

# NaFRA 2007 Technical Note

## Economic Calculations HR Wallingford (April 2008)

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## 1 Introduction

The RASP methodologies and associated source-pathway-receptor models are now well established and recognised within flood risk management. The RASP High Level Methodology *plus* (HLM+) considers a wide range of water level loading conditions on flooding systems and simulates multiple scenarios of defence breaching or failure in order to exhaustively assess the flood risk at any given location within the floodplain.

The primary result from the RASP HLM+ is a series of grid squares covering the flood plain, each with an associated probability of inundation. This headline probability of inundation is the probability of the onset of flooding, however, within the model, a discrete water depth and probability is calculated for each event and scenario, thus the impact of flooding on many different receptors can be evaluated.

The National Flood Risk Assessment (NaFRA) is based on the RASP HLM+ approach, which has been progressively improved over a number of years. During 2007 an intensive development programme was undertaken on the data, methods and tools used for NaFRA. This included a number of key improvements to the overall approach.

The Consequences Sub Group (CSG) was established during 2007 to follow on from the work of the Economic Sub Group (ESG) during 2006. The main aim of the CSG was to develop and improve methods for understanding the consequences of flooding using the NaFRA approach. One area of work was to improve the accuracy of, and to better understand, the NaFRA Expected Annual Damage (EAD) results.

This technical note builds upon the NaFRA 2006 Technical Note. It follows detailed research into a number of issues that were identified during 2006, the findings of which are documented in a Technical Note from Halcrow (30/01/2008). This Technical Note describes the improvements to the economics calculation approach and to the tools developed to enact the approach for NaFRA and other RASP applications.

## **2 Recommended Improvements to 2006 approach**

### ***2.1 Properties added to the NPD using MasterMap outlines.***

Analysis of the NPD2 data alongside aerial photographs and detailed mapping has shown there to be a substantial number of properties missing from the database. Many of the properties are so called “unaddressable” which are not present in NPD2 since they are not included in the Ordnance Survey Address Point dataset – one of the primary sources of NPD2. A good proportion of these are non-residential properties located on industrial estates.

The CSG has undertaken a detailed analysis of the issue and has recommended a process that can be adopted to augment the NPD2 data with these missing properties. The analysis and the proposed approach are described in the Halcrow Technical Note.

To summarise the approach, OS Mastermap has been used to identify properties that are not recorded in the NPD2 database. These properties have been categorised with the DCode of ‘XTRA’ and the Floor Area of type ‘X’ has been used to accrue damage for these properties.

It should be noted that there is presently outstanding work to be completed since type ‘X’ is the weighted average depth damage curve for all non-residential properties while the XTRA properties are made up of both residential properties and commercial properties. There is some research outstanding which should provide evidence that can be used to establish rules to determine whether an ‘XTRA’ property is residential or commercial. The bulk class, ‘DCODE’ value and corresponding MCM code should be determined using the findings of this research.

### ***2.2 Calculating basement damage for residential properties.***

The Census data table UV61 provides information relating to the number of properties in an Output Area and the lowest levels of those properties.

The Output Areas are provided as spatial datasets which can be analysed in conjunction with the enhanced NPD2 property data. It is possible to allocate each property in the enhanced NPD2 dataset with its Output Area and to calculate summary statistics.

A factor 'PC\_Basemt' has been calculated and assigned to the enhanced NPD2 property data. This is a simple calculation of the percentage of properties which have basements. It therefore does not take into consideration the floor level flag.

The following procedure is proposed for calculating the basement damage for residential property;

- Remove the number of properties with the floor level flag 'dB' in each Census Output Area from the calculation of the percentage to eliminate double counting.
- Rather than applying the percentage 'PC\_Basemt' uniformly to all valid properties in an Output Area, use a hierarchy such that those properties most likely to have a basement level are allocated basement damages first. For example, if 5 properties are recorded in the Census data with basement as the lowest level and the NPD lists 3 properties with the floor level flag 'pB' and 3 with 'dG' then basement damages should be applied to 100% of the floor area of the three 'pB' properties and 66.6% (2basements remaining /3 properties) of the three 'dG' properties.
- For those properties that don't have the floor level flag 'dB', apply basement damages to an area smaller than that of the floor area value using a pre-defined percentage reduction. This will reflect that basements in ground floor properties are not usually as big as the ground floor area. Further research is required to provide evidence for this.
- Further variables in the Census table UV61 (0004-0007) identify those properties with the lowest floor level as first floor. This count can be used to influence the inclusion (or not) of those properties with the floor level flag 'pU'.

