Environment Agency

TE2100 Key Products - Data Quality Insert

Product Name and Number:
TE2100_P305_T0211a_Greenhouse Gas Implications of Flood Damages Report and Carbon Foot-print Calculator

Study Name:
Greenhouse Gas Implications of Flood Damages

TE2100 Phase:	3ii	**Study Ref:**	T0211a
Product Type:	Report	**Date:**	

Concluding Quality Statement:
Reference document. Quick, high level but good quality piece of analysis with clear assumptions.

Significance:	5-Medium	**Technical Reliability:**	Medium

Best available or superseded: Best available

Contribution to TE2100:

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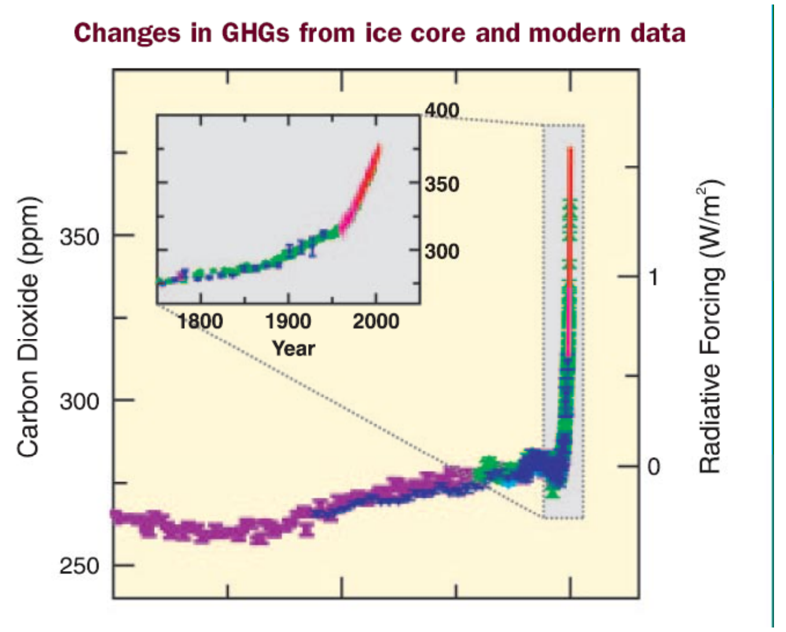
Thames Estuary 2100

Greenhouse gas implications of flood damages

Phase 3 Studies – Work Element 2.11a



Atmospheric forcings of CO_2 over the last 10,000 years (large panel) and since 1750 (small panel) Source: IPCC Climate Change 2007 Synthesis Report p38

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1. Introduction

This report presents the findings of a short, high-level piece of work to determine a broad-scale "multiplier" (suitable for use in strategic appraisal) to be used to adjust monetary estimates of direct damage to property to account for greenhouse gas (GHG) impacts. The TE2100 project team prepared the technical specification for this work commissioned to Halcrow (2-13 October 2008).

Background

Defra's 2007 guidance on the use of the Shadow Price of Carbon in policy appraisal sets the framework for considering the Greenhouse Gas (GHG) impacts of public sector actions, and has been employed to consider the GHG implications of new flood risk management options for the Thames.

The approach has been to estimate the CO2-equivalent emissions associated with new flood risk management works, then apply the Shadow Price of Carbon (SPC) within a discounted cashflow to determine a Net Present Value of GHG impacts in monetary terms. This Net Present Value is then included within benefit-cost analysis of options.

Objective

Clearly, flood damage to property – also a major factor in benefit-cost analysis of flood risk management - also has GHG implications to the extent that works are carried out post-flood events to repair, reinstate or replace buildings, fixtures and fittings. To date, this GHG impact has not been estimated by TE2100, but needs to be to assess the GHG impacts of actions "fairly" and comprehensively.

Scope

- Examine the "Multicoloured manual"[1] estimated direct property damage to flood depth relationships which are used in the TE2100/Halcrow "ECO+" flood risk model and determine assumptions about material and energy use consistent with repairing damage to building fabric, fixtures and fittings, and replacement of household/commercial goods;

- Determine volumes of GHGs (in CO2 equivalent) associated with works;

- Apply the 2007 Shadow Price of Carbon (£25/t) to the CO2e volumes to determine a monetary value – for this study there was no requirement to allow for rising real SPC over time.

- Translate the assessment into an average multiplier (or perhaps two, one for residential properties and one for non-residential properties), which can be applied to undiscounted estimates of direct property damage (e.g. event damages or Annual Average Damage).

Note: In this report, the term "carbon" is shorthand for GHG.

This study draws on experience gained in the recently completed project to assess the carbon footprint/lifecycle of water supply and demand management options for the Environment Agency (Sustainable Development Team) - the Science Report for this project is published at: http://publications.environment-agency.gov.uk/pdf/SCHO0708BOFV-e-e.pdf. Further knowledge came from Halcrow's Carbon Collective - key people working on carbon analysis and sustainability.

[1] The Benefits of Flood and Coastal Risk Management: A Manual of Assessment Techniques, Flood Hazard Research Centre, 2005.

2. Carbon appraisal framework

Carbon footprinting

A carbon footprint is a measure of the impact that human activities have on the environment in terms of the amount of greenhouse gases (GHG) emitted over the full life cycle of a process or product measured in units of carbon dioxide (CO2). Non-carbon GHG (e.g. methane) are converted to CO2-equivalent (CO2e).

Carbon 'footprint' calculation tools are available. The Environment Agency, for example, developed a carbon-wise construction project tool that aims to promote resource efficiency and reduce carbon emissions for construction projects. However, such tools are not designed for life-cycle assessment. The energy to operate rather than construct is consistently the most significant source of GHGs when taken over the life-cycle.

For this study a carbon cost calculator has been used based on a model developed previously for water supply and demand options.

Life-cycle carbon emissions

The embodied GHG of a product can be defined as the total CO_2e emitted during its life-cycle, including for example, emissions from the extraction and processing of raw materials, manufacturing and secondary processing (e.g. factory lighting, transport, etc), packaging, energy consumption during use and maintenance. The deconstruction, recycling and/or disposal of assets can also be included. This study considers only the GHG implications associated with the repair of flood damage to properties and replacement of household/commercial goods.

Defra guidance "placing a value on GhG"

Defra guidance sets out how to value GHG emissions based on the concept of the Shadow Price of Carbon (SPC), which supersedes the Social Cost of Carbon (SCC). The SPC captures the estimated damage costs of climate change caused by each additional tonne of GHG emission, expressed as CO_2e.

The Defra guidance defines the following approach:

- Step 1: quantify the impact on GHG emissions - in tonnes of CO_2e
- Step 2: calculate the SPC schedule over the planning appraisal period set alongside the GHG quantities saved, as illustrated in Figure 2.1 (extract from Defra interim guidance document)
- Step 3: multiply each year's GHG quantities abated/emitted (CO_2e) by SPC
- Step 4: use these monetised GHG values in cost-benefit analysis

The SPC thus depends on the year the carbon is abated/emitted. In 2007 the SPC is £25.5 (per tCO_2e), rising at two per cent per annum to £26.0 in 2008 and £50 in 2040. However, for the base analysis in this study we use the 2007 value throughout (i.e. assume no real growth in the SPC over time), to be consistent with the approach used currently by TE2100 for costing flood risk management options. This approach can be easily modified.

For this study the 2007 SPC (£25/t) is simply used to determine a monetary value.

Table 2: SPC from 2007 to 2050 (in 2007 prices)

Shadow Price of Carbon in 2007 prices (£/tCO2)

Year	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
SPC in 2007 prices and with 2% pa increase	25.5	26.0	26.5	27.0	27.6	28.1	28.7	29.2	29.8	30.4	31.0	31.6

2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034
32.3	32.9	33.6	34.3	34.9	35.6	36.4	37.1	37.8	38.6	39.4	40.1	40.9	41.8	42.6	43.4

2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050
44.3	45.2	46.1	47.0	48.0	48.9	49.9	50.9	51.9	53.0	54.0	55.1	56.2	57.3	58.5	59.6

Figure 2.1 Schedule of Shadow Price of Carbon (CO_2e)

The SPC captures the damage costs of climate change caused by each additional tonne of GHG (CO_2e) emitted, i.e. it reflects the adaptation costs under a 'business as usual' scenario assuming society does nothing to mitigate the climate change effects. However there remains great uncertainty about the damage and adaptation costs for climate change and rising sea levels, and the costs of failing to take early action.

Sensitivity analysis around key variables is fundamental to any appraisal. It is important to test the vulnerability of options to unavoidable future uncertainties. Defra guidance requires that sensitivity analysis consider a +/-5 per cent change in the SPC.

