showing Damage Assessment Data

3. Categorisation of Properties

All properties within the largest modelled floodplain/s are surveyed and classified according to MCM guidelines. Based on the level of assessment, the following attributes may be recorded for residential properties; property type, age and social class. Social class data is provided in the MCM based on social classes AB, C1, C2 and DE based on England and Wales. As social class data is not collated under the same categories and methodology in Scotland as in England and Wales, these cannot be made comparable. As such, social class is not considered in economic damage assessments in Scotland.

The MCM assigns a code to each property type to aid the damage calculations.

Table 7.1and Table 7.2 detail various residential and non-residential property types.

Table 7.1 - Residential Properties MCM Codes

Property Type	MCM code	Property Type - Age
Detached	111	Pre-1919 Detached
	112	1919-1944 Detached
	113	1945-1964 Detached
	114	1965-1974 Detached
	115	1975-1985 Detached
	117	Utility Detached
	118	Post-1985 Detached
Semi-Detached	121	Pre-1919 Semi-Detached
	122	1919-1944 Semi-Detached
	123	1945-1964 Semi-Detached
	124	1965-1974 Semi-Detached
	125	1975-1985 Semi-Detached
	127	Utility Semi-Detached
	128	Post-1985 Semi-Detached
Terrace	131	Pre-1919 Terrace
	132	1919-1944 Terrace
	133	1945-1964 Terrace
	134	1965-1974 Terrace
	135	1975-1985 Terrace
	137	Utility Terrace
	138	Post-1985 Terrace
Bungalow	141	Pre-1919 Bungalow
	142	1919-1944 Bungalow
	143	1945-1964 Bungalow
	144	1965-1974 Bungalow
	145	1975-1985 Bungalow
	148	Post 1985 Bungalow
Flat	151	Pre-1919 Flat
	152	1919-1944 Flat
	153	1945-1964 Flat
	154	1965-1974 Flat
	155	1975-1985 Flat
	157	Utility Flat
	158	Post 1985 Flat

Table 7.2 - Non-Residential Property MCM Codes

MCM Code	Property type	MCM Code	Property type
	Retail	**N/A**	**Sport**
	Shop/Store	521	Sports Grounds and Playing Fields
	(High Street) Shop	521	Golf Courses
	Superstore/Hypermarket	523	Sports and Leisure centres
	Retail Warehouse	523	Amusement Arcade/Park
	Showroom	525	Football Ground and Stadia
	Kiosk	526	Mooring/Wharf/Marina
	Outdoor market	523	Swimming Pool
	Indoor Market		**Public Buildings**
	Vehicle Services		School/College/University/Nursery
	Vehicle Repair Garage		Surgery/Health Centre
2	Petrol Filling Station		Residential Home
	Car Showroom		Community Centres/Halls
	Plant Hire	**6**	Library
	Retail Services		Fire/Ambulance station
	Hairdressing Salon		Police Station
	Betting Shop		Hospital
	Laundrette		Museum
	Pub/Social club/wine bar		Law court
	Restaurant		Church
	Café/Food Court		**Industry**
	Post Office		Workshop
	Garden Centre		Factory/Works/Mill
	Offices	**8**	Extractive/heavy Industry
	Offices (non-specific)		Sewage treatment works
3	Computer Centres (Hi-Tech)		Laboratory
	Bank	**N/A**	**Miscellaneous**
	Warehouses	910	Car Park
	Warehouse	Not currently available	Public Convenience
	Electrical w/h		Cemetery/Crematorium
4	Ambient goods w/h		Bus Station
	Frozen goods w/h	526	Dock Hereditament
	Land Used for Storage	960	Electricity Hereditament
	Road Haulage		
	Leisure		
	Hotel		
	Boarding House		
	Self-catering Unit		
51	Hostel (including prisons)		
	Bingo hall		
	Theatre/Cinema		
	Beach Hut		

Depth damage data is not provided for garages and sheds in the MCM. Properties classified as garages, sheds, or other buildings which will not incur damage are classified with the MCM code -999, and are screened out prior to the next stage in the assessment.