Ideally, the 'PC\_Basemt' field in the NPD2 dataset should be populated correctly at source following the approach described above, such that the definitely basement properties are given a zero value and not counted again, the remainder of the basements in the census data are applied as a factor by floor level class such that the most likely basement properties are allocated factors of basement damage.

### **2.3 Screening residential floor area values**

The resulting floor areas for each type of property, (terrace, detached etc.) should be checked against the average floor areas for those types. Any values greater/less than  $\pm 50\%$  of the average floor area value should be considered outliers. These outliers should be capped at either  $\pm 50\%$  of the average floor area value respectively.

### 3 Approach Adopted

The CSG agreed to adopt the following for the primary method to obtain EAD for NaFRA 2006 and NADNaC. All of the residential and non-residential properties within each Impact Cell (IC) will be matched with the appropriate MCM depth damage table and an IC aggregate depth damage curve will be produced. The EAD is calculated within the RASP HLM+ model run using impact cell specific depth-damage data.

The following methodology, based on the above, sets out the adopted approach to calculating EAD for NaFRA 2008 that has been approved by the CSG.

### 4 Methodology

Within the National Property Data (NPD) and in the MCM, the distinction is made between residential properties and non-residential properties. The method adopted is to retain this distinction and calculate the NRP and RP EAD within the RASP HLM+ model run.

The requirement therefore is a two stage approach;

1. The NaFRA 2008 RASP HLM+ model to calculate both residential and non-residential EAD from saline and fresh water flood events
2. In support of 1 above, preparation of residential and non-residential, saline and freshwater depth-damage curves for each IC.

#### 4.1 The NaFRA RASP HLM+ model.

Two tables will be prepared as a pre-process. These will be; tblCellDamagePerDepthRes for residential and tblCellDamagePerDepthNRP for non-residential properties and will be used to store the input depth damage curves for each Impact Cell. The format for the tables is as follows;

tblCellDamagePerDepthRes & tblCellDamagePerDepthNRP

Field Name	Type	Description
CellID	int	Unique id value for the IC
Depth	real	Depth associated with damage values
DefSys1DamageBE	real	best cost for freshwater events
DefSys1DamageHI	real	upper bound cost for freshwater events
DefSys1DamageLO	real	lower bound cost for freshwater events
DefSys2DamageBE	real	best cost for saline events
DefSys2DamageHI	real	upper bound cost for saline events
DefSys2DamageLO	real	lower bound cost for saline events

The above tables completed appropriately will enable the EAD for non-residential and residential properties to be calculated for both fluvial and saline events.

These tables will be prepared by the methodology described in 4.2

Capping may be undertaken using a query on the table CellPropertyScreened to calculate the sum of the property value by 'CellID' and capping any Cell EAD that exceeds the sum of the property value to equal the sum of property value.

## **4.2 Preparation of residential and non-residential, saline and freshwater depth-damage curves for each IZ**

The MCM published in 2006 and associated data tables are to be used in conjunction with the NPD data and the IC grid representation of the floodplain to derive the depth damage tables described above. The way in which these datasets are to be combined to achieve these tables are as follows.

The recently updated (2005/2006) NPD2 dataset comprises a record for each property in the Ordnance Survey AddressPoint record. Each property is categorised as residential or non-residential and further sub classification describes either the type of residential property or the type of business as appropriate. Each property has been assigned a valuation and a floor area. The valuation has come from a reasonably reliable source The Valuation Office database and the floor area has been obtained by matching the AddressPoint coordinate record with the building polygon within the Ordnance Survey MasterMap vector mapping.

The NPD has been augmented with additional records generated from the centroids of OS MasterMap building outlines which have no corresponding NPD record. This has been described in 2.1 above.