There are considerable uncertainties surrounding estimates of the impacts of climate change and the value of the SPC[2]. Research continues, e.g. by the Meteorological Office Hadley Centre (Integrated Climate Change Programme), Intergovernmental Panel on Climate Change and the wider academic community.

SPC is one of a number of ways to value carbon, and is currently recommended for the assessment of policy by Defra. One alternative method of calculating SPC, based on the global marginal abatement costs (MAC) required to meet a given stabilisation goal, is under assessment by the Government[13]. The initial indications are that the current SPC is consistent with meeting global stabilisation and goals for reducing national emissions.

Boundaries

Defining the boundaries for assessing GHG emissions is an essential first step.

Carbon costing a household item such as a television is difficult, and to be done accurately could in itself form the basis for a lengthy study. For this study, a standard item is split down into very basic components of metal, plastic and glass to provide a rough estimate, and the embedded carbon calculated based on the material weight and applying CO_2e conversion factors.

The embedded carbon used to produce the materials themselves is only one part of the process. Additional carbon is associated with the manufacturing process, which may be done in several different locations, transportation, packaging and assembling, and energy is consumed in factories, etc. The boundaries for this study are defined as the embedded carbon associated with the base materials, with a multiplier (range: 2 to 4) applied to account for the manufacturing process – the justification for this multiplier is discussed later.

[2] Environmental Data Services – ENDS Monthly Report 396, Climate Change: Cost of Carbon, Daylight falls on the shadow price of carbon, article by N Schoon, January 2008.

3. Methodology

Overview

The agreed methodology for this study is as follows:

- Review relevant literature, in particular the MCM and published carbon data[3]
- Identify other sources of data, including recent experiences of flood damage
- Identify key flood damage parameters
- Identify flood damage scenarios for assessment
- Estimate carbon costs using carbon calculator
- Determine average multipliers for flood damage curves, with indication of confidence limits

Key parameters

Key flood damage parameters are identified associated with:

- Building fabric / fixtures / fittings / repairs
- Replacement of household goods
- Energy use for hot air blowers / dryers / de-humidifiers
- Carbon associated with transport / travel of trades and homeowners

Fabric / fixtures / fittings / repairs, and replacement of household goods are based on items listed in MCM Appendix 4.2 and 4.3 tables. This provides examples of a matrix for short and long duration flooding for a pre-1919 detached house occupied by a social class AB household (upper middle and middle class: higher and intermediate managerial, administrative or professional), as used in this study to provide a typical breakdown of repairs following flooding.

Typical pre-1919 detached house from MCM

Household goods are based on a typical inventory of household items contained within MCM Appendix 4.1, again for a social class AB household. For the purpose of this assessment, this is assumed to be a typical residential property. The MCM is based on a large number of secondary data sources, as used in this study to derive the contents of a typical property.

Energy use for hot air blowers / dryers / de-humidifiers are based on MCM Table 4.4 and 4.5 for average clean-up costs. Although these include a several components, such as washing, decontamination and removal / disposal, the energy use contributes the greatest carbon cost.

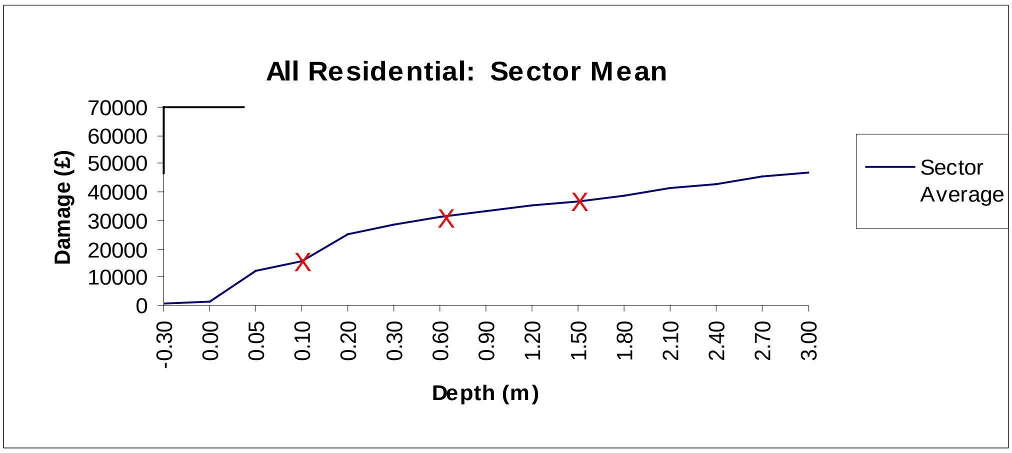
Carbon associated with transport is based on estimated overall driving distance and fuel use.

[3] Principally the Bath University Inventory of Carbon and Energy (ICE) version 1.6a http://www.bath.ac.uk/mech-eng/sert/embodied/ - this is the principal source of carbon parameters adopted in the Environment Agency's carbon calculator

Flood damage scenarios

Flood damage scenarios are considered for typical residential and non-residential properties.

Flood depths of 0.1m, 0.6m and 1.5m are selected to represent a reasonable range of flood depth points taken across the flood depth damage curve. An example depth damage curve that represents the sector mean for residential properties is given below, taken from MCM.



As flood depth increases, the susceptibility of household contents, fixtures and fittings also increases – see the example for one household item, the television, below. Thus it might be expected that the carbon cost multiplier to be applied to the overall depth damage curve may increase at greater depths.

Flood Depth (m)	0.05	0.1	0.2	0.3	0.6	0.9	1.2	1.5	1.8	2.1
Susceptibility (%)	0	0	0	50	100	100	100	100	100	100

Flood damage scenarios are sub-divided into short (less than 12 hour) and long (greater than 12 hour) duration flooding to represent the increased susceptibility of materials such as the actual building fabric to damage over longer periods as water soaks into the structure.

Carbon calculation – residential properties

The carbon calculation for building fabric / fixtures / fittings and household inventory items is based on the carbon associated with the embedded weight of materials within each of these items. This is because any carbon data associated with the carbon associated with the manufacturing process (for example a television) is currently extremely limited. However, the embedded carbon of constituent materials, such as steel, concrete, plastics glass, has been researched and is available (Section 4).

The approach taken for this study is to assess the overall weight of items and sub-divide these into the proportion by weight of constituent components. The embedded carbon for these materials is then applied to these totals to provide an overall kg CO_2e. To offset the fact that the embedded carbon within the materials does not include manufacturing, a multiplier is applied to take this into account.

The carbon cost associated with energy consumed by hot air blowers / dryers / de-humidifiers is directly converted from energy consumed in kWh into kg CO_2e using a direct conversion factor (see 'Data Sources').

The carbon associated with vehicle emissions is directly converted from kg CO_2e / km.

Direct and indirect effects of flooding

Only the carbon associated with the direct effects of flooding are considered, i.e. direct tangible losses for flooded households – damage to building fabric, damage to inventory items, clean-up and drying, and transport associated with these. No account is taken of intangible losses and indirect losses both to flooded and non-flooded households (e.g. increased travel necessary for commuting to work).

The range of possible flood impacts on households – direct / indirect / intangible are listed below. (red outline indicates the losses assessed in carbon terms by this study)

Direct tangible losses for flooded households	Intangible losses on flooded households	Indirect losses on flooded households	Indirect losses for non-flooded households
▪ Damage to building fabric ▪ Damage to household inventory items ▪ Clean-up costs	▪ Worry about future flooding ▪ Loss of memorabilia and irreplaceable items and pets ▪ Damage to physical and/or mental health, death or injury ▪ Loss of community ▪ Loss of confidence in authorities and services	▪ Permanent evacuation from area ▪ Disruption to household due to flood damage ▪ Evacuation costs ▪ Disruption due to flood warnings or alarms ▪ Loss of utility services ▪ Loss or income/earnings ▪ Loss of leisure and recreational opportunities ▪ Additional communication costs ▪ Loss of services ▪ Increased travel costs ▪ Increased cost of shopping and recreational opportunities	▪ Increased travel costs ▪ Loss of income ▪ Loss of utility services ▪ Loss of other services ▪ Loss of leisure and recreational opportunities ▪ Increased cost of shopping and recreational opportunities

Assumptions

- Replacement of building materials and household items on a like-for-like basis
- Replacement by more energy efficient devices is ignored - in some instances, replacement of items may be more energy efficient than the originals, and it may be significant over the lifetime of the product e.g. a fridge or washing machine
- Life of appliances - the embodied CO_2e per year within appliances will depend on the length of the product life, and this variable is not considered.
- No saving in domestic energy use during repairs - although the property might be unoccupied, there would be domestic energy use associated with alternative (e.g temporary) accommodation and thus no net change.

4. Key data

Overview

The key data derive from a number of sources in addition to the MCM (see references).

