

Preliminary Flood Risk Assessment - The Republic of Ireland

The Predictive Assessment of Potentially Significant Flood Risk

June 2011

The Office of Public Works

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Executive Summary

There is a requirement under the first stage (Articles 4 and 5) of the EU Floods Directive (2007/60/EC) for the Republic of Ireland to complete a national Preliminary Flood Risk Assessment (PFRA). The objective of this work is to develop a method to indicatively assess potential future flood risk to enable the identification of 'Areas of Potentially Significant Risk of Flooding' (APSRs) using available or readily derivable data. These APSRs will form the focus of the more detailed Catchment-based Flood Risk Assessments and Management studies, which will be used to complete the next stage of the responses to the Directive for Ireland (comprising Articles 6, 7 and 8, plus the Annex, of the Directive).

This report provides a description of the methods that have been developed to complete the predictive aspects of the PFRA, i.e., the assessment of potential future flood risks based on analysis of projected flood extents and the damage these floods could cause. This work has been undertaken by Mott MacDonald for the Office of Public Works.

The document outlines the two principal components of the predictive flood risk assessment:

- Flood hazard areas, showing the extents of inundation of flood water for extreme events;
- Flood receptors, defining people, places, assets or activities that would suffer harm or damage during a flood. Receptors have been classified across social, economic, cultural heritage and environmental categories.

Indicative flood hazard areas have been defined for flooding from rivers, tides, groundwater and extreme, high-intensity rainfall. Automated processes, using a Geographical Information System (GIS), have been developed to identify receptors, which are located within flood hazard areas.

By assessing the probability of the flood event, the 'importance' of the receptor and the magnitude of the potential impact on the receptor from flooding, an estimate of flood risk has been defined for each receptor located inside a flood hazard area.

The 'significance' of flood risk has been assessed based on the type of receptor affected and the magnitude of the impact. Where the overall level of flood risk for a local area or community is determined as significant, an APSR has been identified. For example, a group of properties and a fire station located inside a flood hazard area may be an APSR. In addition, APSRs may be defined for individual, highly important receptors such as power stations or nationally important galleries and museums, irrespective of the other receptors at risk in the local area.

This report forms part of a suite of reports that have been developed for the PFRA. Details of the derivation of predictive flood extents are provided in other reports, and are not covered in detail in this document.

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1. Introduction

1.1 Overview

Flooding occurs naturally from a variety of sources of water including rivers, extreme tides along the coast, locally intense rainfall and groundwater.

Articles 4 and 5 of the European Floods Directive (2007/60/EC, referenced in this document as the 'Floods Directive') require the Republic of Ireland to identify 'Areas of Potentially Significant Risk' (APSRs) from flooding as part of a 'Preliminary Flood Risk Assessment' (PFRA). The PFRA is an initial 'high-level' investigation to identify, for each River Basin District and Unit of Management throughout the country, APSRs based on 'available or readily derivable' information. The results of this initial assessment will be used to focus the subsequent, and more detailed, Catchment-based Flood Risk Assessment and Management (CFRAM) studies for Ireland (under Articles 6, 7, 8 and Annex of the Directive).

The PFRA in Ireland is being undertaken using three approaches:

- Use of historic data on past flood events;
- Predictive assessment;
- Consultation with relevant stakeholders.

Mott MacDonald has been commissioned by The Office of Public Works (OPW), to assist in the development of methods to evaluate the potential future risk in Ireland to comply with the requirements of the Floods Directive. The objective of this report is to provide a summary of the approaches used in the predictive assessment where Mott MacDonald has principally been involved. OPW will be undertaking consultation with the local authorities regarding the results of the historical and predictive approaches in order to finalise the APSR list.

1.2 Structure of this Document

This report is organised in the following sections, focussing on the work completed for the predictive flood risk assessment. Reference is also made to the approaches adopted for the analysis of the historical flood data.

- **Section 2:** An overview of the **predictive** assessment of flood risk that has been completed;
- **Sections 3-5:** Details of the three elements of the **predictive** flood risk assessment: the definition of 'flood hazard areas', 'flood receptors' and the combination of these to determine the predictive APSRs;
- **Section 6:** Conclusions of the analysis.

2. Predictive Flood Risk Assessment - Overview

2.1 Introduction

The predictive flood risk assessment for the PFRA comprises three main elements. These cover the definition of '**flood hazard**' areas and of '**flood receptors**'. The third stage involves combining these two data sets to evaluate '**flood risk**'.

- '**Flood hazard areas**' are the predicted extents of flood inundation for extreme events of a range of probabilities.

Flood hazard areas have been defined nationally for the following principal flood mechanisms:

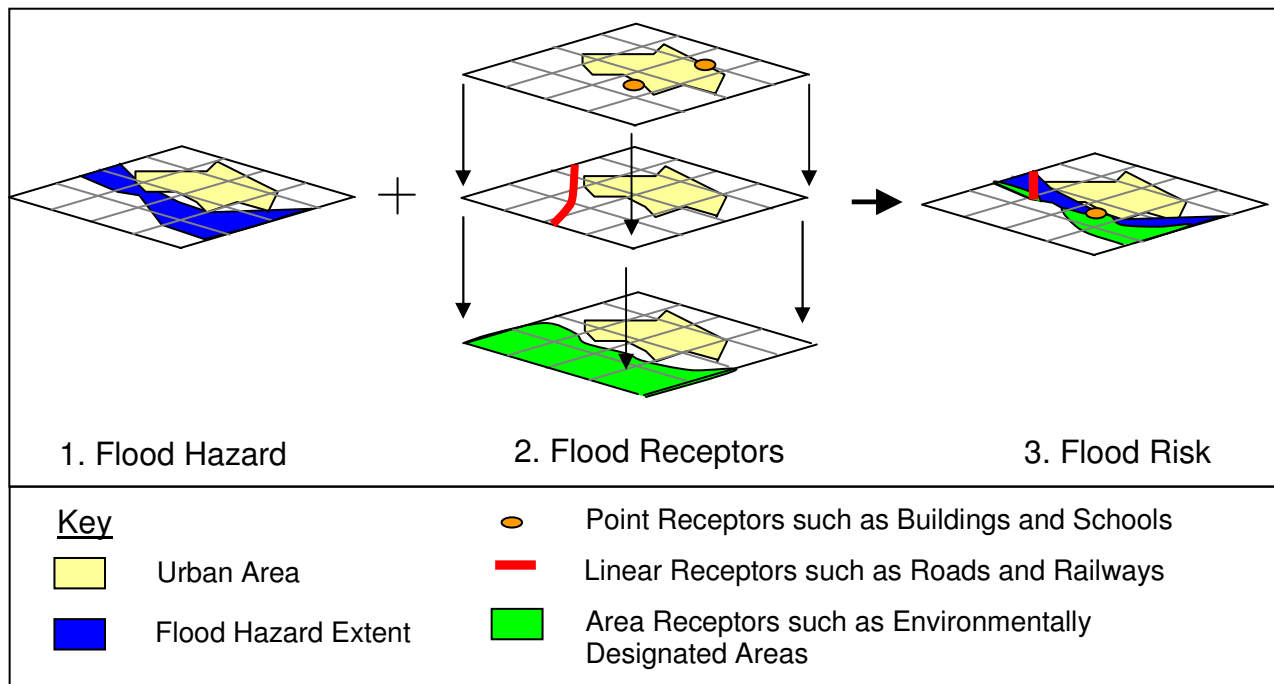
- i. Fluvial flooding from rivers;
 - ii. Tidal flooding along the coast and estuaries;
 - iii. Groundwater flooding from emergent subsurface water;
 - iv. Pluvial flooding from extreme, high intensity rainfall.
- '**Flood receptors**' can be defined as people, places, objects or activities that would suffer harm or damage in the event of a flood. The receptors reflect the impact of flooding on human health, the environment, cultural heritage and economic activity.
 - '**Flood risk**' is a combination of the probability of an area or receptor being flooded with the impact, or consequences, if that area or receptor were to flood.