The MCM data tables are statistically representative depth damage lookup tables for each sub-class of property. Tables exist for saline and freshwater flooding, for properties with basements and without basements, and for short and long duration flood events. The values are based on damages to building and contents and are quoted by square metre of floor space.

### **4.2.1 NPD screening**

Previous work has shown that significant errors in EAD can be obtained as a result of errors in the floor area value in the NPD. For this reason, an initial NPD data screening phase is to be undertaken by Halcrow Group Limited (HGL) to compare the values of floor area and valuation with national statistics for each property subclass and to flag outliers and add regional or national averages as alternatives to be used in the subsequent analysis.

- **Residential Properties**

The floor area for residential property is extracted from OS MasterMap polygons. Properties with the floor level flag 'pU' or 'rU' are not assigned a value. Where multiple addresses with the floor area flag 'dG' or 'pG' occupy the same building footprint, the area of that footprint is divided equally between those records in the NPD.

Properties with no floor area value will be assigned an average floor area by type of property. If the type of property is not known then the average type 'AVG' will be used. Any property without a floor level flag will be included in the analysis as a standard ground level property.

- **Non Residential Properties**

Initial screening will be undertaken to populate the NPD data that have zero or null values in the Floor Area or Valuation field with the mean value for that class.

Thereafter, properties where the value of floor area and the valuation are 3 standard deviations or more apart are flagged as outliers. Outliers will have also have the valuation and floor area substituted by mean values for the class. See 4.2.3 below for more detail.

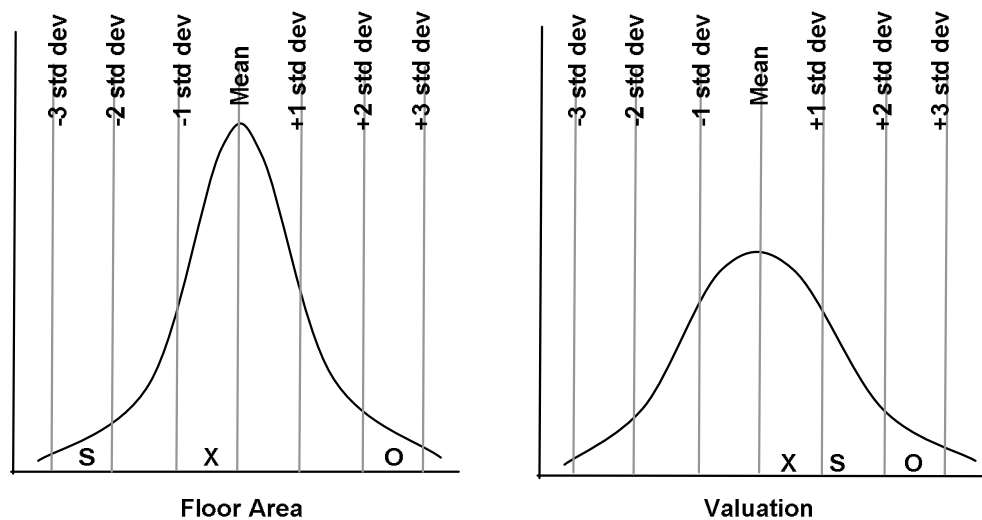


Figure 1. Property floor area vs. valuation pre-screening example.

In the pre-screening example shown in Figure 1. O is valid since it has large area and large valuation. X is also valid. S however is not valid since there are more than 3 standard deviations between the floor area and the valuation.

## 4.2.2 Property Categorisation

- **Residential Properties**

The MCM tables and NPD2 dataset allow the residential properties to be classified. These will be categorised as;

- Detached (DET)
- Semi-detached (SDET)
- Terraced (TERR)
- Flat (FLAT)
- Average (AVG)

Residential properties have additionally been sub-classified within the MCM tables (e.g. Victorian terraced property). However, NPD2 dataset is not currently populated to the detailed level from which this additional data can be exploited. Although the data can be obtained to utilise this sub-classification detail, the CSG agreed that the risk to NaFRA2006 and NADNaC schedule was not acceptable. This will be considered for future campaigns.

The classified residential depth damage tables will be used with the NPD2 in the analysis. If no classification value exists, then the residential average damage tables will be used.