Recent experience of flood damage – Appendix A

Details of recent damage experience advised by Halcrow have proved a useful cross-check against MCM datasets. The importance of these examples is that they represent real situations and real data, rather than data based on estimates and assumptions as in the MCM. Overall the data (Appendix A) verify the MCM flood damage data.

Energy conversion factor (Defra)

- electricity 1 kWh = 0.43 kg CO_2e

The basis for this Defra CO2e value for electricity is as follows:

'the long-term marginal factor assumes that, over a long time period (a decade or more) avoided electricity use will displace generation at a new Combined Cycle Gas Turbine (CCGT) plant. Policies and measures that produce long-term reductions in electricity use should therefore use this factor to assess what carbon saving will result. When calculating emissions reductions based on long term investment decisions (for example, building zero carbon housing or business premises, investing in on-site renewables etc.) companies should use this factor. Carbon savings used for the purposes of Climate Change Agreements (CCAs) have historically been calculated using this factor, and it should continue to be used for this purpose.'

Embedded carbon conversion factors associated with different materials

These conversion factors are sourced from the Bath University Inventory of Carbon & Energy.

- steel 1 kg = 1.77 kg CO_2e
- aluminium 1 kg = 8.24 kg CO_2e
- concrete 1 kg = 0.13 kg CO_2e
- asphalt 1 kg = 0.045 kg CO_2e
- bricks 1 kg = 0.22 kg CO_2e
- ceramics/tiles 1 kg = 0.65 kg CO_2e
- glass 1 kg = 0.85 kg CO_2e
- plasterboard 1 kg = 0.38 kg CO_2e
- paper 1 kg = 1.92 kg CO_2e
- timber 1 kg = 0.46 kg CO_2e
- carpets 1 kg = 3.89 kg CO_2e
- paint 1 kg = 3.56 kg CO_2e
- plastic 1 kg = 2.53 kg CO_2e

Key extracts on the basis for this inventory on the definition of embodied carbon and considerations illustrating the complexity of carbon accounting are reproduced below.

Key extracts from the Bath University Inventory of Carbon & Energy

Definition of embodied energy (carbon)

"The embodied energy (carbon) of a building material can be taken as the total primary energy consumed (carbon released) over its life cycle. This would normally include (at least) extraction, manufacturing and transportation. Ideally the boundaries would be set from the extraction of raw materials (inc fuels) until the end of the products lifetime (including energy from manufacturing, transport, energy to manufacture capital equipment, heating & lighting of factory, maintenance, disposal...etc), known as 'Cradle-to-Grave'. It has become common practice to specify the embodied energy as 'Cradle-to-Gate', which includes all energy (in primary form) until the product leaves the factory gate. The final boundary condition is 'Cradle-to-Site', which includes all of the energy consumed until the product has reached the point of use (i.e. building site)."

Considerations illustrating the complexity of carbon accounting

- **Functional units:** It is inappropriate to compare materials solely on a kilogram basis. Products must be compared on a functional unit basis, a comparative study should consider the quantity of materials required to provide a set function. It is only then that two materials can be compared for a set purpose. For example, what if the quantity of aluminium that is required to provide a square meter of façade versus the quantity of timber?
- **Lifetime:** Ideally the functional unit should consider the lifetime of the product. For example, what if product A lasts 40 years and product B only lasts 20 years? This may change the conclusion of the study.
- **Waste:** The manufacture of 1 kg of product requires more than this quantity of material. The quantity of waste must be considered. Additionally what happens to the wasted materials? Is it re-used, recycled, or disposed?
- **Maintenance:** What are the maintenance requirements and how does this impact on the energy and material consumption? Does the product require periodical attention, e.g. re-painting?
- **Further processing energy:** Highly fabricated and intricate items require manufacturing operations that are beyond the boundaries of this report. In the case of a whole building such a contribution could be assumed to be minimal, however the study of an individual product may require this energy to be investigated.

Embedded carbon within household items

Only very limited data are available on the embedded carbon within household items. The most informative source found to date is the Guide to Low Carbon Lifestyles[4]. An extract is reproduced below that claims that:

"*…around 20kg of CO2 is produced for every kilo of goods manufactured, and this can be used as a rough estimate for most products made of plastic, glass, and metal*".

The guide also provides estimates of embodied kg CO_2 within some typical domestic appliances, and this has provided a useful cross-check against the carbon calculation for the same appliances in this study.

Key extract from the Guide to Low Carbon Lifestyles website

Embodied CO2 in manufacturing appliances

Appliance	Embodied CO2 in kg	CO2 per yr 5-yr life	CO2 per yr 10-yr life	CO2 per yr 25-yr life
Cooker	509	102	51	20
Fridge	955	191	95	38
Washing machine	764	153	76	31
Tumble dryer	318	64	32	13
Microwave	191	38	19	8
Dishwasher	700	140	70	28
Electric Kettle	11	2	1	0.4
Electric Drill	15	3	2	1
Total	3,463kg	693kg	346kg	139kg

A typical range of appliances in a house have emitted 3.5 tonnes of CO2 in their manufacture. If they last 5 years, this works out at around 700kg a year. If they last 25 years, it works out at 140kg a year. The energy it takes to make long lasting products is little more than short-life products. So it is worth buying quality products wherever possible. They give more satisfaction too.

If you have the choice between repairing a product or buying new, and they both cost the same, repair it. The CO2 emitted will be much less.

The bigger the item you buy, the more CO2 has been emitted to make it. For the above appliances, around 20kg of CO2 is produced for every kilo of goods manufactured, and this can be used as a rough estimation for most products made of plastic, glass and metal.

The less we buy and the longer we make it last, the less CO2 is produced. This frees up time that used to be spent in shopping for recreation.

[4] http://www.lowcarbonlifestyle.org/downloadables/TheGuideToLowCarbonLifestyles.pdf)

5. Flood damage parameters: residential properties

Overview

Carbon costs associated with flood damages for residential properties are sub-divided as:

- Building fabric / fixtures / fittings / repairs
- Replacement of household goods
- Energy use for hot air blowers / dryers / de-humidifiers
- Transport / travel of trades and homeowners, etc

Building fabric/fixtures/fittings repair – Appendix B

The MCM provides a list of building repairs following flood damage. This covers a very wide range of different items e.g. from replacement of garden sheds and green-houses, re-rendering brickwork, replacing stud-partitions, re-plastering, renewing doors and redecorating. An assessment has been made of the carbon cost associated with each of these items for different flood depths. This assessment is based on the carbon associated with the embedded material within each of these items, as explained previously.

The overall range of building fabric / fixtures / fittings / repairs include:

- Paths and paved areas
- Fences and garages
- Main building work
- Plasterwork
- Internal floors
- Joinery
- Decoration
- Services

The MCM table includes susceptibility curves, which provide an indication of the percentage of damage to each item depending on the flood depth assessed (0.1m, 0.6m and 1.5m are assessed by this study).

The following points can be noted:

- Some items have a very high susceptibility at flood depths of only 0.1m, e.g. replacement of hardwood floors, whereas other items have low susceptibility until much greater depths of flooding (2.7m), e.g. replacement of internal doors to properties.
- Susceptibility curves cover both short (<12 hours) and long (>12 hours) flooding, because some items – e.g. plastering – are dependent on the duration of flooding.
- The overall embedded carbon content associated with building fabric / fixtures / fittings / repairs is based on the estimated weight of material.
- For some items, the estimated weight of material associated with each item has been based on reasonable judgement, e.g. both a greenhouse and a garden shed are assumed to weigh approximately 100 kg.
- For other items, an approximate length or area is provided in the table and this has been used in the estimate, together with manufacturer's information, e.g. 350m^2 of stud partitions with an estimated weight of 30 kg/m^2 have a total weight of approximately 10 tons.
- In many instances the estimated material weight is necessarily very approximate.
- An estimate of the proportion of constituent materials is also made, e.g. plasterboard, concrete, asphalt, steel, bricks, paper, paint, glass, timber and ceramic tiles.

The embedded carbon associated with many of these materials is generally fairly low – for example – concrete 0.13 $kgCO_2e$ per kg, asphalt 0.045 $kgCO_2e$ per kg, bricks 0.22 $kgCO_2e$ per kg – however this is generally offset by the fact that a much greater weight of these materials is likely to be used when compared to household inventory items.

The above only includes the carbon associated with the embedded materials within each item, but not the manufacturing process or distribution as discussed previously. To take this into account a multiplier of 2 is applied to the embedded carbon cost (i.e. double the cost).

Household goods – Appendix C

The MCM provides an extensive list of household inventory items, including a depth / damage function. The list includes items from kitchen 'white goods' (e.g. washing machine, dishwasher, fridge-freezer), to television and furniture. An assessment is made of the carbon cost associated with the replacement of these items for different flood depths. This assessment is based on the carbon associated with the embedded material within each of these items, as explained previously.