Both the flood hazard areas and the flood receptors have been compiled and reviewed in a Geographical Information System (GIS). This approach has enabled layers of spatial data covering different flood mechanisms and different types of receptors to be used to define flood risk. This method is illustrated in the schematic shown in Figure 2.1.

The diagram shows how flood risk has only been defined for receptors located within the flood hazard areas, whether they are 'point receptors' such as individual residential properties or 'area receptors' such as environmentally designated areas. A third type of flood receptor is also possible where 'linear' transportation routes such as railways and major roads are situated inside flood hazard areas.

Therefore, although the PFRA process has ensured that the best available national data sets have been collated for each receptor type, it is only the receptors that are located within the extreme flood extents which have been taken forward to determine flood risk.

Figure 2.1: Schematic Diagram Illustrating the Concept of Combining 'Layers' of Data for Flood Hazard Areas and Flood Receptors in a GIS to Determine 'Flood Risk'



2.2 Report Structure for Predictive Flood Risk Assessment

The methods used to define and analyse the three principal components of the predictive flood risk assessment are detailed in the following sections.

- **Section 3:** A summary of the approaches that have been adopted for the development of the flood hazard areas for the different flood mechanisms. Full details of the methods are contained in the accompanying reports as noted through Section 3.
- **Section 4:** This section contains details of the receptor data that was obtained and how this data was analysed to make it appropriate for use in the flood risk assessment for the PFRA.
- **Section 5:** This component of the report provides a summary of the method using the predictive flood hazard areas and receptor analysis to assist in the definition of APSRs.

3. Predictive Flood Risk Assessment - Flood Hazard Areas

3.1 Introduction

As explained in Section 2, a fundamental component of flood risk is the definition of the extent and probability of the flood event. A set of national flood hazard areas has been developed to define the areas that would be inundated by flood water by one or more of the four principal flood mechanisms.

Each of these flood hazard areas is indicatively representative of a specified probability of the flood event occurrence. For the PFRA, the following three flood events have been used to evaluate flood risk: the indicative 10%, 1% and 0.1% annual exceedance probabilities (AEP)¹.

The following sections provide summaries of the methods used to define these flood hazard areas for the PFRA.

3.2 Fluvial Flood Hazard Areas

Indicative flood hazard areas have been defined for the PFRA for the main river network in the country. Although detailed analysis of flooding from rivers has been previously completed over a range of studies for particular catchments and settlements, a national assessment of hazard due to fluvial flooding is required to facilitate the implementation of the Floods Directive.

The OPW has developed a set of 'major nodes' in GIS which are distributed at 500m intervals along the main river network for the purposes of a separate project that is currently being undertaken². There are of the order of 139,000 major nodes located in GIS across the national river network. Given a river network of this scale, detailed hydraulic modelling of all of the river channels would have been impractical and inconsistent with the intentions of the Flood Directive for the use of "readily available and derivable data" for the PFRA³.

Instead an alternative approach has been adopted to define fluvial flood hazard. Each of the major nodes contains details of the hydrological parameters of the catchment upstream of the node. This data was used to generate estimates of flow at each of these major nodes for the three flood events being considered for the PFRA.

These estimated flows were translated into peak flood levels using basic hydraulic principles of the 'normal depth' relationship between river flow and level, together with details of the topography of the surrounding land. The topographic data has been taken from a Digital Terrain Model⁴ (DTM) of the country compiled from aerial survey of the land surface.

¹ Annual exceedance probability represents the probability of an event being exceeded in any one year and is an alternative means of defining flood probability to 'return periods'. The 10%, 1% and 0.1% AEP events are equivalent to the 10-year, 100-year and 1000-year return period events respectively.

² Flood Studies Update (Under Development, The Office of Public Works)

³ Directive 2007/60/EC of the European Parliament and of the Council on the Assessment and Management of Flood Risk (October 2007), Chapter II, Article 4.2

⁴ A Digital Terrain Model (DTM) is a digital data file, commonly viewed and analysed in a GIS software package, containing topographic elevation data.

The intersection of the peak flood levels with the topographic data on the left and right floodplain defines the indicative flood widths at each node. The resultant flood widths were connected to form flood hazard extents for the full river network across the country. The resolution of the flood extents was improved by the estimation of peak water levels and flood extents at an additional set of 'minor' river nodes in GIS, which are spaced approximately every 100m along the watercourses.

Full details of the method used to define the flood hazard areas for rivers are contained in an accompanying document⁵. A high level summary document covering this method is also available⁶.

3.3 Tidal Flood Hazard Areas

Detailed tidal modelling defining the flood hazard areas for tidal flooding along the east and south coast of Ireland has been completed by RPS Consultant Engineers for the OPW⁷. This work involved advanced numerical modelling of combined storm surges and tide levels to obtain extreme water levels along these coastlines. The resultant extreme water levels were projected inland using GIS software and compared to a DTM of the land along the coastline to determine the tidal flood hazard areas.

At the time of this initial version of the PFRA in June / July 2010, an equivalent model for the west coast of Ireland had not been completed. To enable the PFRA to be completed with a tidal hazard data set for the full country, a simplified method was used for the calculation of extreme tidal water levels along the west coast. Tide gauge data along the west coast has been reviewed and a statistical analysis has been completed on the tide gauge record at Malin at the northern end of the west coast. This data, together with the results of the RPS modelling for the western extent of the south coast near Bantry Bay, was used as part of a method to interpolate the extreme water levels along the west coast. Adjustments were made to these results to allow for the variations in extreme tide levels in estuaries.

At the time of the analysis it was recognised that this method only provides an interim solution for this coastline and these results were to be superseded by the more advanced modelling results from RPS Consultants which were due during Autumn 2010.

Full details of the approach adopted to generate the hazard areas along the west coast are provided in a separate report.⁸ A short high-level summary of this method has also been produced⁹.

3.4 Groundwater Flood Hazard Areas

Groundwater flood hazard has been mapped across Ireland primarily using an 'evidence-based' approach. This method has taken into account the available information from a range of sources including published and unpublished studies, newspaper articles, historic maps, aerial photography and satellite imagery showing the extents of flooding during past events. Consultation has also been undertaken with groundwater experts at the Geological Survey of Ireland, Trinity College Dublin and the Environmental Protection Agency.