- **Non Residential Properties**

The non-residential properties are classified into 4 Bulk Classes (and a non-bulk class), 60 MCM categories (codes) and 346 Valuation Office codes. The Valuation Office codes will be matched between the NPD data and the MCM Tables.

- The notional VOCode value 'X' (unknown or no data) is given an MCM Code value of '999' and a notional Bulk Class value of 'X' (non-bulk).
- The notional VOCode value 'XTRA' (property extracted from OS MasterMap) is given an MCM Code value of '999' and a notional Bulk Class value of 'X' (non-bulk).
- MCM Codes 217, 224, 238, 411, 412, 413, 513, 625, 690 are missing from the VOCode table, that is, there is no associated VOCode. Although Depth damage curves exist, these properties are not included in the analysis since they are not identifiable in the NPD dataset.

### 4.2.3 Floor Area and Valuation

The MCM tables quote the cost of flood damage per square metre of floor area for NRP property. For residential property the MCM tables quote both the absolute cost per property class and the damage per square metre. The cost per metre squared will be used. To build the depth damage curve for each impact cell, the product of the property floor area and its damage will be calculated through the depth profile.

Each property is assigned a floor area, valuation, value standard deviation and floor area standard deviation using the data from the NPD and the lookup tables. Each property is also assigned a set of damage curves, each curve related to a particular MCM Code category (e.g. 211 = high street shop) or category average (e.g. 21 = shop/store).

Average Residential property valuations have not been updated to 2006 by request from Defra/EA.

The logic used is as follows:

- **Non Residential Properties**

For all properties where the Valuation Office Code is not residential (DCode not = "RES"):

1. If a property has no Valuation Office Code then it is disregarded. (This should be rare and is listed for completeness).
2. Attribute an MCM Code to the property (using the VOCode table which relates the two code sets).
3. If a property has a VOCode which does not match an MCM Code (on the VOCode table) then disregard it (e.g. advertising hoardings, VO Code CA).
4. Assign a bulk class (retail, office, industry or warehouse) to the property using the VOCode table (which relates bulk classes to VOCodes).
5. Any property without a bulk class is regarded as non-bulk.
6. If a property has no (or 0) floor area then:
  - i) Assign the MCM code specific default floor area ("Av\_Area" in the table "MCM\_code") if this is not available then assign the Bulk Class average floor area (from the Bulk\_Class table) if the property has no bulk class, then use the non-bulk class floor area (X in the bulk class table).
  - ii) Reset the floor area standard deviation (FloorAreaSd) to 0 to prevent the replacement of valid valuations with default values where the floor area has been modified from null to default values.

7. If a property has the VO code of CC (caravan park) then the depth damage curves for CC are not representative since these reflect the damage to each caravan per square metre, whereas the property and associated floor area listed in NPD will be obtained from the fixed property below the address point, which may be the toilet block, games room or reception area etc. The VOCode of X (all NRP default) is to be used for this code.
8. If a property has no (or 0) valuation then:
  - i) Assign the valuation using its Bulk Class (from the Bulk\_Class table) if the property has no bulk class, then use the non-bulk class valuation (X in the bulk class table).
  - ii) Reset the valuation standard deviation (ValuationSd) to 0 to prevent the replacement of valid valuations with default values where the floor area has been modified from null to default values.
9. Assign a set of damage curves to the property (by linking from MCMCode.MCMCurve to Flood\_Damage\_Curve\_Non\_Res.MCMCode).

London has a much higher than average property value per bulk class. A possible improvement would be to introduce a weighted average value per bulk class for London (or the South East).

- **Residential Properties**

For All Properties where the Valuation Office Code indicates residential (DCode = "RES"):

1. If the residential property has no valid residential type (i.e. no "ResType" or has a "ResType" which does not match one in the "Residential\_Average\_Area" table) then assign it an 'average' type of "AVG".
2. If a property has no (or 0) floor area then:
  - i) Assign the average floor area for its type (from the "Residential\_Average\_Area" table).
  - ii) Reset the floor area standard deviation (FloorStdDev) to 0.
3. If a property has no (or 0) valuation then:
  - i) Assign an average valuation by county (using the valuation from "RESVAL05" in the "Res\_Type\_Val" table by matching the "County\_LA" and "Res\_Type").
  - ii) Reset the valuation standard deviation (ValuationSd) to 0.
4. Assign a set of damage curves to the property (by linking from the property's "ResType" to the Flood\_Damage\_Curve\_Res table).