The overall embedded carbon content of household materials is calculated as follows:

- The MCM table includes a % ownership for each item – for example, 40% contain a dishwasher whereas 98% contain a TV. The carbon calculation takes into account this % ownership as a multiplication factor for each individual item within the calculation.
- The MCM table includes susceptibility curves, which provide an indication of the percentage of damage to each item depending on the flood depth assessed (0.1m, 0.6m and 1.5m are assessed by this study).
- Some items are more susceptible than others, for example, carpet underlay has 100% susceptibility to flooding at all flood depths, whereas a TV has no susceptibility for flood depths of 0.2m or less.
- The total inventory list comprises approximately 150 items; this study considers only items with a ARV (Average Remaining Value) of £300 or more, with results scaled up to take into account the more minor items. The total ARV of all items is £75,000, with £62,000 (80%) of these assessed, so this scaling factor is 1.2.
- An assessment is made of the total weight of each inventory item, e.g. television estimated to weigh 15 kg, washing machine estimated to weigh 50 kg. Clearly, there will be variation depending on type/model, however, these items are reasonably straightforward; others are more difficult, e.g. what weight should be assumed for books?
- Overall, estimates of weight are based on reasonable judgement. In total, the estimated weight of inventory items within a typical property is 1095 kg – approximately 1 ton. For 5 rooms, this works out at 200 kg within each room, which appears reasonable.

An estimate of the proportion of constituent materials of each item is made. Overall, these are sub-divided into basic materials: steel, aluminium, plastic, glass, paper, timber, carpet etc – these materials are included within the Inventory of Carbon & Energy database. For example, a washing machine may comprise 60% steel, 30% aluminium, 10% plastic. There is no readily available database comprising proportion of constituent components so again these are based on reasonable judgement.

In practice, the majority of constituent materials have similar embedded carbon content (typically around 1 to 3 $kgCO_2e$ per kg) and so the sensitivity to proportion of different materials is less important than the overall weight. Aluminium is one exception with a higher carbon content (approximately 8 $kgCO_2$ per kg).

The above only includes the carbon associated with embedded materials within each item, but not the manufacturing process or distribution as discussed previously. To take this into account a scaling factor of 2 is applied to the embedded carbon cost (i.e. double the cost).

Energy for hot air blowers/dehumidifiers – Appendix D

Energy consumed in drying property following flooding is a significant contributor to the overall carbon. The principal components comprise of blower-heaters, air movers (i.e. blowers) and de-humidifiers. The MCM provides an indication of average clean up costs for residential properties for depths of less than and greater than 0.1m. In reality this will vary, e.g. in summer months property drying can be expected to be faster than in winter.

We have assumed average power consumption for each of these units (based on manufacturer's product information[5]) of:

- 2000 Watts – blower-heater
- 250 Watts – air mover
- 500 Watts – dehumidifiers

It is the length of time that these units are required for (1 or 2 months) which results in the significant carbon contribution. The total power consumption of these units combined is 6.5 kW. This is an energy consumption of 4400 kWh - for 28 days continuous running, and 8800 kWh - for 56 days continuous running.

Recent experience of flood damage

Details of recent damage experience advised by Halcrow employees (Appendix A) provide a useful comparison against the above estimates. The total electricity for drying property is claimed to be 2500 kWh (based on 3.9kWatts for 27 days) and 6500 kWh (based on 4 dehumidifiers assumed rated at 500W and 1 air blower assumed rated at 250W for 4 months, excluding under-floor heating). These estimates are broadly consistent with the MCM estimates.

Transport

Transport is associated with travel by trades (transit van), and homeowners from suppliers to / from the residential or commercial properties. The carbon estimate assumes 100 journeys at 50 km for each property, i.e. total distance of 5000 km equivalent to 2 return journeys of 25 kilometres each way per day for approximately 2 months. A conversion factor of 0.2 kgCO_2e /km is adopted (source: Environment Agency carbon calculator). This estimate excludes transport associated with manufacture of goods.

[5] For example, http://www.energystar.gov/ia/products/prod_lists/dehumid_prod_list.xls provides indication of de-humidifier efficiency

6. Flood damage parameters: non-residential properties

Overview

Estimating carbon costs associated with flood damages for non-residential properties (NRP) is more difficult than for residential properties. One key reason for this is the huge variety of property types that makes defining a ‘typical’ non-residential property very difficult.

Non-residential properties include the commercial / office sector, retail (shops), the industrial sector (e.g. factories), schools, hospitals and churches. Clearly both the design of the buildings themselves, their size, and their content are factors in determining the carbon footprint associated with flood damages.

This contrasts with residential property, which is more straightforward. Almost all residential property include items such as a cooker, a fridge, living room furniture etc. The same cannot be said for NRP – for example, a factory will contain manufacturing equipment, an office will contain office furniture and a warehouse will contain various stock types, and carbon footprints.

Non-residential property types

The MCM (Section 5) provides details of different non-residential property types as below.

Category	Average value of (per m^2)			
	Building Cost	Moveable Equipment	Fixtures/ Fittings	Stock
Retail (shops / stores)	737	63	339	375
Vehicle services (e.g garages)	686	57	190	120
Retail services (e.g. restaurants)	1275	269	213	42
Offices	1911	6157	285	25
Distribution / logistics (e.g. warehouses)	300	75	40	1852
Leisure (e.g. hotels / cinemas)	2222	67	378	34
Sport (e.g. leisure centres)	1000	75	208	0
Public buildings (e.g schools, libraries)	782	100	100	100
Industrial (e.g workshops / factories)	749	118	355	226
Weighted average for non-residential property	**982**	**1474**	**285**	**379**

As a first approximation it seems reasonable to assume that the value / cost of the building and contents is likely to bear some proportionate relationship with the embedded carbon content, although this is a very broad assumption.

The relative cost of buildings, moveable equipment, fixtures and fittings and stock will be dependent on the category, as can clearly be seen in the above table. Building costs for warehouses are typically lower than other categories, e.g. office buildings will typically have a large amount of moveable equipment in comparison to other categories. Distribution / warehouses will tend to have a large amount of stock, whereas other categories such as public buildings may have virtually none at all. Broadly speaking, most categories have a similar level of fittings and fixtures.

The example MCM tables, reproduced in Appendix E, give more detail for typical building services, moveable equipment, fixtures and fittings and stock that might be found in typical retail premises, and in typical manufacturing / engineering workshops. The huge variety and complexity of items (ranging from is immediately clear and illustrates the difficulty of attempting to calculate a carbon cost associated with flooding.

For this reason, it is not possible to meaningfully carry out an embodied carbon assessment in the same way as has been done for residential properties (by assessing approximate weights of items affected). A further important factor to consider is susceptibility of items to flood damage - this point is also discussed below and again exhibits huge variation.

Building costs

Building costs are lowest for warehouses and highest for offices and leisure facilities with other categories broadly similar in between. The carbon cost associated with repair of repair following flood damage will be highly dependent on the building type. For example, flooded buildings which comprise steel frame structures with concrete floors (e.g. for warehouses) are likely to require a much lower level of remedial works than rendered brick buildings with significant internal plastering and carpets etc.(for example, offices).

Moveable equipment

Again, moveable equipment will vary greatly from category to category. Offices typically have a high value of moveable equipment - comprising office furniture and computers, whereas for other categories this is much lower. For example, for distribution centres this might comprise fork lift trucks and other vehicles. Moveable equipment may in some cases overlap with fixtures / fittings.

Fixtures / Fittings

These are broadly similar across different property categories, but lower for warehouses.

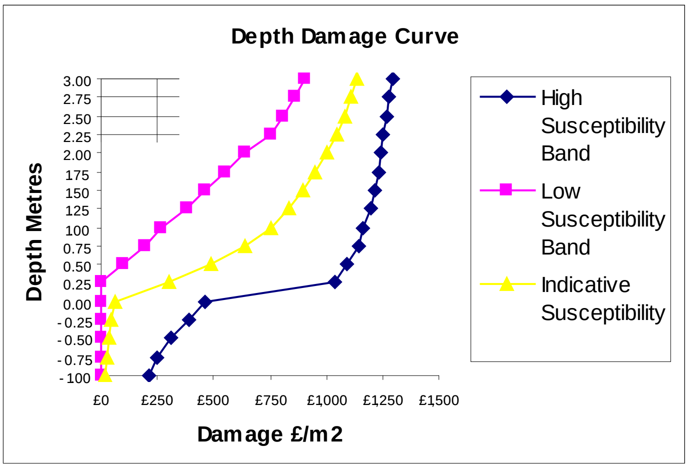
- shelving / racking (retail outlets)
- seating (cinemas and theatres)
- hydraulic ramps / fuel dispensing equipment (workshops, garages)
- cupboards
- flooring
- carpets
- counters
- freezers
- lighting
- kitchen / bathroom fittings

Stock

For retail outlets stock will comprise the goods that they sell, while for manufacturing companies this will comprise either raw materials, work in progress, or finished goods. For public buildings there will be little or no stock, for warehouses this will comprise the majority of the cost. The carbon cost of the stock will be dependent on its embodied carbon and this will be highly variable as it will depend on what the stock is.