⁵ PFRA - Fluvial Hazard Areas (Compass Informatics, Under Development)

⁶ PFRA - Fluvial Hazard Areas, High-Level Summary Document (Mott MacDonald, 2010)

⁷ Irish Coastal Protection Strategy Study - Various Phases (RPS Consultants, from 2008 onwards)

⁸ PFRA - West Coast Tidal Analysis and Flood Hazard Areas (Mott MacDonald, 2010)

⁹ PFRA - West Coast Tidal Hazard Areas, High-Level Summary Document (Mott MacDonald, 2010)

The evidence indicates that the vast majority of extensive, recurring groundwater flooding occurs at turloughs, which are groundwater-fed seasonal lakes that have developed in particular karstified¹⁰ limestone environments. A total of 482 turloughs have been identified, the majority of which are located in the west and north-west of the country. The following three principal approaches have been adopted to define indicative groundwater hazard areas for the country.

- (i). Analysis of historic flood maps from major flood events over the past twenty years using data from aerial photography and satellite imagery for parts of western Ireland.
- (ii). The approximation of hazard areas for turloughs lying outside the spatial extents of the available aerial and satellite imagery. A 'median' depth of flooding has been derived from analysis of the 85 turloughs that lie within the observed data sets for western Ireland and this depth of flooding has been applied to the turloughs located throughout the rest of the country. The use of DTM data for these turloughs has enabled the flood depth to be converted into a flood extent in each case.
- (iii). A total of 37 reports have been identified as being associated with turloughs in the national flood event database held by the OPW. These reports were used, where possible, to corroborate or adjust the flood extents derived using the other two approaches.

These methods to define indicative estimates of groundwater hazard in Ireland are explained in significantly more detail in a report accompanying this document¹¹. A further high-level summary document has been prepared for this mechanism of flooding¹².

3.5 Pluvial Flood Hazard Areas

As stated in Section 2.1, pluvial flooding occurs where areas become inundated by flood water arising from excess rainfall, prior to the water reaching drainage networks, rivers or the sea. Indicative pluvial hazard maps for Ireland are currently being finalised to identify potential areas of the country where this flooding process would be significant.

The study to identify pluvial flood hazard is currently being completed by Hydraulics Research Wallingford in consultation with the OPW. Further details of the approaches used can be found in the forthcoming reports for this study.

¹⁰ Karstification is the process where limestone is slowly dissolved away by percolating waters along fractures, fissures and joints in the rock. It results in underground drainage with flow occurring through interconnected fissures and conduits.

¹¹ PFRA - Groundwater Flooding (Mott MacDonald, 2010)

¹² PFRA - Mapping Groundwater Hazard in the Republic of Ireland (Mott MacDonald, 2010)

4. Predictive Flood Risk Assessment - Flood Receptors

4.1 Introduction

The Floods Directive requires the Preliminary Flood Risk Assessment to consider “significant adverse impacts” of flooding on “human health, the environment, cultural heritage and economic activity.”¹³

In order to determine areas of flood risk across the country, data on flood risk ‘receptors’ have been assessed in combination with the flood hazard extents described in Section 3. Receptors can be defined as people, places, objects or activities that would suffer harm or damage, or be impaired in the event of a flood. The receptors have been classified under the following four broad categories referenced in the Floods Directive:

- **Social:** Social receptors include the impact of flooding on human health and community infrastructure. The effects on human health could range from death and personal injury to stress and anxiety due to the loss of personal possessions and, in some cases, enforced relocation to alternative properties whilst repairs to homes are completed.
Community infrastructure comprises social services including education, emergency services, government administration buildings and emergency and long-term health service organisations.
- **Economic:** This covers infrastructure with economic importance such as utility supplies and transport services, plus agricultural areas. In addition, the flooding of commercial properties will impact on the function of the business and would also cause damage to ‘matters of value’ located inside the property.
- **Environment:** For the PFRA, receptor data for the natural environment has been obtained for areas of designated habitats and species across Ireland.
- **Cultural Heritage:** These receptors cover sites of importance from the man-made environment including architecturally significant sites, national monuments and principal museums and galleries.

This section explains how the receptor data has been collated for use in the predictive flood risk analysis and how the impact of flooding for each receptor type has been determined.

- **Section 5.2:** How the receptors have been selected and classified into groups;
- **Section 5.3:** Details of the data available for property locations and how this information has been used;
- **Section 5.4:** The assessment of the vulnerability of the different types of receptors to flooding.

¹³ Directive 2007/60/EC of the European Parliament and of the Council on the Assessment and Management of Flood Risk (October 2007), Chapter II, Article 4.2.

4.2 The Selection and Classification of Flood Receptors

This core structure to the receptor classifications has been taken from the previous work completed by Halcrow consultants for the OPW in 2008.¹⁴ A hierarchical classification structure for the receptors had been developed including four levels ranging from the principal categories listed above in Level 1 to the specific types at Level 4. The classification table (Table 3.1, Page 11 in the report by Halcrow consultants) has been adapted, based on the data found to be available, to include the key receptors being taken forward in the analysis for the PFRA. The receptor classification system and the list of the receptors for the PFRA process are included in Table 4.1 below.

Table 4.1: List of Receptors and the Classification Structure used for the PFRA

Receptor Classification				Receptor
Level 1	Level 2	Level 3	Level 4	
Social	Human Health	Residential Properties	Death, Injury, Stress *	Geo-Directory Property Database - Residential Properties
	Community	Social Infrastructure	Education	Primary Schools
				Post Primary Schools
				Third Level
			Emergency Services	Fire Stations
				Garda Stations
			Governance	Civil Defence
				OPW / Government Buildings
				Nursing Homes
				Hospitals
			Health Centre	Health Centres
Economic	Business	Commercial Properties	Economic Impact on Business Activity	Geo-Directory Property Database - Commercial Properties
	Infrastructure	Utilities	Power	ESB Power Stations
				ESB High-Voltage Substations
				Bord Gais Assets
			Water	Water Treatment Plants
				Wastewater Treatment Plants
			Telecommunications	Eircom Assets
		Transport	Road	Motorways
			Rail	National Primary Routes
			Ports	Railway Lines and Infrastructure
			Airports	Ports
				Airfields and Aerodromes
	Agriculture & Land	Arable and Horticulture	Arable Farming, Greenhouses and Market Gardens	Airports - National and Regional
		Livestock Pasture		Airports - International
		Minerals	Mining	Arable and Horticulture
		Forestry		Livestock Farming
Cultural Heritage	Cultural Heritage	Built Heritage		Livestock Farming
		Museums and Cultural Records		Mineral Works
		Archaeological / Historical Monument Sites		Forestry
Environment	Natural Environment	Protected and Designated Land / Areas		Architectural Heritage
				Museums, Archives and Art Galleries
				National Monuments
				Special Area of Conservation
Environment	Natural Environment	Protected and Designated Land / Areas		Special Protected Area
				Natural Heritage Area
				Proposed Natural Heritage Area

* See discussion in Section 4.3 of the use of the flooding of residential properties as an indicator of the impact of flooding on human health.