The following details are recorded for each building within the largest modelled flood extent:

Table 7.3 - Categorisation of Properties Data

Data Type	Attribute Name	Data Details
Property Use	Use	"R" for residential and "C" for commercial
MCM Code	MCM_CODE	As per MCM guidelines
Property Type	Prop_Type	As per MCM guidelines
Floor Area	Area	Floor area of the property

4. Property Threshold Level

The damage assigned to a property relates to the depth of water above floor level. As such the threshold level of all properties is required as part of the damage assessment. As a general rule most properties are constructed with the floor level raised 300mm above the adjacent ground level. This would be particularly characteristic of fluvial or coastal floodplains which are generally low lying and flat in nature. Steep topography also has an influence on finished floor levels whereby some properties have split level front doors and back doors and some properties enter at ground level but have basements below.

Where a finished flood level (FFL) survey has been carried out, FFLs are directly transposed into the damage assessment shapefile/s. These are considered the most accurate method of providing FFLs. RPS ensure that any FFL surveys which are carried out specify the surveyor to use a total station, to avoid errors induced by differential GPS stations being used close to buildings which reduced the accuracy due to disturbing clear lines of site to GPS satellites. In the occurrence of multiple entrances to a property being surveyed, a conservative threshold is chosen based on the lowest level surveyed for the FFL.

In absence of FFL surveys, RPS calculate the average level from LiDAR across the building footprint to provide a ground level. A survey of steps into the property allows the height the FFL is raised to be estimated. Each step is counted as +150mm above LiDAR defined ground level. For example if there are two steps the raised height above ground level would be 300mm. Table 7.4 shows the details recorded in the damage assessment shapefile. A number of QA checks are carried out to ensure damages are not over / underestimated, with any manual updates recorded in the attribute tables of the shapefile.

Table 7.4 - Property Threshold Data

Ground Level	GL	LiDAR data extracted at each property, measured in mOD Newlyn. Where an FFL survey is available, a null value of -999 is recorded.
How many steps into property	Steps	Number of steps into property entrance. Where details of property entry are unknown "-999" value recorded.
Is ground floor raised	Raised	Calculated from "Steps" column. Each step to be 0.15m, on basis of 0.3 standard entry to residential properties. Where "-999" value recorded the 0.3m standard entry is assumed for residential properties and 0m for non-residential properties.
Finished Floor Level	FFL	GL + Raised = FFL. For properties with basements FFL is calculated to be ground level minus 2.5m.

5. Flood Depth of Properties

To estimate the damage to a property, estimations of predicted flood depths are required for a wide range of flood events. The depths to which properties in the assessment are flooded are calculated for modelled events prescribed in the brief; for Scottish assessments the events prescribed are commonly 1 in 2, 1 in 5, 1 in 10, 1 in 30, 1 in 50, 1 in 100, 1 in 200 and 1 in 1000.

The depth of flooding is calculated by finding the difference between the flood water elevation and the estimated threshold level. The flood elevation is extracted from hydraulic model outputs to find the maximum depth of water touching each building polygon. This process is achieved by carrying out a statistical analysis in ArcGIS and is carried out for each property and for each flood event. Table 7.5 shows details which are recorded within the attribute tables of the damage assessment shapefile:

Table 7.5 - Flood Depth of Properties Data

Data type	Attribute name	Data details
Flood level for all flood events	Q1000_ELEV, Q200_ELEV, Q100_ELEV, Q50_ELEV, Q30_ELEV, Q10_ELEV, Q5_ELEV, Q2_ELEV.	The maximum flood level adjacent to the building (mOD)
Flood depth for all flood events	Q1000_Dp, Q200_Dp, Q100_Dp, Q50_Dp, Q30_Dp, Q10_Dp, Q5_Dp, Q2_Dp.	Difference between the flood level and FFL

6. Flood Damage to Properties

Once the depths of flooding are known the damage can be calculated using the MCM depth damage data. This is known as direct damage in that the flooding directly damages assets; it does not account for indirect damages such as heating costs to dry out the house. For each property type, a typical damage based on historical data has been assigned to a depth of flooding. The latest version of the MCM data is sourced, where the damage per square metre of the floor area of a building is used.

The direct damage in each flood event for each building in pounds sterling prices per square metre is calculated by interpolating between the depth damage figures provided in the MCM guidance. This damage figure is then multiplied by the floor area of the property to give the total damage. This information is recorded in the attributes listed in Table 7.6.