Susceptibility and depth-damage curves

The MCM has generated depth-damage curves for different non-commercial property types, which are based on the value of buildings, moveable equipment, fixtures and fittings and stock that are affected by flooding to different depths. An example is shown below for typical retail premises. The figure illustrates the range of damages that might be expected at each depth.



Typical depth-damage curve for Retail (high, low and indicative susceptibility (MCM Section 5)

The reason the range is high is because of the varying susceptibility of different components to flood damage. For example, fresh food is highly susceptible and would almost certainly be written off on the grounds of public health. Premises such as cinemas are highly susceptible because of the large amounts of immoveable seating. For buildings themselves, steel frame buildings will be much less susceptible than older office buildings with plasterboard partitions etc.

Flood warning may have the potential to reduce susceptibility, as described below.

Flood warnings

Flood warnings may have the potential to reduce flood damages. For example, this may enable some removal of stock and equipment to avoid damage. However, this is dependent on numerous factors – some of which are listed below. One of the key factors is the potential lead-time available for businesses to act to minimise losses. Carbon costs associated with flooding to non-residential properties are therefore dependent on these factors.

Warnings are likely to be effective in reducing flood losses for NRPs when (MCM Section 5):

- They have a long lead time (at least eight hours)
- People have confidence in the warning
- They give specific information on the timing and likely level of flooding
- Staff are aware of what actions to take
- There are enough staff or contractors available to move equipment and goods and take mitigating actions
- Equipment and goods are able to be moved (e.g. not too large or heavy)
- There is space on upper floors or storage areas, in an alternative location, or on higher ground to move equipment and goods to
- Appropriate refrigeration is available for storing perishable foodstuffs, drinks etc. elsewhere (e.g. beer needs to be refrigerated if moved)
- Surrounding areas and roads are not flooded

Flood Duration

A longer flood duration is not considered likely to significantly increase flood damages. Although there may be an increase in damage to building fabric, in general it is considered that the damage is done once the floodwaters have entered the property.

Implications of salt content in flooding

Some particular implications of the salt-water content of flooding are listed below. These would be likely to result in an increase in carbon costs associated with flooding. (For example, if saltwater corrosion to steel piping and conduits in manufacturing / industrial premises results in their need for replacement, and this would not have been the case if the flooding was fluvial). Flooding in the Thames Estuary will most likely include a saltwater content.

Possible damage from coastal (saltwater) flooding (MCM Box 5.4)

- Saltwater corrosion (e.g. of steel piping and conduits)
- Wave and spray damage
- Possible scouring around building structure by water action
- Damage to metal parts due to oxidation
- Damage to building fabric and woodwork from penetration of salts
- Damage to electrical wiring due to electrochemical action in presence of saltwater
- Pitting to plaster and other boards
- Damage to paintwork due to salt being trapped between layers.
- Discolouration of internal decoration
- Damage to metallic finishes
- Damage to furniture and soft furnishings due to staining from salts
- Clean-up can be more damaging due to salt content
- Increased loss of production (indirect losses) while plant is repaired or replaced

Indirect flood damages

In addition to direct flood damages, there may be indirect flood damages and carbon costs associated with flooding to non-residential properties. For example, carbon costs associated with relocation to temporary premises, increased travel associated with customers accessing goods or services elsewhere etc.

Basis for carbon assessment

The above discussion provides examples of issues affecting flood damages to non-residential properties. The range and complexity of issues makes it very difficult to attempt a meaningful estimate of carbon costs associated with this.

The MCM damage calculations estimate the economic damages associated with flood damages to residential and commercial property, so they already make an attempt to take into account different non-residential property categories and depth – damage relationships.

In broad terms, it seems reasonable to assume that the non-residential properties carbon cost associated with damage to the building fabric and fixtures and fittings (i.e. the multiplier to the damage curves) will be broadly similar to that assumed for residential properties. Thus as a first pass it can be assumed that the same multipliers for residential properties may be reasonably applied to non-residential properties.

Clearly, there are major limitations with this approach, in particular because the carbon cost associated with moveable equipment and stock will be dependent on the specifics of the individual premises that are flooded.

It is also considered reasonable to assume that carbon costs associated with the use of heater / dryers and de-humidifiers, and carbon costs associated with transport, will be a similar multiplier to the depth / damage curves as for residential properties.

7. Carbon calculation results

A summary of the carbon calculation results for an average residential property is presented below. Appendix F includes a detailed breakdown of the carbon footprint of individual items, and the carbon calculator developed for this study accompanies this report. These results based on rapid appraisal can only be indicative, providing the broad-scale "multiplier" required.

Energy Consumption - flood depth <0.1m		
Item	Energy (kWh)	kgCO2e
Blower Heater	2690	1157
Air mover	336	145
De Humidifier	1345	578
Total	**4371**	**1880**

Energy Consumption - flood depth >0.1m		
Item	Energy (kWh)	kgCO2e
Blower Heater	5380	2314
Air mover	673	289
De Humidifier	2690	1157
Total	**8743**	**3759**

Household Inventory Items* (incl. multipliers)				
Flood depth	0.1m	0.6m	1.5m	Multiplier =
kgCO2e	1686	9758	10713	4

Repairs (incl. multipliers) - short duration (<12 hours)				
Flood depth	0.1m	0.6m	1.5m	
Paths and paved areas	0	153	314	
Fences and Garages	515	1750	4329	
Main Building	0	0	338	
Plasterwork	848	6764	9260	
Internal floors	690	1380	1380	
Joinery	131	659	691	
Decoration	381	478	478	
Services	23	114	152	Multiplier =
Totals kgCO2e	**2588**	**11297**	**16942**	2

Multipliers take into account carbon associated with manufacture of goods - e.g energy consumption, transportation from factory to supplier and supplier to household.

Repairs (incl. multipliers) - long duration (>12 hours)				
Flood depth	0.1m	0.6m	1.5m	
Paths and paved areas	190	576	1054	
Fences and Garages	1202	3243	7009	
Main Building	273	585	1445	
Plasterwork	2495	9236	9753	
Internal floors	1380	1380	1380	
Joinery	415	699	718	
Decoration	324	478	478	
Services	46	329	329	Multiplier =
Totals kgCO2e	**6324**	**16527**	**22165**	2

Transport	kgCO2e	1000

Estimated total carbon and carbon cost (£25 per tCO_2e) for short and long duration flooding

Grand Total - short duration (<12 hours)			
Flood depth	0.1m	0.6m	1.5m
Carbon kg CO2e	**7154**	**25814**	**32414**
Carbon Cost	179	645	810
Damages at this depth	15,000	30,000	40,000
Percentage	**1.2%**	**2.2%**	**2.0%**

Grand Total - long duration (>12 hours)			
Flood depth	0.1m	0.6m	1.5m
Carbon kg CO2e	**10890**	**31044**	**37638**
Carbon Cost	272	776	941
Damages at this dept	15,000	30,000	40,000
Percentage	**1.8%**	**2.6%**	**2.4%**

The flood damage curve multipliers are calculated as:

Short duration flooding

- +2.2% for 0.6m flood depth
- +2.0% for 1.5m flood depth
- +1.2% for 0.1m flood depth

Long duration flooding

- +1.8% for 0.6m flood depth
- +2.6% for 1.5m flood depth
- +2.4% for 0.1m flood depth

8. Concluding remarks

The recommended broad-scale “multipliers” (suitable for use in strategic appraisal) to be used to adjust monetary estimates of direct damage to property to account for greenhouse gas (GHG) impacts are:

- +2% for short duration flooding of residential and non-residential properties
- +2.5% for long duration flooding of residential and non-residential properties

The “multipliers” can be applied to undiscounted estimates of direct property damage (e.g. event damages or Annual Average Damage). This applies in Year 0 of an economic appraisal, and can be increased by 2% year-on-year in line with Defra guidance. This almost doubles the “multiplier” by 2040 (as discussed in Section 2).

Though these figures are based on assessment of residential property data, the same “multipliers” can be applied to non-residential property - separate estimates cannot be made in view of the complexity of issues.

There are uncertainties associated with both the MCM data and, to a much greater extent, the carbon footprinting. The 2-2.5% “multipliers” recommended is the right order of magnitude, and an upper limit could be say 50% higher. A more refined estimate could be derived in more detailed study, including for example, approach to manufacturers to request carbon footprint data for household items.