¹⁴ Halcrow Group Ireland Ltd for The Office of Public Works (September 2008), Flood Risk Assessment: Indicators, Methods and Data Sets – Scoring Study

These receptor data sets have been used in the PFRA to evaluate the potential impact of flooding. The data sets were selected on the basis of being “available or readily-derivable”, as specified in the Floods Directive¹⁵. Further criteria for the data sets were requirements that the data had a national coverage, were spatially identified for processing in GIS and, wherever possible, were sub-classified to allow for the consideration of variations in flood impact within each receptor class. The quality of each of the data sets has been reviewed and will be taken forward to consultation with the relevant stakeholders in each case to ensure that the receptor data for the final version of the PFRA is complete.

4.3 Property Data - Types of Flood Receptor

As discussed in Section 4.1, one of the major impacts of a flood event is the risk to human health both in terms of the risk to life and the impact of damage to personal property. For the purposes of the PFRA, data on residential property distribution across Ireland is being used as a surrogate indicator of these receptors. One of the principal impacts of the flooding of commercial property would be the cost of repairs and replacement to IT equipment, furnishings and stockpiles of manufactured items, as a few examples.

It is recognised that the impact of flooding to residential properties extends beyond the effect on human health to include damage to the building structure and contents which would require repair and replacement. Similarly, the flooding of people's places of work will also generate an impact to human health. The impacts of flooding residential and commercial properties have been separated in the receptor classification as described above to avoid double-counting (see the receptor classification list in Appendix B.1).

The Geo-Directory receptor, published by ‘An Post’, is the Irish national database of property locations covering residential, commercial and ‘unclassified’ postal addresses. The unclassified addresses cover a range of buildings including storage units and new-build properties where the current version of the database has missing information on the function of these sites. For the PFRA, the unclassified addresses, in the absence of any further information regarding the function of these sites, have been apportioned between the residential and commercial classes according to the proportions of the total national property list in these main categories. The latest available version of the Geo-Directory database from January 2010 has been used for the PFRA.

The impacts of flooding on both residential and commercial properties have been taken as being equivalent to each other for the PFRA, although it is recognised that, in reality, individual residential and commercial properties will encompass a range of sizes and monetary values. The Geo-Directory database contains over 2.3 million addresses of which in the order of 180,000 are located inside the fluvial flood hazard areas. Considering the objective of the PFRA to act as a high-level national screening process, it has not been possible to evaluate the detailed use of these buildings and the relative impact of flooding between each site. Therefore, each address has been assigned the same level of importance.

The method outlined above indicates how properties have been classified according to use for the PFRA. However, the assessment of sensitivity to flooding for properties, even within a single property type, is complex and is affected by a number of issues. The assessment is further complicated by the nature of the information available in the Geo-Directory database. For example, in some cases there are multiple addresses in the database referenced at the same location due to residential flats and properties above

¹⁵ See Footnote 2 on Page 4.

shops. As the Geo-Directory data does not contain details of the specific floor of the building that each address is located on, each individual address has been assessed independently as a separate property. For a block of residential flats, for example, flood risk can be identified not only for the ground floor properties which could be inundated with flood water, but also the impairment to emergency access to properties on the upper floors.

Despite these issues, the Geo-Directory database represents the best available data set for property locations in Ireland and as such has been used in the national flood risk analysis for the PFRA.

4.4 Evaluating the Impact of Flooding on Different Receptors

The information in Sections 4.1 to 4.3 shows the diversity of flood receptors that have been considered under the PFRA. A monetary assessment of flood impact across each of the receptor types at the PFRA stage would have been difficult and was difficult to justify given the residual uncertainties in the flood hazard extents. An alternative 'semi-quantitative' method of evaluating the impact of flooding across all the receptor types was therefore developed. The first part of this method, with the aim of distinguishing the impact of flooding between the different receptor types, is summarised in the following stages:

Stage (i) The Principles of Defining the Impact of Flooding for Each Receptor

The flood impact for each receptor, or sub-group of a receptor, can be represented as a function of the receptor '**importance**' and '**potential damage**' from flooding. The **importance** of a receptor is based on its function, scale of influence and ease of replacement. For example, an international airport providing national and international flights will have a greater importance than a local, private airfield.

Potential damage from flooding could, for example, be defined as the degree of permanent damage to a receptor or the impairment of the ability of that receptor to function as a service to the local, or wider, population.

Higher importance and higher potential damage equate to higher levels of vulnerability (see the description of the following stage) to flooding for the receptor.

Stage (ii) The Basis for Assessing Receptor Vulnerability

The combined function of level of importance and the potential damage from flooding has been used to define the flood '**vulnerability**' of each receptor. The vulnerability scale used in this method comprises five categories as listed in Table 4.2.

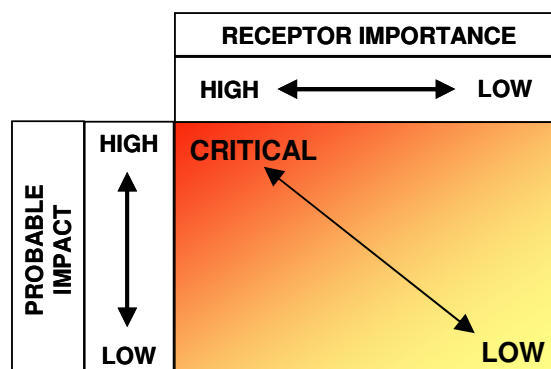
Table 4.2: List of Vulnerability Classifications

Critical Vulnerability
Extreme Vulnerability
High Vulnerability
Moderate Vulnerability
Low Vulnerability

Flood vulnerability has been systematically assessed using a set of tables to relate receptor importance and potential damage. The specific layout of these tables depends on the type of

receptor and therefore the impact of flooding involved. Figure 4.1 shows a schematic of a table with the combined impact of receptor importance and susceptibility on receptor vulnerability.

Figure 4.1: Schematic showing the relationship between Receptor Importance and Susceptibility in determining Vulnerability to Flooding



Stage (iii) Defining Vulnerabilities According to the Types of Flood Impact

In developing this method it has been recognised that the nature of the impact of flooding will be different across the range of receptors being considered for the PFRA. Each different type of impact of flooding has been assessed using a table set out in a similar format to the example shown in Figure 2.1. The full set of 'vulnerability derivation' tables is shown in Appendix A. These cover the following types of impact:

- **Risk to Life:** This category includes all care homes, health centres, hospitals and schools where there would be a risk to life from extreme flood events.
- **Damage to Matters of Value:** This assessment is appropriate to sites where there would be a level of permanent damage to the receptor. This would include all cultural heritage sites, agricultural land and environmentally designated areas.
- **Significant Loss of Service:** This covers severe impacts from the loss or interruption of a service which is either classed a 'lifeline' service, such as power and water supply, or the complete loss of a transport link with no reasonable diversion route available.
- **Less Significant Loss of Service:** This includes services where the impact of flooding would still be important, but could be judged as being less severe, such as most administrative or bureaucratic services. This covers driving test centres, most government service departments and arts centres, for example.
- **Emergency Response and Recovery:** The final category covers the impact of flooding on the emergency services and related organisations, which may play a key role in the mitigation of damage and risk to loss of life during extreme flood events.