Table 7.6 - Flood Damage to Properties Data

Data type	Attribute name	Data details
Direct damage per meter square	Q1000_M2Dm, Q200_M2Dm, Q100_M2Dm, Q50_M2Dm, Q30_M2Dm, Q10_M2Dm, Q5_M2Dm, Q2_M2Dm.	Damage per meter square to each property according to the depth of flooding from each flood event as per MCM data.
Principal Direct Damage (PDD) - Damage to property over full floor area	Q1000_PDD, Q200_PDD, Q100_PDD, Q50_PDD, Q30_PDD, Q10_PDD, Q5_PDD, Q2_PDD.	Damage per meter square multiplied by floor area of building.

7. Emergency and Utility Costs

A cost will be associated with emergency services dealing with the flood events. Following the Environment Agency's Flood or Coastal Erosion Risk Management (FCERM) appraisal guidance, which the MCM guidance has been adapted to comply with, a value of 10.7% of the principal direct damages is assigned to the emergency services costs. This figure is based on data collected from previous flood events in the UK.

An economic damage will also be incurred in flood events relating to infrastructure utility assets. Examples of these may include electrical sub-stations and telecommunications assets. A utility damage of 20% of the principal direct damage is applied to account for these impacts, based on the analysis of damages from historical flooding in the UK.

The details in Table 7.7 are recorded within the economic risk shapefile attribute tables:

Table 7.7 - Emergency and Utility Cost Data

Data type	Attribute name	Data details
Emergency costs	Q1000_Emerg, Q200_Emerg, Q100_Emerg, Q50_Emerg, Q30_Emerg, Q10_Emerg, Q5_Emerg, Q2_Emerg.	Equal to 10.7% of the Principal Direct Damages (PDD).
Utility costs	Q1000_Util, Q200_Util, Q100_Util, Q50_Util, Q30_Util, Q10_Util, Q5_Util, Q2_Util.	Equal to 20% of the PDD.

8. Event Damage

The event damage is defined as the total of the direct damages in any one event, calculated to be the sum of the principal direct damage (PDD) to properties, emergency damages and utility damages. The event damage is required for later steps in the process, specifically in calculating annual average and present value damages. The event damage is recorded in the damage assessment shapefile as shown in Table 7.8.

Table 7.8 - Event Damage Data

Data type	Attribute name	Data details
Event Damage	Q1000_EvDam, Q200_EvDam, Q100_EvDam, Q50_EvDam, Q30_EvDam, Q10_EvDam, Q5_EvDam, Q2_EvDam.	Summed direct damage of any one event. This is the total of the PDD, utility damage and emergency costs.

9. Annual Average Damage and Present Value Damage

In order to gain an appreciation of the economic risk the overall damage needs to be calculated. This is represented by assessing the likelihood of each of these flood events occurring in any given year and applying this as a percentage to the damage; this is known as the Annual Average Damage (AAD). The AAD can then be taken over the lifetime of the study that has been set at 100 years and discounted back to present day costs; this is known as present value damage (PvD).

The AAD can best be described by considering the graph shown Figure 7.3. The points shown represent the various design flood events where the event damage is calculated. Their position on the graph is dictated by the damage caused and the frequency of the flood event occurring in any given year. These points are joined together to create a damage curve. The area under the curve is therefore a function of the damage and the frequency and gives the AAD.