#### **4.2.4 Ground Level and Threshold level**

The use of actual property ground level was considered by the CSG who agreed that the data available (i.e. Nextmap) was not accurate enough to support its inclusion in the 2006 campaign. Therefore, the ground level for each Impact Cell will be assumed for all corresponding properties. This is the mean ground level obtained from the Nextmap data within each 1km grid square of the floodplain.

The vertical reference frame used within MCM tables is the property threshold. Therefore, there needs to be an adjustment to the property level in order to compensate for the height of the threshold above the ground level and thus apply the depth damage data correctly. Previous analysis (ref Anglian analysis - J Chatterton, 29/05/2006) has shown average property threshold to be 0.28m. The CSG has agreed that a threshold of 0.25m will be adopted for the purpose of the current analysis.

In the MCM approach and corresponding tables, minor damages are incurred before the flood water reaches the property threshold. These are costs incurred as a result of damage to sub floors, pointing, cables, gullies, drains etc. Once the flood depth rises above 0m, the cost of damage rapidly increases as can be seen in Figure 2.

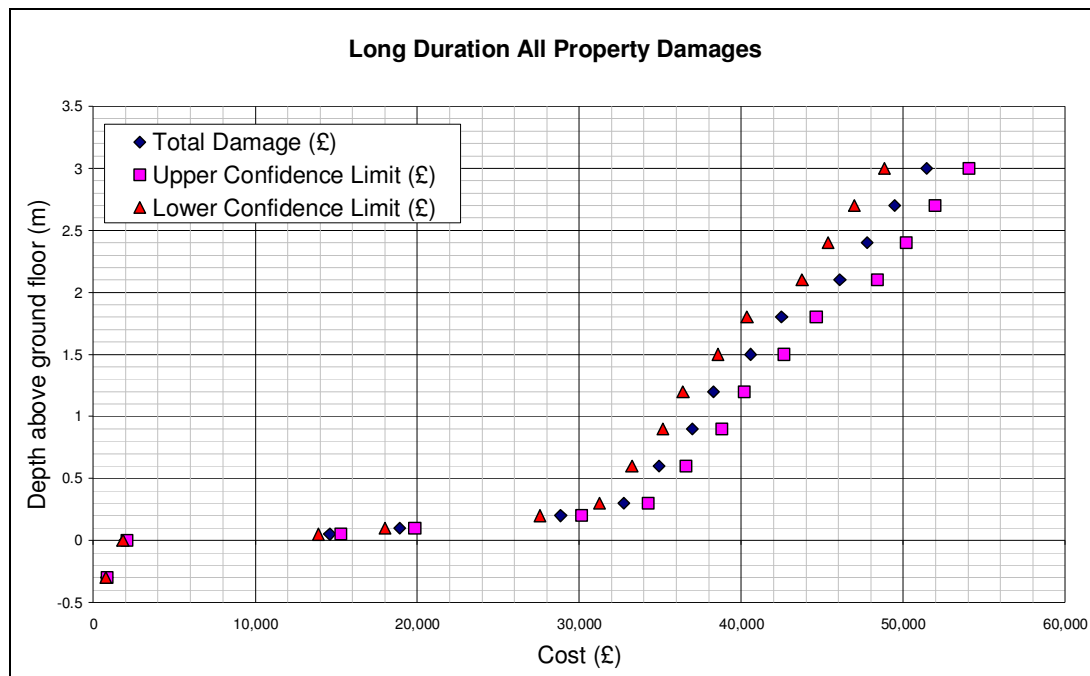


Figure 2. MCM Depth Damage curve for All Residential Property – Long Duration events.

It can be seen that between 0m and 20cm above the threshold, the cost of damages to residential property rises from £2,000 to near £30,000. It is therefore critical that the approach to ground level and threshold level is described in detail and implemented carefully.