Most receptor types have not been subdivided according to flood impact and the same vulnerability level has been assigned to each individual site across each receptor type. For example, the impact to power stations and high-voltage electricity substations from flooding would be power supply disruption and the loss of a significant service. The following section, entitled Example 1, highlights how the vulnerability levels for these two specific receptors have been determined.

Example 1: Table 4.3 shows how the vulnerability of flooding to electricity utility sites can be determined by the combination of the relative importance of the site and the probable impact. An extreme flood at a major, 'nationally' important power station could result in a loss of service of electricity supply for 'over six months' and therefore the vulnerability level would be 'Critical' (blue oval in the table). For less important, 'regional' high-voltage substations the impact may be shorter at '1 to 6 months' causing this receptor to have a slightly lower flood vulnerability of 'Extreme' (green oval). There will also clearly be other, more minor electricity supply infrastructure including lower-grade sub-stations around the country which may also be within flood hazard areas. However, it is understood, subject to more thorough consultation, that adjustments could be made relatively easily to maintain the local supply from other sub-stations and so these sites have not been assigned a vulnerability class.

Table 4.3: Flood Vulnerability for Loss of Significant Service

PROBABLE DURATION OF IMPACT	DEGREE OF RECEPTOR IMPORTANCE / DESIGNATION			
	International	National	Regional	Local
Very Long (6 months+)	Critical	Critical	Critical	Extreme
Long (1 - 6 months)	Critical	Critical	Extreme	High
Moderate (3 days - 1 month)	Critical	Extreme	High	Moderate
Short (<3 days)	Extreme	High	Moderate	Low

For some other receptors, a range of vulnerability levels is required within one receptor category to account for the differences in importance and role of individual buildings and sites. Example 2, below, illustrates how flood impact has been evaluated for one particular set of receptors with varying vulnerability levels.

Example 2: For museums and art galleries, the damage from flooding would be permanent damage not only to the building but, probably most significantly, to the books and records contained in the building. For this type of impact, the flood vulnerability would be determined from Table 5.4, which assesses the 'Damage to Matters of Value'.

Table 4.4: Flood Vulnerability for Permanent Damage to Matters of Value

PROBABLE IMPACT	DEGREE OF RECEPTOR IMPORTANCE / DESIGNATION			
	International	National	Regional	Local
Total Loss	Critical	Critical	Extreme	High
Severe Degradation	Critical	Extreme	High	Moderate
Moderate Damage	Extreme	High	Moderate	Low
Minor Damage	High	Moderate	Low	Low
No / Negligible Damage	Low**	Low	Low	Low

** It should be noted that the vulnerability classification for 'Internationally Important' sites with 'No or Negligible' impact of flood damage has been intentionally left as 'Low Vulnerability'. This is a reflection of the very low impact, even for internationally significant sites, of flooding in these cases.

For this type of receptor, the probable flood damage could include the 'Total Loss' of all or part of the literature or art collection. For the National Museum and the National Gallery, both clearly under the 'Nationally Important' classification, the flood vulnerability would be 'Critical' (as indicated by the blue oval on the table). For more regional or local museums and galleries a decrease in the importance of the collection and potentially a decrease in the amount of damage that would be caused, leads to a reduction in the flood vulnerability according to the above table.

A list of the vulnerability classifications for the range of receptors shown in Table 4.1 is included in Appendix B. Two further columns have been included at the far right-hand side of this table. These

columns record which of the five vulnerability derivation tables has been used for each receptor and the combination of receptor importance and probable impact that has been assigned in each case.

It is evident from the information presented in Appendix B that variable vulnerabilities have been assigned for some receptor types. In these cases, in a similar way to the approach outlined in Example 2 above, either the importance or the probable damage from flooding will vary across the different sub-categories or individual sites included in the receptor type. The vulnerabilities for the individual sites in these cases have been evaluated independently, although in each case the same systematic method using one of the five vulnerability derivation tables has been applied. The final vulnerability classifications in these instances are provided in Appendix B for OPW / Government Buildings and for museums, archives and art galleries. The vulnerability assessments for environmentally designated sites and for cultural heritage are detailed in separate reports.

5. Predictive Flood Risk Assessment - Identification of Areas of Flood Risk

5.1 Introduction

The method explained in Section 2 covers the definition of flood receptors and the evaluation of a flood vulnerability class for each receptor type.

The main objective of the PFRA is to determine Areas of Potentially Significant Risk (APSRs) across Ireland. The first part of this section details the method that has been used to translate the data on predictive flood extents and the vulnerabilities of point receptors into areas of flood risk. The following issues are addressed:

- **Section 5.2:** The transfer of the vulnerability levels assigned for each receptor into a numerical 'score' depending on the probability of the flood event.
- **Section 5.3:** A 'semi-quantified' method for evaluating the combined flood risk 'scores' for all **point receptors** in the same local area.
- **Section 5.4:** The method applied to determine the 'significance' of flood risk for **point receptors** in each area using a threshold score. Areas with a combined flood risk above the threshold score have been defined as APSRs.

Due to the characteristics of the linear and area receptors, the evaluation of flood risk and APSRs for these sites does not follow the same set of methods. The definition of flood risk for these types of receptors is explored in two sections of an Appendix to this report. The report has been organised on this basis to try to assist the reader with clarity on the methods that have been used for the different types of receptors.

- **Appendix D.1:** Assessing the level of flood risk for **linear receptors** such as transport routes.
- **Appendix D.2:** Determining flood risk for **area receptors** covering agricultural land and environmentally designated areas.

In addition, a separate analysis has been completed to identify receptors vulnerable to pollution which are located downstream of any sites containing hazardous substances (IPPC and Seveso sites). This analysis is covered in more detail in Appendix E.

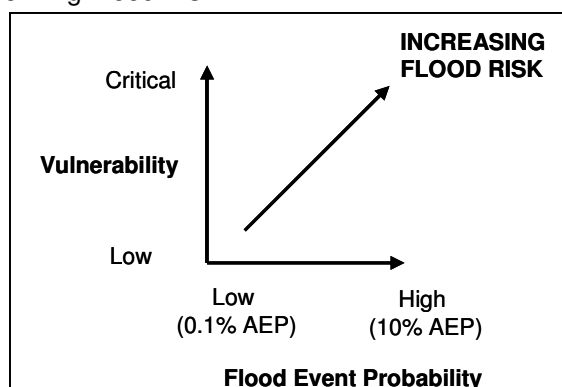
5.2 Flood Risk Index

The purpose of defining vulnerability levels was to ensure that flood susceptibility for each receptor type was assessed using a standardised method. Section 3 explains how flood risk is a function of the flood vulnerability of the receptors and the probability of flooding of the receptors.