Appendix A: Recent flood damage experience

Halcrow Employee 1

"…Here are details of elec usage when we got flooded in July 2007.These details are for 3 flooded rooms (2 @ 5m X 5m , 1 @ 6m X 5m) with plaster stripped to 1 m above ground. Chemdry Express franchises might have alternative "rule of thumb" time/cost estimates.

Electricity cost

The blowers and dehumidifiers were used from 7/9/07 until 4/10/07, 27 days in total, 24 hours per day. Installed power advised by Chemdry was as follows:

4 No "Sahara Pro" Turbo Dryers @ 375 W each	=	1500 W
1 no Calarex Porta-Dry @ 750 W	=	750 W
1 No Dry Pro 5000 @ 650 W	=	650 W
2 No Model No FB230's @ 500 W	=	500 W
Total installed power	=	3900 W (3.9 kW)

nPower marginal cost of electricity is 8.440p per kWh + 5% VAT

100% utilisation cost = 27days X 24 hours X 3.9 kW X 8.44p X 1.05% VAT = £223-96p

Re-plastering

The majority of the walls needed between 35mm and 80mm of render…."

Halcrow Employee 2:

"…I can give you a detailed list of what 4'8" (1425mm) of flood water can destroy/damage when it goes through your house and hangs around for a day or so!

Approx £30k worth of items plus approx £15k of repairs.
All white goods replaced – dishwasher/fridge freezer/oven/hob/washing machine/dryer
All other electrical items replaced – TV, stereo, kitchen equipment etc

Repairs included replacement of all timber products on the ground floor, lots of MDF & chipboard, new power outlets, 10m2 of re-plastering, complete redecoration to ground floor

Equipment i.e. power usage:-
2 weeks of power tool usage – charging drills, saws etc, cement mixers, builders vans
4 months of running 4 no dehumidifiers for 24 hours/7 days (2 of which were industrial quality, 2 were smaller household type)
2 months of running 1 no 12/7 warm air blower (basically a 2 bar electric fire with a big fan)
4 months of running 1 no 24/7 air blower (a big fan)
2 months of running under floor heating 24/7 (ground floor only) at 24deg (warm water type run off a brand new WB gas condensing boiler)

For info - Approx 60sqm ground floor area, ceiling height approx 2.1m, approx 60sqm 1st floor, ceiling height 3.0m.."

Appendix B: Depth / damage matrix of building fabric items (MCM Appendix 4.2)

Depth / Damage matrix of building fabric items for short duration (less than 12 hours) flooding (MCM Appendix 4.2)

HOUSE TYPE: PRE-1918 DETACHED						**SHORT DURATION FLOODING**							SOCIAL CLASS: AB					
	No	**UNIT**	**PERCENTAGE SUSCEPTIBLE TO DAMAGE**															UNIT COST (£)
DEPTH ABOVE GROUND FLOOR (M)			**-0.3**	**0**	**0.05**	**0.1**	**0.2**	**0.3**	**0.6**	**0.9**	**1.2**	**1.5**	**1.8**	**2.1**	**2.4**	**2.7**	**3**	
BUILDING FABRIC ITEM																		
PATHS & PAVED AREAS																		
Rake gravel, roll	0	M2	0	0	0	10	12	14	16	20	25	30	35	40	60	80	100	**2.44**
Paving and re-bed	10	M2	0	0	0	0	0	10	12	14	18	24	28	32	40	55	65	**12.77**
Asphalt finish	28	M2	0	0	0	0	0	0	1	1	2	2	5	10	15	20	35	**5.66**
Concrete finish	10	M2	0	0	0	0	0	0	0	0	1	1	2	2	5	5	10	**20.54**
Asphalt base & fill	28	M2	0	0	0	0	0	0	0	0	0	1	1	2	5	10	20	**13.88**
Natural stone	0	M2	0	0	0	0	0	0	5	10	12	14	16	18	20	25	30	**94.35**
Brick paviour	0	M2	0	0	0	0	0	10	12	14	18	24	28	32	40	55	65	**32.19**
		Sub Total (£)	**0**	**0**	**0**	**0**	**0**	**13**	**17**	**19**	**28**	**40**	**52**	**69**	**105**	**151**	**237**	
FENCES/GARAGES ETC																		
Single skin wall with piers	39	M2	0	0	0	0	0	0	1	5	10	20	30	45	60	80	100	**56.85**
Stone wall	0	M2	0	0	0	0	0	0	2	10	12	14	16	18	20	25	30	**105.45**
23 cm brick wall repair	39	M2	0	0	0	0	0	0	0	0	1	5	10	20	30	40	50	**122.10**
Rendering to walls	54	M2	0	0	0	0	0	5	10	15	20	25	30	35	40	55	60	**13.32**
Concrete post and panel	0	ML	0	0	0	0	1	2	5	15	25	35	48	59	73	85	100	**49.95**
Fence with arris rail and board	68	ML	0	0	0	0	0	0	0	5	15	25	35	45	55	65	75	**39.96**
Garage doors	0	1	0	0	0	0	5	10	15	30	50	60	90	100	100	100	100	**355.20**
Garden shed – new	1	1	0	0	0	0	0	0	0	0	0	0	0	0	100	100	100	**466.20**
Garden shed – repaired	1	1	0	0	0	2	5	10	15	18	20	50	80	95	0	0	0	**88.80**
Greenhouse – new	1	1	0	0	0	0	0	0	0	0	50	60	80	100	100	100	100	**610.50**
Gate	1	1	0	0	0	0	0	5	12	20	30	40	50	80	100	100	100	**127.65**
Timber garage	0	1	0	0	0	2	5	10	15	18	20	50	80	95	100	100	100	**2500.00**
Brick/concrete garage	0	1	0	0	0	5	5	10	15	20	25	30	35	40	50	65	80	**4500.00**
Brick and glass conservatory	0	1	0	0	5	5	10	10	15	15	25	30	40	50	55	65	75	**10000.00**
		Sub Total (£)	**0**	**0**	**0**	**2**	**4**	**51**	**123**	**396**	**1182**	**2002**	**2931**	**4222**	**5745**	**7045**	**8272**	

HOUSE TYPE: PRE-1918 DETACHED								**SHORT DURATION FLOODING**						SOCIAL CLASS: AB				
	No	**UNIT**	**PERCENTAGE SUSCEPTIBLE TO DAMAGE**															UNIT COST (£)
DEPTH ABOVE GROUND FLOOR (M)			**-0.3**	**0**	**0.05**	**0.1**	**0.2**	**0.3**	**0.6**	**0.9**	**1.2**	**1.5**	**1.8**	**2.1**	**2.4**	**2.7**	**3**	
BUILDING FABRIC ITEM																		
MAIN BUILDING																		
Pump out basement	1	1	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	**288.60**
Clean dry treat sub floor	1	1	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	**260.85**
Check dry cables sub floor	1	1	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	**127.65**
Clean gullies rod and flush drains	4	1	0	0	25	25	25	50	50	50	50	75	75	75	100	100	100	**61.05**
Rake and repoint brick	189	M2	0	0	0	0	0	0	0	0	0	5	10	12	15	20	25	**24.42**
Rendering to brick	54	M2	0	0	0	0	0	0	0	10	15	20	25	28	30	33	35	**19.98**
External render paint	54	M2	0	0	0	0	5	10	12	14	16	18	20	24	26	30	35	**5.16**
Glaze & paint ww's	29	M2	0	0	0	0	0	0	0	0	0	5	10	12	15	20	25	**52.72**
Clean silt	1	E	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	**38.85**
Repair ext door & frame	2	E	0	0	0	0	2	10	12	14	16	20	20	40	60	0	0	**72.15**
Replace glass	25	M2	0	0	0	0	0	0	0	0	0	0	5	10	12	15	20	**53.28**
New sash window	29	E	0	0	0	0	0	0	0	0	5	10	15	20	20	20	20	**299.70**
New casement	0	E	0	0	0	0	0	0	0	0	5	10	15	20	20	20	20	**266.40**
Paint external doors inside and out	6	E	0	0	0	0	0	5	10	12	18	20	22	24	26	28	28	**61.05**
Treat brick with anti fungal silicone	203	M2	0	0	0	0	10	15	20	25	30	35	40	45	50	58	75	**7.77**
		Sub Total (£)	**716**	**716**	**777**	**777**	**952**	**1135**	**1241**	**1443**	**2041**	**2996**	**3950**	**4732**	**5146**	**5584**	**6262**	
PLASTERWORK																		
Remove lath and plaster, replace & skim	379	M2	0	0	0	0	10	15	20	25	30	35	40	45	50	58	75	**21.98**
Repair and replace coving	0	ML	0	0	0	0	0	0	0	0	10	30	50	55	60	75	80	**4.99**
Block plaster remove & redo	203	M2	0	0	0	0	2	5	9	15	18	22	30	40	48	53	60	**16.09**
Stud partitions redo	348	M2	0	0	5	10	25	50	75	100	100	100	100	100	100	100	100	**17.48**
Special pre-fab item	0	ML	0	0	0	10	15	20	25	30	35	40	50	55	60	75	80	**5.33**
Take down and renew dry lining to solid wall	0	M2	0	0	0	5	10	30	60	75	100	100	100	100	100	100	100	**19.98**
Repair and replace moulded cornice	140	ML	0	0	0	0	0	0	0	0	10	30	50	55	60	75	80	**36.08**
		Sub Total (£)	**0**	**0**	**304**	**608**	**2419**	**4454**	**6522**	**8656**	**9675**	**11233**	**12921**	**13916**	**14847**	**16434**	**18332**	