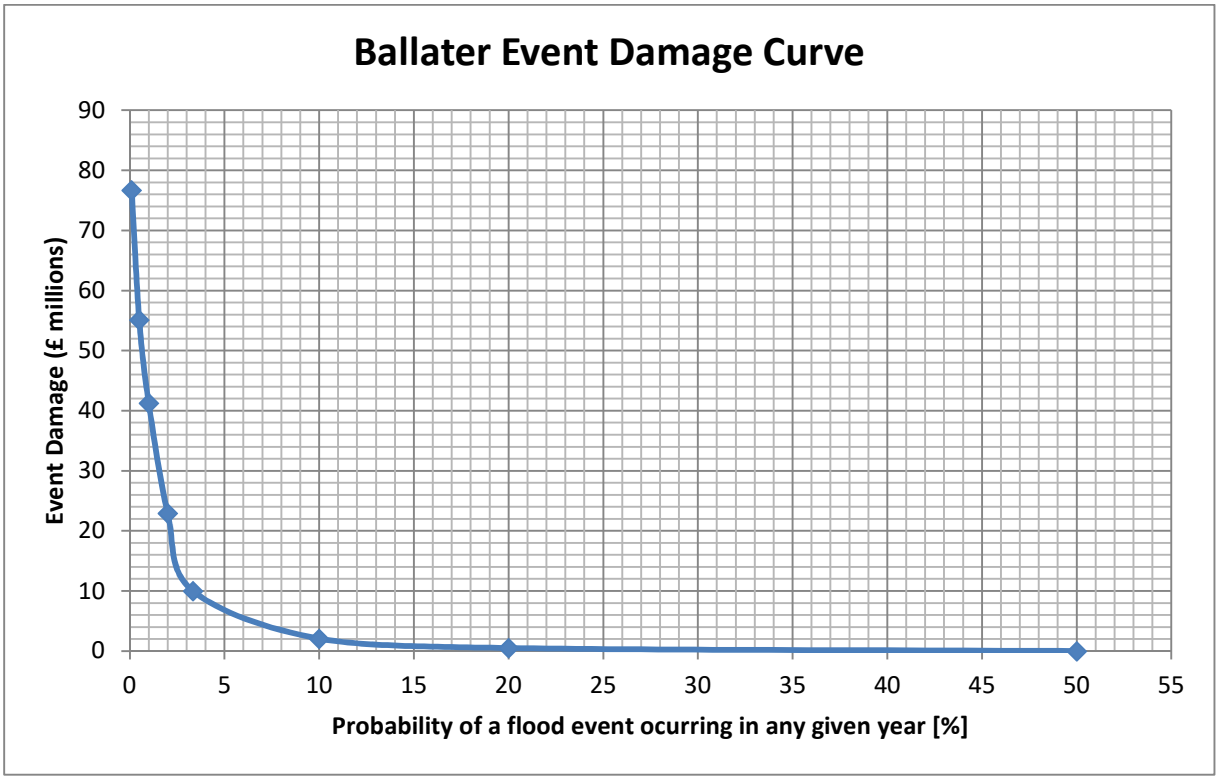


Figure 7.3 –Ballater Event Damage Curve

Once the AAD is calculated the present value damage can be determined. The present value damage calculation sums the AAD that is expected to occur for each of the 100 years considered in Scottish studies. In order for the damage value in each year to be comparable with each other they are discounted to represent the equivalent present damage value. Discounting damage values in the future is based on the principle that generally people prefer to receive goods or services now rather than later. This is known as time preference. The cost therefore of providing a flood management option will also be discounted to present day values. Discount rates are taken from the Treasury's 'Green Book' (HM Treasury, 2018), as shown in Table 7.9.

Table 7.9 - The Green Book's Long Term Discount Rate

Period of Years	**0 - 30**	**31 - 75**	**76 - 125**
Discount Rate	3.5%	3.0%	2.5%

This results in factoring the AAD by 29.813. The AAD and PvD are calculated for the direct damages. The following details are recorded within the damage assessment shapefile attribute tables:

Table 7.10 - AAD and PvD Data

Data type	Attribute name	Data details
Annual Average Damage for direct damages, intangible damages	AAD	The equation to calculate the AAD is as follows: (([Q2_EvDam]+[Q5_EvDam])/2*(0.5-0.2)+ ([Q5_EvDam]+[Q10_EvDam])/2*(0.2-0.1)+ ([Q10_EvDam]+[Q30_EvDam])/2*(0.1-0.03333)+ ([Q30_EvDam]+[Q50_EvDam])/2*(0.03333-0.02)+ ([Q50_EvDam]+[Q100_EvDam])/2*(0.02-0.01)+ ([Q100_EvDam]+[Q200_EvDam])/2*(0.01-0.005)+ ([Q200_EvDam]+[Q1000_EvDam])/2*(0.005-0.001))
Present value damage	PvD	The AAD factored by 29.813.

10. Capping Damages

It is recognised that for certain properties the overall damage associated with it can far exceed the market value of the property. This can be due to either the depth to which it floods or the frequency with which it floods or a combination of both factors. Where such a situation occurs it is necessary to cap the damages at the market value.

When capping damages for residential properties, the regional average risk free market value is used. Detailed research is carried out in order to establish an accurate and robust representation of property values for the study area.

For a non-residential property its capping value is calculated by its rateable value multiplied by a factor which reflects the added value of percentage rental yield from that property is used. The methods used to acquire robust values for capping damages are recommended in the FCERM Manual 2013 and the MCM 2016. Research is carried out to identify both the rateable value and the average rental yield for commercial properties in the region. For percentage rental yield, an average for Scotland of around 6% is identified using data produced by Savills, 2017; therefore using MCM guidance a multiplier of 16.7 would be appropriate.