A 'Flood Risk Index' scoring system was developed to combine the vulnerabilities of the different receptors depending on the severity of the flood concerned. The information in Section 3 summarises how the flood hazard extents for fluvial and tidal flood mechanisms have been indicatively determined for the 10%, 1% and 0.1% Annual Exceedance Probability (AEP) events. A schematic graph shown in Figure 5.1 shows the relationship between flood vulnerability and flood event probability to generate flood risk. Higher receptor

vulnerability classifications and greater flood severities (lower annual exceedance probabilities) translate to higher levels of flood risk.

Figure 5.1: Schematic Graph showing the link between Receptor Vulnerability and Flood Event Probability in Defining Flood Risk



The basis for the Flood Risk Index system is shown in Table 5.1. This approach means that every receptor located inside a flood extent can be assigned a Flood Risk Index score, the magnitude of which depends on the vulnerability class and the probability of flooding. For each vulnerability class, the flood risk index score varies according to the probability of the flood event concerned. The multiplying factor of ten between the scores for the different flood events is a reflection in the difference in percentage probability of the flood extents, between the 10%, 1% and 0.1% AEP events. For example, a receptor classified with Extreme Vulnerability to flooding would receive a score of 2500 if it is located inside the 10% AEP flood extent, but only a score of 25 if it is located within the lower probability 0.1% AEP flood extent (i.e. with the former flood event 100 times more likely to occur in any given year than the latter event).

Table 5.1: Flood Risk Index Scores Derived from Vulnerability Classes and the Probability of Flooding

Vulnerability Class	Vulnerability Class Factor	Probability of Flood Event (Annual Exceedance Probability)		
		10% - High	1% - Medium	0.1% - Low
Critical Vulnerability	2500	25000	2500	250
Extreme Vulnerability	250	2500	250	25
High Vulnerability	25	250	25	2.5
Moderate Vulnerability	2.5	25	2.5	0.25
Low Vulnerability	1	10	1	0.1

5.3 Defining 'Areas of Flood Risk' – Point Receptors

The method set out in this document as far as Section 5.2 has determined Flood Risk Index scores for each receptor located inside the flood extents. However, instead of limiting the review of flood risk to individual receptors, an area-based flood risk analysis has been developed to determine areas where the cumulative flood risk to a number of different receptors can be regarded as 'significant'.

Please note that the following method describes how the flood risk for 'point' receptors grouped within the same spatial area can be evaluated. It does not refer to the assessment of flood risk for linear and area

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(agriculture and environmentally protected areas) receptors which are explained separately in Sections 5.5 and 5.6.

For example, within a settlement a group of properties plus a school may be located within the 10% AEP flood extent of a river, with further receptors located in the other flood hazard zones for less frequent flood events. Whilst flood vulnerabilities and individual Flood Risk Index scores can be assigned to each receptor, the combined flood risk to all of the receptors can be determined and used to define the overall risk to a community or part of a larger settlement.

The following stages were developed to identify combined areas of flood risk:

Stage (i) A 500m by 500m grid system was developed across the country in GIS to provide a systematic method for evaluating the aggregate flood risk at a settlement scale. For a given flood mechanism, the receptors located inside the flood extents were identified. Any grid square containing one or more flooded receptor was identified as a 'risk square'. For residential and commercial property receptors, 'one receptor' is the equivalent of one property. This means that all properties inside flood hazard areas, whether in rural or urban environments, have equal weighting and the potential to be identified as APSRs according to the following stages detailed below.

Stage (ii) From the defined vulnerability classes for these receptors as listed in the table in Appendix B and on the basis of the probability of flooding, each flooded receptor was assigned a Flood Risk Index score in accordance with Table 6.1. The different scores for the flooded receptors for each individual grid square were totalled.

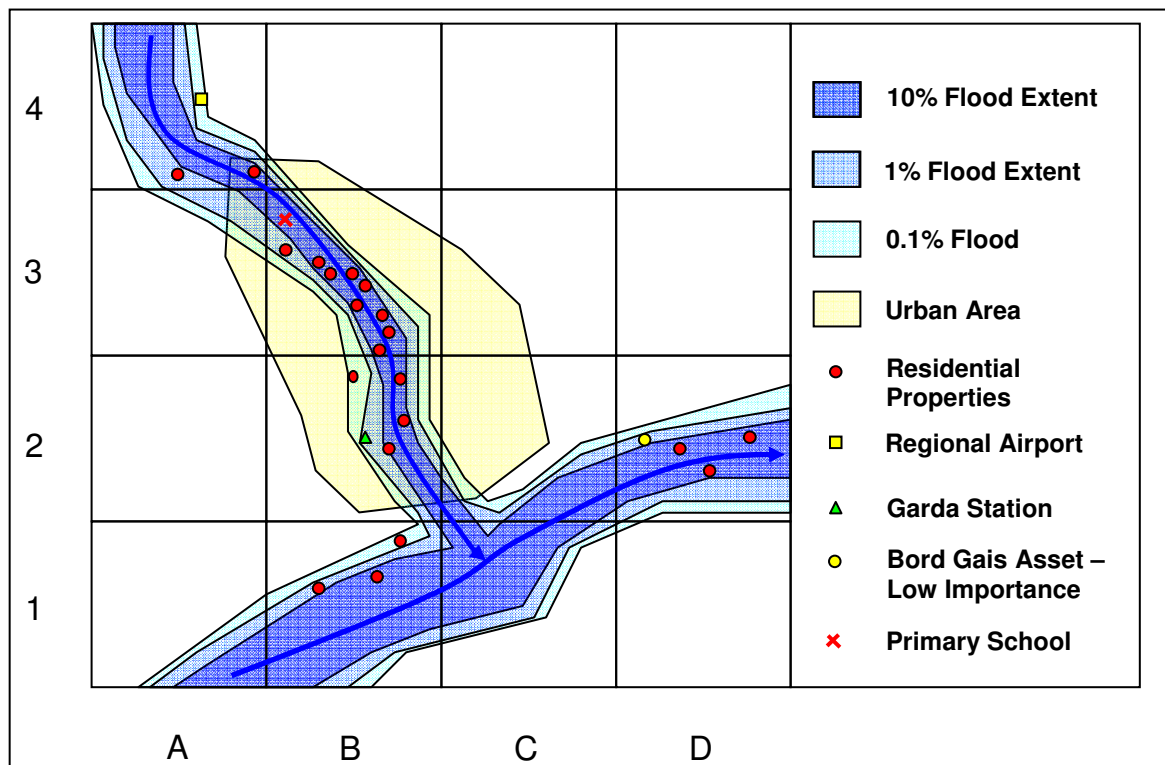
Stage (iii) A GIS routine was developed to combine any adjacent (horizontally, vertically or diagonally) 'risk squares' into 'amalgamated areas'. The Flood Risk Index scores for each of the amalgamated sets of grid squares were determined from a sum of the constituent scores.

It was also possible that individual risk squares may be left from this process where no nearby receptors in the surrounding grid squares are inside the flood hazard areas. These individual squares would be assessed on the basis of the Flood Risk Index score for that specific square.

The following section provides an example as to how amalgamated areas have been defined across a range of receptor types and flood probabilities.

Example 3: Figure 5.2 shows a hypothetical settlement with a main river flowing from west to east (grid squares A1 to D2) and a major tributary channel located through the centre of the town.