HOUSE TYPE: PRE-1918 DETACHED						SHORT DURATION FLOODING							SOCIAL CLASS: AB					
	No	UNIT	PERCENTAGE SUSCEPTIBLE TO DAMAGE															UNIT COST (£)
DEPTH ABOVE GROUND FLOOR (M)			**-0.3**	**0**	**0.05**	**0.1**	**0.2**	**0.3**	**0.6**	**0.9**	**1.2**	**1.5**	**1.8**	**2.1**	**2.4**	**2.7**	**3**	
BUILDING FABRIC ITEM																		
INTERNAL FLOORS																		
Hardwood floor and tiling	139	M2	0	0	20	50	80	100	100	100	100	100	100	100	100	100	100	**77.70**
Sand & repair boards	157	M2	0	0	0	0	2	8	12	16	20	25	30	38	45	50	25	**6.66**
Skirtings average	140	ML	0	0	2	2	8	12	16	20	25	30	35	45	55	60	70	**13.88**
Chipboard flooring	0	M2	0	0	80	85	90	100	100	100	100	100	100	100	100	100	100	**17.98**
Floor boards redo	157	M2	0	0	0	0	0	0	0	1	1	1	2	5	10	50	75	**31.64**
Floor tiling strip	18	M2	0	0	20	40	60	80	100	100	100	100	100	100	100	100	100	**5.33**
Thermoplastic tiles	18	M2	0	0	20	40	60	80	100	100	100	100	100	100	100	100	100	**27.20**
Carpet grounds	123	ML	0	0	0	1	2	4	10	15	20	30	45	50	65	75	85	**1.34**
19mm x 100mm splayed and rounded skirting	0	ML	0	0	2	2	8	12	16	20	25	30	35	45	55	60	70	**6.94**
Take up and replace 50 to 75mm cement sand screed	0	M2	0	0	2	2	10	15	25	35	40	60	80	100	100	100	100	**14.98**
Take up and replace polystyrene floor insulation under screed	0	M2	0	0	2	2	10	15	25	35	40	60	80	100	100	100	100	**3.44**
		Sub Total (£)	**0**	**0**	**2316**	**5675**	**9171**	**11592**	**11839**	**12016**	**12163**	**12329**	**12553**	**12988**	**13529**	**15682**	**16873**	
JOINERY																		
Renew door (C2 DE)	0	E	0	0	0	0	0	0	0	0	0	0	0	0	0	100	100	**122.10**
Renew door (AB C1)	8	E	0	0	0	0	0	0	0	0	0	0	0	0	0	100	100	**299.70**
Patio doors	0	E	0	0	0	0	2	10	12	14	16	20	20	40	60	100	100	**1054.50**
Sink	2	E	0	0	0	0	0	0	0	0	0	10	20	25	30	35	40	**310.80**
Broom cupboard	1	E	0	0	0	0	0	10	12	24	50	75	100	100	100	100	100	**199.60**
Contract quality kitchen	0	E	0	0	10	20	50	75	100	100	100	100	100	100	100	100	100	**2220.00**
Intermediate quality kitchen	0	E	0	0	10	20	50	75	100	100	100	100	100	100	100	100	100	**3885.00**
Good quality kitchen	1	E	0	0	10	20	50	75	100	100	100	100	100	100	100	100	100	**5550.00**
		Sub Total (£)	**0**	**0**	**555**	**1110**	**2775**	**4182**	**5574**	**5598**	**5650**	**5762**	**5874**	**5905**	**5936**	**8365**	**8396**	

HOUSE TYPE: PRE-1918 DETACHED							SHORT DURATION FLOODING						SOCIAL CLASS: AB					
	No	**UNIT**	**PERCENTAGE SUSCEPTIBLE TO DAMAGE**															UNIT COST (£)
DEPTH ABOVE GROUND FLOOR (M)			**-0.3**	**0**	**0.05**	**0.1**	**0.2**	**0.3**	**0.6**	**0.9**	**1.2**	**1.5**	**1.8**	**2.1**	**2.4**	**2.7**	**3**	
BUILDING FABRIC ITEM																		
DECORATION																		
Wash down	551	M2	0	0	0	5	10	15	30	45	60	80	100	100	100	100	100	**1.67**
Paint windows	29	M2	0	0	0	0	0	0	0	0	10	15	20	30	40	50	60	**12.10**
Paint doors	24	M2	0	0	0	0	0	5	10	15	18	20	28	30	40	60	80	**8.37**
Limewash cellar/int. Garage	50	M2	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	**3.44**
Emulsion paint to plaster	0	M2	0	0	0	100	100	100	100	100	100	100	100	100	100	100	100	**3.99**
Gloss paint walls	0	M2	0	0	0	100	100	100	100	100	100	100	100	100	100	100	100	**5.33**
Strip paper prepare	551	M2	0	0	0	50	100	100	100	100	100	100	100	100	100	100	100	**3.05**
Hang paper only	0	M2	0	0	0	50	100	100	100	100	100	100	100	100	100	100	100	**3.61**
Hang vinyl paper	551	M2	0	0	0	50	100	100	100	100	100	100	100	100	100	100	100	**2.01**
		Sub Total (£)	**172**	**172**	**172**	**1612**	**3052**	**3108**	**3256**	**3404**	**3583**	**3789**	**4007**	**4046**	**4101**	**4176**	**4251**	
SERVICES																		
Repair plumbing	1	E	0	0	0	0	0	0	0	10	15	20	25	30	35	40	50	**55.50**
Overhaul boiler	1	E	0	0	0	0	0	0	0	0	0	0	10	20	100	100	100	**244.20**
Thorough overhaul of boiler and/or insulation	1	E	0	0	0	0	0	0	0	0	0	0	100	100	100	100	100	**388.50**
Test house electrics	1	E	0	0	100	100	0	0	0	0	0	0	0	0	0	0	0	**133.20**
Overhaul/repair to all electrical installation including power lighting, TV and telecom	1	E	0	0	10	15	50	50	75	75	100	100	100	100	100	100	100	**2053.50**
		Sub Total (£)	**0**	**0**	**339**	**441**	**1027**	**1027**	**1540**	**1546**	**2062**	**2065**	**2480**	**2507**	**2706**	**2708**	**2714**	
		Total (£)	**888**	**888**	**4463**	**10225**	**19400**	**25563**	**30112**	**33079**	**36385**	**40215**	**44767**	**48386**	**52115**	**60145**	**65336**	

Appendix C: Depth / damage matrix of household items (MCM Appendix 4.1)