The approach taken by RPS, in line with MCM guidance, is to cap the direct damages and to leave the intangible flood impacts uncapped before totalling up the overall damages. This process described in Section 11 (Intangible Impacts of Flooding), and capping details summarised in Table 7.11 and Table 7.12.

Table 7.11 – Ballater Commercial Capping Damages Data

MCM_Code	Property Type	Capping Value /m^2
2	Shops	£142.91 x 16.7 = 2386.60
3	Offices	£98.94 x 16.7 = 1652.30
4	Warehouses	£36.78 x 16.7 = 614.23
5 51 52 521 523 525 526 9 910 960	Leisure & Sport Leisure Sport Playing Field Sports Centre Sports Stadium Marina Miscellaneous Car park Substation	£41.43 x 16.7 = 691.88
6	Public Buildings	£59.61 x 16.7 = 995.49
8	Industry	£29.17 x 16.7 = 487.14

Table 7.12 – Ballater Capping Damages Data

Data type	Attribute name	Data details
Capped direct damages (baseline scenario)	PvD_BL_Cap	Residential property damages over capping value are set equal to this value. Commercial property damages capping value = rateable value x % rental yield.
Capped direct damages (defended scenario)	PvD_Df_Cap	The direct damages in the defended scenario are also capped using the same capping data for the baseline.

11. Intangible Impacts of Flooding

Apart from the material damages to the building structure and the goods inside the property, it is recognised that there are monetary damages associated with stress, health effects and loss of memorabilia, which can be as important as direct material damage to householders. The MCM guidance assesses these impacts as intangible benefits that are associated with flood defence improvements. For analysis of intangible benefits Defra's risk reduction matrix is commonly used (Defra, 2004), as shown in Table 7.13**.** The calculated intangible benefits are summed with the benefits relating to direct damages to provide the total benefit; this is discussed in more detail later. In line with the Defra methodology, the intangible benefit is not capped.

Table 7.13 - Intangible benefits associated with flood risk management improvements (2016/2017 prices) (FHRC, 2016)

Standard of Protection After - AFP (RP in years)										
Standard of protection before AFP (RP in years)			0.007	0.008	0.01	0.013	0.02	0.0033	0.05	0.1
			-150	-125	-100	-75	-50	-30	-20	-10
	1	-1	£284	£280	£260	£199	£95	£33	£15	£6
	0.1	-10	£279	£274	£254	£193	£88	£28	£10	£0
	0.05	-20	£267	£262	£245	£183	£78	£17	£0	
	0.033	-30	£251	£246	£227	£166	£61	£0		
	0.02	-50	£189	£184	£165	£105	£0			
	0.013	-75	£85	£81	£61	£0				
	0.01	-100	£24	£19	£0					
	0.008	-125	£5	£0						

AFP = Annual Flood Probability
RP = Return Period
Annual Benefits = Damages (before) – Damages (after)

No intangible damages are assigned to commercial properties as these costs do not apply at the same level.

12. Damage Assessment Review

A review of damage assessments are carried out to quality check the data being used. Some basic checks carried out by the damage assessors include reviewing the properties that contribute over 1% of the capped PvD, checking the area and thresholds of large commercial buildings and spot checking depth damage data is correctly applied. Checks are also carried out by the modeller, to ensure the model is calibrated to historic events and to inform the optioneering process.

A quality assurance spreadsheet has been developed by RPS to ensure a number of checks are carried out throughout the process, which is included as part of the appendices of any flood risk study which includes a damage assessment.

13. Calculation of Total Benefit

The total economic benefit for study areas are calculated as the sum of the direct and intangible benefits. Damages are assessed up the 0.1% AEP, protecting all properties in the assessment within the 0.5%CC AEP extent. As damages for the 0.5%CC AEP cannot be reasonably estimated without a full suite of climate change model runs, there will be a residual damage in the study area where properties are not protected above the 0.5% AEP event (excluding climate change). To be conservative the benefit is derived based on providing the 0.5% AEP without climate change. The intangible benefit is uncapped as discussed previously. The relevant fields in the economic risk shapefile are provided in Table 7.14.