Figure 5.2: Schematic of Hypothetical Town, Flood Extents and Receptors



For both channels, flood extents for the 10%, 1% and 0.1% AEP events are shown. Throughout the urban area and also parts of the surrounding rural areas, receptors which are located inside these flood extents have been identified (Stage (i), listed above).

As detailed in Stage (ii), the vulnerability class of each receptor has been defined and, with the receptors located inside one of the three flood extents, a flood risk index score can be assigned in each case. The index scores have then been combined for each grid square. So, for example, the following table shows the results that would have been found in the assessment of flood risk for the hypothetical settlement shown in Figure 5.2. For clarity, only grid squares with receptors located inside the flood extents have been included in the table, as the flood risk index of the other grid squares would be zero. The index scores for each individual receptor and flood probability are shown separately and then a total for each square is also listed.

Table5.2: Example of Flood Risk Index Results

Grid Squares	Flood Extent (AEP)	Receptor Type	Vulnerability	Number	Flood Risk Index Score
A4	10%	Property	Low	1	10
	1%	Property	Low	1	1
	0.1%	Regional Airport	Extreme	1	25
TOTAL FOR GRID SQUARE A4					36
B1	10%	Property	Low	1	10
	1%	Property	Low	1	1
	0.1%	Property	Low	1	0.1
TOTAL FOR GRID SQUARE B1					11.1
B2	10%	Property	Low	3	30
	1%	Garda Station	High	1	25
	0.1%	Property	Low	1	0.1
TOTAL FOR GRID SQUARE B2					55.1
B3	10%	Property	Low	8	80
	10%	Primary School	High	1	250
	1%	Property	Low	1	10
TOTAL FOR GRID SQUARE B3					340
D2	10%	Property	Low	3	30
	1%	Bord Gais Asset – Low Importance	Moderate	1	2.5
TOTAL FOR GRID SQUARE D2					32.5

Stage (iii) of the areal assessment of flood risk combines neighbouring 'risk squares' to form amalgamated areas. The results are illustrated in Figure 5.3 with four of the risk squares combined to form one amalgamated area. Grid square D2 remains as a single risk square after this amalgamation process.

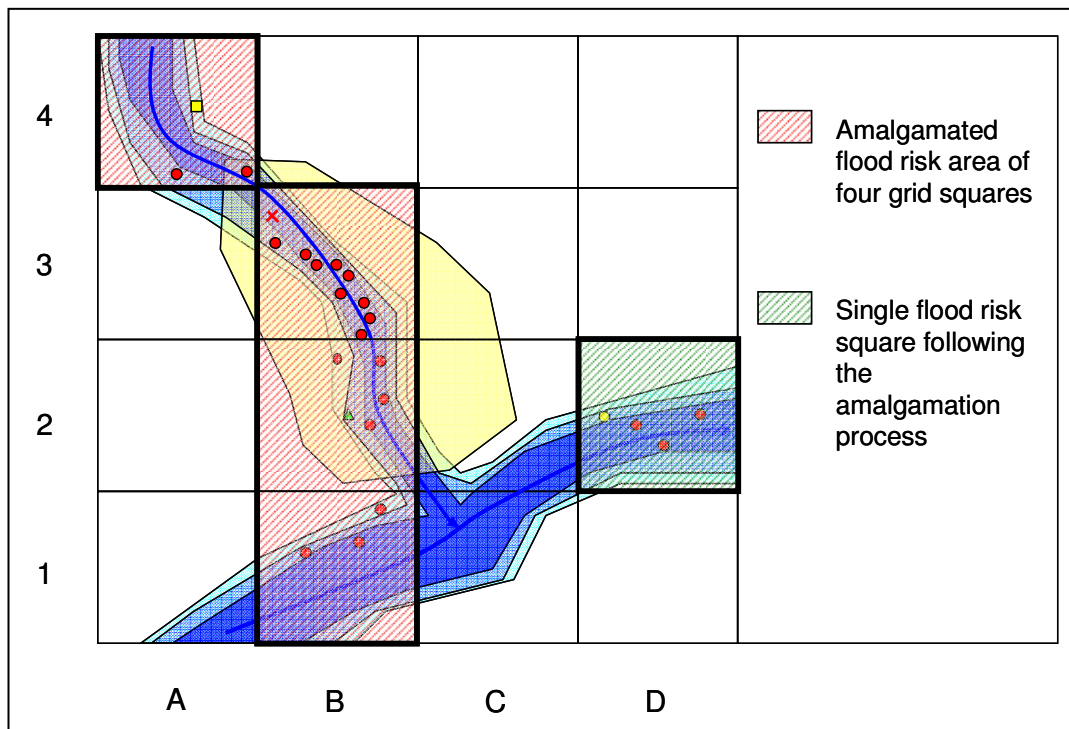
It should be noted that a similar method has been applied for the evaluation of risk for tidal flooding. The only difference in the method was the inclusion of a weighting factor for receptors located within the tidal flood hazard areas, due to the greater damage caused by flooding from saline water as opposed to freshwater sources¹⁶. Where flood hazard occurs from both fluvial and tidal mechanisms in one grid square, the overall FRI score was taken from the total score based on the receptors located in the fluvial and tidal hazard areas.

This approach means that it is possible for a property or another type of receptor to be at risk from more than one type of flood hazard. In these cases the FRI score would add the flood risk from the different flood mechanisms for each individual receptor. This approach ensures that

¹⁶ As discussed in Section 5.10.2 of the 'Multi-Coloured Manual' ('The Benefits of Flood and Coastal Defence: Techniques and Data', Flood Hazard Research Centre, Middlesex University, 2005)

flood risk from both fluvial and tidal flood mechanisms are incorporated into the FRI scoring procedure and that the combined flood risk for each receptor is assessed.

Figure 5.3: Example of the Amalgamation of Neighbouring Flood Risk Squares



5.4 Definition of the 'APSR threshold' – Point Receptors

The explanation of the method to this point has summarised the translation of flood risk results for individual receptors into an assessment of flood risk for amalgamated areas (either individual grid squares or combined set of grid squares).

Although this standardised approach ensures that all receptors are considered in the process, it is clear from the example of the hypothetical settlement shown in Example 3 in Section 5.3, that the amalgamated areas could cover a wide range of total flood risks. The amalgamated set of four grid squares (B1, B2, B3 and A4 in the schematic diagrams) has a combined flood risk index of 442.2. The single flood risk square, 'D2', only has a flood risk index of 32.5.

Although the grid system has been used as a framework to provide a 'semi-quantified' analysis of the receptors at flood risk, the APSRs have been defined at a 'settlement' scale. For example, flood hazard may be defined adjacent to a watercourse in part of a town, creating flood risk for a number of receptors. However, due to the known limitations and uncertainties of the definition of the flood hazard extents across the different types of flood mechanism, the APSR has been defined at the scale of the whole town, as opposed to just the flooded areas.