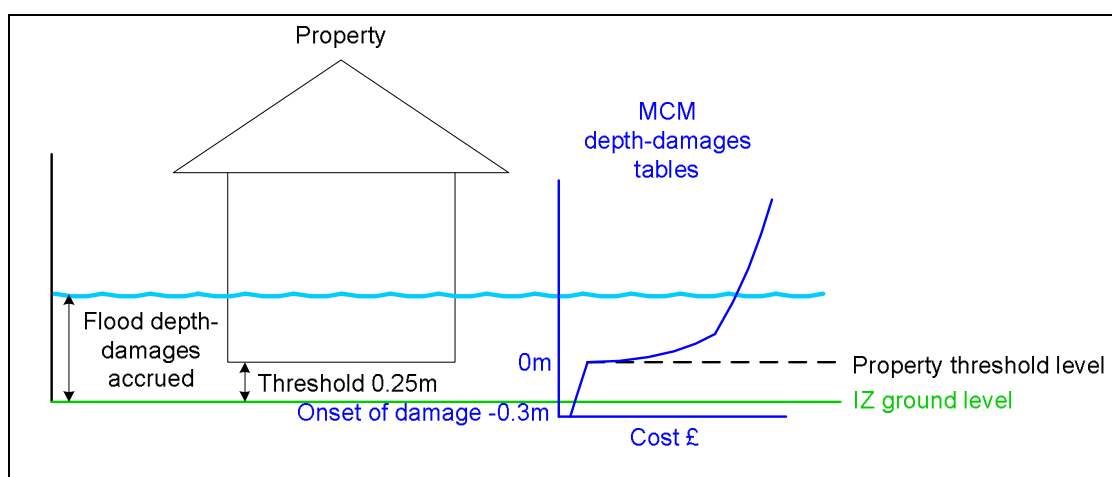


Figure 3. Schematic diagram of the comparable datums used for residential properties, the Impact Zones and the corresponding damage tables.

Figure 3 shows a schematic diagram describing the vertical relationships between the Impact Zone and associated flood depths, the property and the MCM tables.

In this schematic it can be seen that the property is raised by 0.25m above the ground level, representing the threshold. The MCM tables consider damage below the threshold and that damage is accrued for all inundation events above ground level, even when the flood water is below the property threshold.

#### **4.2.5 Floor Level**

There are a number of categories used within the NPD dataset which allow the consideration of the floor level of a particular building. These will be treated as follows.

a. Definitely Basement(dB)

The flag dB refers to definitely basement where the complete property is below ground level. The threshold is applied as with all other properties and damage at flood depths below the threshold are read directly from the corresponding MCM table. When the flood depth exceeds the threshold, it is assumed that there is sufficient depth to completely fill the property and so the average ceiling height (2.2m) needs to be added to the water depth where water depth is greater than 0.25m.

b. Potential Basement (pB)

These are included in the analysis but treated as standard ground-level properties.

c. Definite Ground (dG)

These are included in the analysis and treated as standard ground-level properties.

d. Potential Ground (pG)

These are included in the analysis and treated as standard ground-level properties.

e. Potential Upper (pU)

Properties with the flag pU for potential upper floor are not included in the analysis.

f. Recorded Upper (rU)

Properties with the flag rU for recorded upper floor are not included in the analysis.

g. Null or any other value

If the field is null or has any value other than the six listed above the property will be included in the analysis and treated as a standard ground-level property.

#### **4.2.6 Residential basement flooding**

Properties with the floor level flag 'dB' will be dealt with as described in 4.2.5 above. Properties with the floor level flag 'pB', 'dG', or 'pG' may accrue basement damages additional to the standard ground floor damages. Basement damages will be applied to a percentage of the floor area as defined in the field PC\_Basemt. This percentage is derived using 2001 Census data at Output Area level that gives the number of properties with their lowest floor level as basement (table UV61, variable 0002). The percentage is derived by dividing this number of properties by the total number in the output area.

#### **4.2.7 Non-residential basement flooding**

Properties with the floor level flag 'dB' will be dealt with as described in 4.2.5 above. No other basement damages will be accrued.

## 4.2.8 Long duration events

Although there are MCM tables specific to long duration flood events, the analysis will only consider implementing damage calculations based on the short duration tables. This is due to the uncertainty inherent in estimating the duration of an event based on its flood depth.