Table 7.14 – Benefits and Related Fields in the Economic Damage Assessment

Data Type	Attribute Name	Data Details
Present value damage (PvD) in baseline scenario	PvD_BL	Damages assessed up to 0.1% AEP.
PvD in baseline scenario (capped)	PvD_BL_Cap	Any present value damage greater than CapVal is capped at the CapVal. Any damage less than the CapVal is let equal to the original present value damage.
PvD in defended scenario	PvD_Df	Residual damages with properties protected up to 0.5% AEP (only 0.1% AEP damages remain).
PvD in defended scenario (capped)	PvD_Df_Cap	Capping applied similar to PvD_BL_Cap.
Present value benefit (PvB) derived from direct damage avoided (capped)	PvB_Cap	Calculated by the following: PvD_BL_Cap - PvD_Df_Cap
PvB relating to intangible impacts avoided	PvB_Int	Derived from Defra Intangible Matrix. Intangible benefits are not capped.
Final PvB for the study area	PvB_Final	Calculated by the following: PvB_Cap + PvB_Int

14. Benefits Derived from Non-Structural Options

As part of the optioneering process a range of structural and non-structural options are assessed. Non-structural options are subject to higher uncertainties compared to structural options, which may reduce their effectiveness. As such, the benefits derived from non-structural options are not afforded the same benefit as structural options. Each non-structural option has been allocated a unique percentage effectiveness, applied to the benefit calculated for a 0.5% standard of protection. Each Non-Structural option considered by RPS has been discussed below. A summary of the percentage effectiveness and how relative benefits have been calculated is provided in Table 7.15.

Property Level Protection (PLP)

Damage avoided by PLP options are calculated by assuming protection up to a flood depth of 0.6m. Beyond this level it is assumed water can enter the property and fills to the equivalent existing scenario flood depth. Protecting to flood depths in this nature will result in differing resulting standards of protections afforded to properties in the defended scenario. For this reason, any intangible benefits derived from this option are to be specifically calculated and summed for each property in the assessment area. The intangible benefit is added to the capped direct damages avoided to provide the total benefit. This value assumes the option is fully effective; therefore a factor of effectiveness needs to be applied. PLP assumed to be 75% effective. This percentage is to account for factors such as

property owners not being available to install their PLP in time should flooding occur during night time or work hours or PLP not being installed correctly.

Self Help

In this option, damage avoided is calculated by considering the percentage of damage attributed to the household inventory. It may be possible to move belongings away from flooded areas, e.g. move television and other items upstairs. Using the latest MCM depth damage data, household items equal 6.4% of the damages per square metre. Self Help assumed to be 20% effective, accounting for property owners not being available to remove household inventory items from flood risk. The resulting percentage applied to the capped direct damages avoided to provide a Self Help benefit is 1.3%.

Emergency Plan

During the existing scenario emergency costs are calculated as 10.7% of the direct damages incurred. The emergency plan assumes that emergency costs would be reduced by half to 5.35%. This accounts for reduced number of incidents and call outs which may lead to more efficient route plan for emergency vehicles and reduced response time.

Flood Forecasting and Warning

Implementation of a flood forecasting and warning system would allow additional time to prepare for flooding therefore increasing the damage avoided. The effectiveness of this system depends on many factors, but a key consideration is the warning time available. The following warning times and corresponding effectiveness is assumed: >12hrs = 10%; 6-12hrs = 6%; 2-6hrs = 4% and <2hrs = 0%.

Flood Resilience

It may be necessary to ensure properties which are at risk in floodplains are flood resilient. An example may be changing rooms for a sports pitch in an area which is at risk, which is not expected to incur significant damages as long as flood resilience measures are in place. Such properties are often outliers, which would require significant capital cost to provide protection from structural options. Flood resilience measures can included waterproof floors and substructure, as well as raising plug sockets and wiring above the design standard of protection flood elevation level.

Property Relocation

For properties where the flood damage exceeds their market value relocation is considered. Only single isolated properties or groups are considered suitable due to the social impacts to the community, where options are not ruled out technically, environmentally or economically.

Table 7.15 - Benefits Derived from Non-Structural Options

Non-Structural Option	Total Non-Structural Option Benefit =
PLP	[Capped Event Damage Avoided + Intangible Benefits Derived] *0.75] +
Self Help	[Capped direct damage avoided * 0.013] +
Emergency Plan	[Capped direct damage avoided * 0.0535] +
FF&W	[Capped direct damage avoided * (0.06 or 0.04 or 0)] +
Flood Resilience	Full benefit extracted for specific properties made flood resilient +
Property Relocation	Full benefit extracted for relocated properties