***Susceptibility curve, depth in m**

Item	AB Ownership (%)	Unit Cost (£)	ARV	0.05*	0.1*	0.2*	0.3*	0.6*	0.9*	1.2*	1.5*	1.8*	2.1*
Domestic cleanup	100	9985	100	57	57	100	100	100	100	100	100	100	100
Living room furniture	91	4927	50	5	10	100	100	100	100	100	100	100	100
Audio separates	18	3300	50	0	0	0	15	40	100	100	100	100	100
Laptops	3	2552	65	20	20	20	20	20	100	100	100	100	100
Carpet	84	2500	60	100	100	100	100	100	100	100	100	100	100
CD-albums	58	2500	100	10	40	60	70	85	95	100	100	100	100
Toys	30	2191	50	20	40	50	65	75	85	90	100	100	100
Clothes, female	100	2155	50	10	15	20	30	40	75	75	90	90	100
Books	79	2124	100	5	15	25	35	55	65	75	90	100	100
Colour TV, large	98	2040	55	0	0	0	50	100	100	100	100	100	100
Second tv	38	2040	55	0	0	0	50	100	100	100	100	100	100
Other bedroom furniture	81	1985	50	10	10	100	100	100	100	100	100	100	100
Home computer	63	1418	65	20	20	20	20	20	100	100	100	100	100
Clothes, male	100	1354	50	10	15	20	30	40	75	75	90	90	100
CD-singles	32	1250	100	10	40	60	70	85	95	100	100	100	100
Video camera/ camcorder	26	1200	55	10	20	25	50	75	100	100	100	100	100
Washing machine	75	1021	50	0	0	100	100	100	100	100	100	100	100
Gas cooker (free standing)	26	964	50	0	5	100	100	100	100	100	100	100	100
Food stocks	100	923	100	0	0	25	50	75	100	100	100	100	100
Pre-recorded audio tapes	43	875	100	10	40	60	70	85	95	100	100	100	100
Fitted bedroom	43	825	50	10	10	100	100	100	100	100	100	100	100
Dining room furniture	60	802	50	10	10	100	100	100	100	100	100	100	100
Bicycle	42	766	50	0	20	30	40	40	40	40	40	40	40
Fridge-freezer	95	736	50	0	10	100	100	100	100	100	100	100	100
Gym equipment	20	734	50	30	50	60	75	80	100	100	100	100	100
Sports equipment	23	692	50	30	50	60	75	80	80	80	90	90	90
Built in electric ovens	38	664	50	0	0	20	50	100	100	100	100	100	100
Electric cooker (free standing)	23	652	50	0	0	5	100	100	100	100	100	100	100
Washer dryer	14	638	50	0	0	100	100	100	100	100	100	100	100
Bed, double	100	620	50	0	0	30	50	100	100	100	100	100	100
Carpet underlay	84	600	55	100	100	100	100	100	100	100	100	100	100
Tower/rack system	14	595	50	0	0	15	40	100	100	100	100	100	100
Built in gas ovens	7	553	50	0	0	20	50	100	100	100	100	100	100
Music centre (midi system)	36	539	50	0	0	0	15	40	100	100	100	100	100
Built in electric hobs	20	539	50	0	0	0	0	50	100	100	100	100	100
Children's clothes	30	487	50	10	15	20	30	40	75	75	90	90	100
Gas heater	41	467	50	0	33	65	100	100	100	100	100	100	100
Garden tools, motor	8	462	50	0	15	30	50	60	75	75	75	75	75
Dishwasher	40	442	50	0	0	100	100	100	100	100	100	100	100
Central heating	95	381	80	0	0	0	0	30	40	50	50	50	50
Refrigerator	68	373	50	0	10	100	100	100	100	100	100	100	100
Tumble dryer	39	360	50	0	0	100	100	100	100	100	100	100	100
Rug, large	58	350	60	20	100	100	100	100	100	100	100	100	100
Freezer	54	335	50	0	0	15	100	100	100	100	100	100	100
DVD player	16	312	55	15	60	85	95	100	100	100	100	100	100
Luggage	83	307	100	10	10	10	20	30	40	40	40	70	70
Record player	63	304	50	0	15	40	40	40	100	100	100	100	100
Curtains	67	300	50	0	0	0	0	15	33	70	100	100	100
Total		**62139**											

Appendix D:
Average clean up costs at flood depths (MCM Tables 4.4 & 4.5)

Average Clean up Costs at flood depths below 0.1m (MCM Table 4.3)

Clean-up component	Unit cost (£)	No. units	No. days	Other Costs (£)	Total (£)
Pressure washer	30 p/d	1	1		30
Aquavac/transformer	30 p/d	1	1		30
Decontamination	100 p/d	2	2		200
Skip	176 p/w	1	7		176
Storage cabin	220 p/m	1	28	195 Delivery - 195 Collection	610
Blower heater	112 p/m	2	28		224
Air mover	180 p/m	2	28		360
Dehumidifier	340 p/m	4	28		1360
Labour costs					
Pressure washer	195 p/d		1		195
Aquavac	195 p/d		1		195
Decontamination	195 p/d		2		390
Carpet removal	195 p/d		2		390
Flooring removal	195 p/d		2		390
Skip loading	195 p/d		1		195
Dehumidifier maintenance	35 p/d		28		980
Total					**£ 5725**

Average Clean up Costs at flood depths above 0.1m (MCM Table 4.5)

Clean-up component	Unit cost (£)	No. units	No. days	Other costs (£)	Total (£)
Pressure washer	30 p/d	2	2		60
Aquavac/transformer	30 p/d	2	2		60
Decontamination	100 p/d	3	3		300
Skip	176 p/w	2	7		352
Storage cabin	220 p/m	1	56	195 Delivery - 195 Collection	830
Blower heater	112 p/m	2	56		448
Air mover	180 p/m	2	56		720
Dehumidifier	340 p/m	4	56		2720
Labour costs					
Pressure washer	195 p/d		2		390
Aquavac	195 p/d		2		390
Decontamination	195 p/d		3		585
Carpet removal	195 p/d		2		390
Flooring removal	195 p/d		2		390
Skip loading	195 p/d		2		390
Dehumidifier maintenance	35 p/d		56		1960
Total					**9985**

Appendix E: Flood damage components for non-residential (MCM Annexe 5.1)

Retail - shops, stores and retail warehouses

Table 5.1 Flood Damage Components for Retail Codes 211 (High Street Shops), 213 (Superstores/ Supermarkets), 214 (Retail warehouses)	
High Street shops: e.g. fashion and clothing stores; shoes, and sports goods retailers; electrical goods suppliers; video rental shops; mobile telephone shops; those selling cosmetics, pharmaceuticals and toiletries; general household goods, hardware and soft furnishings; bookstores and stationers; wine merchants; charity shops; newsagents shops; and discount 'All for a pound' stores. **Superstores/Supermarkets:** e.g. medium to large high street or out of town supermarkets. **Retail warehouses:** e.g. furniture stores, electrical household goods, motor vehicle accessories, toys and games, computing supplies.	
Services (in addition to basic):	**Moveable Equipment:**
Generators	Racking e.g. for clothing, books
Sprinkler pumps and equipment	Storage units
Lifts	Counters
Escalators	Computers, Photocopiers
Electric shutters/gates	Tills (mostly computerised)
Overhead door heaters	Furniture (tables, chairs, sofas, desks)
Satellite systems	Display tables, Display equipment/gondolas
Mobile telephone boosters	Trolleys, Baskets and stands
Aerials	Pallet trucks, Ladders, Forklifts
Tagging equipment	Catering/baking equipment
Refrigeration equipment	Packing machinery, Delivery vehicles
Fixtures and Fittings	**Stock**
Freezers/chiller cabinets	Clothing
Shelving and racking	Shoes
Counters/service desks	Clothing accessories
Display equipment/gondolas	Toiletries
Seating	Cosmetics
Signage	Pharmaceutical products
Carpets and floor covering	Stationary
Wall coverings	Books/magazines/greetings cards
Cupboards/cabinets	Household goods and soft furnishings
Partitioning	Electrical goods and equipment
Suspended ceilings	DVDs/videos/CDs/cassettes/computer games
Plasma screens	Mobile telephones and accessories
Light fittings	Office furniture and accessories
Bathroom fittings	Fresh foodstuffs/dry groceries/confectionery
Kitchen fittings	Wine, spirits, beer, soft drinks
Safes	Toys
ATMs/cash machines	DIY home improvement materials and goods
Fire prevention equipment	Tools
Dishwashers	Furniture (including garden furniture)
Scales	Bathroom/kitchen fittings
Rotisseries	Lighting
Photo processing equipment	Bicycles and vehicle components
Dry cleaning equipment	Indoor and garden plants, gardening equipment
Sanitary fittings (toilets, basins)	

Manufacturing / engineering workshops

Table 5.12 Flood Damage Components for Code 810 (Workshops)	
Data reported is from printing, furniture manufacturing, and engineering workshops	
Services (in addition to basic):	**Moveable Equipment:**
Air and dust extractors	Office furniture and equipment
Compressed air supply	Computers
Boilers	Printers
	Air compressors
	Forklifts
	Generators
	Vehicles (vans, lorries)
	Plant
	Office furniture
	Hand tools, jigs, cutters
	Cutters blocks and cutting sheets
	Welders
	Pallets
Fixtures and Fittings	**Stock**
Woodworking and joinery machines	Raw materials (e.g. paper, inks, film chemicals, timber, boards, veneers, sheet steel)
Moulders	Work in progress
Mortices	Finished goods (brochures, leaflets, furniture etc.)
Saws, planers	Oils and diesel
Stair strenchers	Protective clothing, boots
High precision electronic machines	Tools
Paint spray booths	Printed circuit boards
Lays	Motors, drivers
Welders	Polythene sheeting
Drills	Plastic netting
Guillotines	Galvanised steel tubes
Ring rolling equipment	
Press breaks	
Partitioning	
Benches	
Heaters	
Shelving/racking	
Sanitary fittings (toilets, sinks)	
Kitchen fittings (sinks etc.)	
Refrigeration equipment	
Spotlighting	
Carpets	

Appendix F: Carbon calculator results - flood damage curve “multiplier”

For a breakdown of the carbon footprint of individual items and the carbon calculator developed for this study to assess the flood damage curve ‘multiplier’, refer to the calculator spreadsheet accompanying this report.

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