## 4.2.9 Saline and fresh water damage tables

Table 5.8 in the MCM quotes uplift factors by depth for damages from coastal flooding. In order to exploit this level of detail in the reporting, separate depth damage curves will be prepared for saline and for freshwater flooding in each impact zone. When the RASP HLM+ model runs, it will read from the freshwater depth damage curve for flooding from fluvial defence systems and from the saline damage curve when considering coastal flooding systems.

Note: Table 5.8 relates to NRP. It will be used to uplift cost of damage for both residential and non-residential property.

## 4.2.10 Depth Damage Curves for Non-Residential Property

Depth / damage curves have been produced for non-residential property classifications as follows:

- The depth damage curves link each MCM code to preferred damage values thus showroom (code 215) does not have a specific depth damage curve and so the weighted mean for shop and store (21) is preferred.
- There are MCM codes where a preferred surrogate is used to represent the type of property rather than using the weighted average e.g. 660 (Hospital) uses 311 (High Tech Office) as a surrogate to represent the potential for high tech equipment and crucial nature of the facility. A full list of preferred damage values is found in the table "MCMcode"
- Other MCM curves with no depth damage data such as sports grounds and playing fields assume a nominal damage of up to £25 per m<sup>2</sup>
- Some non-residential MCM Codes adopt the same curve for all of HIGH, Indicative and LOW. For example:
  - i) 420 (land used for storage) uses the LOW curve from 410 (warehouse).
  - ii) 830 (Heavy Industry) and 840 (STW) use the LOW curve from 810 (workshop).
- HIGH, Indicative and LOW curves for some MCM Codes are exactly the same.

## 4.2.11 Source Datasets

Full details of the datasets used in the process are as follows:

- Average property valuations by local authority from the Land Registry Office.
- Non Residential Bulk Class average valuation from Commercial and Industrial Floorspace and Rateable Value Statistics (provisional) 2004 for England and Wales, December 2004.
- Bulk Class average area from the MCM.
- Flood Damage Curves (both residential and non-residential) MCM
- MCM Code data from Multicoloured manual table 5.12.
- Residential Average Area from MCM
- Saline Uplift from Multicoloured manual table 5.8.
- VOCode / MCMCode / Bulk Class relationships from MCM, supplemented by John Chatterton.
- UK Census 2001, table UV61, variables 0001 and 0002.

## 4.2.12 Table Revisions

Revision Number	Description
Economics_Lookup_R01r01_July2006	Base data content and table design.
Economics_Lookup_R01r02_July2006	Additional tables following completion of module coding.
Economics_Lookup_R01r03_July2006	Additional PropertySD table population.
Economics_Lookup_R01r04_July2006	Changes to the Valuation by bulk classes (previous tables were RV these values are now capital values) and non-residential depth damage curves following discussions with John Chatterton.
Economics_Template_R01r06_Feb2008	Added field 'PC_Basemt' to table 'CellProperty'. Added a record to table 'VOCODE' for new code 'XTRA'.

## 5 Running the economic calculations

The economic calculations and analysis methods described in this Technical Note are implemented by following a procedure of preparing the input datasets in a pre-determined fashion, storing them within a database template and running the economics calculation software, "PropDamage". This procedure is fully documented in the form of a user guide in the HR Wallingford Technical Note, Economic Calculations (PropDamage) (April 2008)

## 6 Further work to support the methods

The research undertaken by the CSG during the 2007 development project has highlighted a number of areas where the methods may be improved. Where possible, these have been taken on board within the current methods documented in this Technical Note. The work has highlighted a number of areas where further would allow more accuracy and confidence to be achieved in the method. These include;

- Undertaking further screening procedures to ensure the data in the NPD is as accurate as possible. For example screening residential property sizes by property type to eliminate suspected errors in the data
- Undertaking further research into the floor area by type of property to allow better classification of "Xtra" properties added to the dataset from OS MasterMap polygons. This will also aid the checking for outliers in the floor area field.

## 7 References

Halcrow technical Note. Project: NaFRA 2007, Note: EAD and NPD Issues, Author: R Deakin, Date: 30 January 2008, Ref: WPSNDT 511.