The Floods Directive requires the identification for the PFRA of areas where “potential **significant** flood risks exist or might be considered likely to occur.”¹⁷ Therefore a threshold level for the flood risk index scores for each of the amalgamated areas needs to be defined, in order to ascertain which amalgamated areas potentially have a ‘significant’ risk of flooding. This is discussed in the PFRA Overview Report.

¹⁷ Directive 2007/60/EC of the European Parliament and of the Council on the Assessment and Management of Flood Risk (October 2007), Chapter II Article 5.1

6. Conclusions

This report provides a summary of the methods that have been used to undertake a predictive assessment of flood risk for the PFRA for the Republic of Ireland. This assessment has been designed to meet the requirements of Articles 4 and 5 of the Floods Directive.

The methods that have been developed for this analysis are in accordance with the national and preliminary nature of the PFRA. There are some limitations in the analysis of the flood receptors and also in the derivation of the flood hazard areas, as explained in the more detailed reports on fluvial, tidal, groundwater and pluvial hazard which support this document.

Despite these limitations, the methods provide a systematic approach for a high-level and preliminary assessment of flood risk across Ireland commensurate with the objectives of the Floods Directive.

Flood risk has also been assessed, as far as reasonably possible at this level of assessment, for linear receptors, such as transport routes, and area receptors, including agriculture and environmentally designated areas. However, the initial results for these types of receptors will be subject to further consultation by OPW with the relevant authorities.

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Appendix A. Tables to Derive Receptor Vulnerabilities

The use of tables relating receptor importance and the degree of impact of flooding on each receptor to a level of 'receptor vulnerability' is described in Section 2.4.

The full set of these tables are shown below. The selection of which table is appropriate for specific receptors depends on the type of impact of flooding.

1. Risk to Life

Probable Impact	VULNERABILITY
Significant Risk of Loss of Life	Critical
Highly Elevated Risk of Loss of Life	Extreme
Elevated Risk of Loss of Life	High

2. Permanent Damage to Matters of Value

PROBABLE IMPACT	DEGREE OF RECEPTOR IMPORTANCE / DESIGNATION			
	International	National	Regional	Local
Total Loss	Critical	Critical	Extreme	High
Severe Degradation	Critical	Extreme	High	Moderate
Moderate Damage	Extreme	High	Moderate	Low
Minor Damage	High	Moderate	Low	Low
No / Negligible Damage	Low	Low	Low	Low

3a. Temporary Impacts – Significant Loss of Service

PROBABLE DURATION OF IMPACT	DEGREE OF RECEPTOR IMPORTANCE / DESIGNATION			
	International	National	Regional	Local
Very Long (6 months+)	Critical	Critical	Critical	Extreme
Long (1 - 6 months)	Critical	Critical	Extreme	High
Moderate (3 days - 1 month)	Critical	Extreme	High	Moderate
Short (<3 days)	Extreme	High	Moderate	Low

3b. Temporary Impacts – Less Significant Loss of Service

PROBABLE DURATION OF IMPACT	DEGREE OF RECEPTOR IMPORTANCE / DESIGNATION			
	International	National	Regional	Local
Very Long (6 months+)	Critical	Critical	Extreme	High
Long (1 - 6 months)	Critical	Extreme	High	Moderate
Moderate (3 days - 1 month)	Extreme	High	Moderate	Low
Short (<3 days)	High	Moderate	Low	Low

4. Emergency Response and Recovery

PROBABLE IMPACT	DEGREE OF RECEPTOR IMPORTANCE / DESIGNATION		
	National	Regional	Local
Total Loss of Service	Critical	Extreme	High
Partial Loss of Service	Extreme	High	Moderate
Negligible Loss of Service	High	Moderate	Low

Appendix B. Receptor Vulnerability Classes

B.1. Main Receptor Vulnerability Classifications

RECEPTOR CLASSIFICATION						Receptor Type	Vulnerability Classification	Table Used to Define Receptor Vulnerability	Reason for Vulnerability Classification - Table	
Level 1	Level 2	Level 3	Level 4	Level 5 - Receptors	Receptor Sub-class					
Social	Human Health	Residential Properties	Death, Injury, Stress		Geo-Directory Property Database - Residential Properties		Point			
	Community	Social Infrastructure	Education	Primary Schools		Point	High Vulnerability	1. Risk to Life 3a. Significant Loss of Service	Elevated Risk to Life Local, Long Duration	
				Post Primary Schools		Point	High Vulnerability	1. Risk to Life 3a. Significant Loss of Service	Elevated Risk to Life Local, Long Duration	
				Third Level		Point	High Vulnerability	1. Risk to Life 3a. Significant Loss of Service	Elevated Risk to Life Local, Long Duration	
			Emergency Services	Fire Stations		Point	High Vulnerability	4. Emergency Response	Regional, Partial Loss of Service	
				Garda Stations		Point	Moderate Vulnerability	4. Emergency Response	Local, Partial Loss of Service	
				Civil Defence		Point	Moderate Vulnerability	4. Emergency Response	Local, Partial Loss of Service	
			Governance		OPW / Government Buildings		Point	VARIABLE	3a. Significant Loss of Service	VARIABLE, see individual worksheet
			Care Homes		Nursing Homes		Point	Extreme Vulnerability	1. Risk to Life	Highly Elevated
			Hospitals		Hospitals		Point	Critical Vulnerability	1. Risk to Life	Significant Risk
			Health Centre		Health Centres		Point	Moderate Vulnerability	3a. Significant Loss of Service	Local, Long Duration
Economic	Business	Commercial Properties	Economic Impact on Business Activity		Geo-Directory Property Database - Commercial Properties		Point			
	Infrastructure	Utilities	Power	ESB Power Stations		Point	Critical Vulnerability	3a. Significant Loss of Service	National, Very Long Duration	
				ESB HV Substations		Point	Extreme Vulnerability	3a. Significant Loss of Service	Regional, Long Duration	
				Bord Gais Assets		Very Low	Point	Low Vulnerability	3b. Less Significant Loss of Service	Local, Short Duration
				Bord Gais Assets		Low	Point	Low Vulnerability	3b. Less Significant Loss of Service	Local, Moderate Duration
				Bord Gais Assets		Medium	Point	Moderate Vulnerability	3b. Less Significant Loss of Service	Regional Moderate Duration
				Bord Gais Assets		High	Point	Moderate Vulnerability	3b. Less Significant Loss of Service	Regional Moderate Duration
			Water	Water Treatment Plants		Point	Moderate Vulnerability	3a. Significant Loss of Service	Local, Moderate Duration	
				Wastewater Treatment Plants		Point	Moderate Vulnerability	3a. Significant Loss of Service	Local, Moderate Duration	
			Telecommunications	Eircom Assets		Non-Core Exchange	Point	Low Vulnerability	3b. Less Significant Loss of Service	Local, Moderate Duration
				Eircom Assets		Core Exchange	Point	Moderate Vulnerability	3b. Less Significant Loss of Service	Regional Moderate Duration
		Transport		Road	Motorways		Linear	High Vulnerability	3a. Significant Loss of Service	National, Short Duration
					National Primary Routes		Linear	High Vulnerability	3a. Significant Loss of Service	National, Short Duration
					Rail		Linear	High Vulnerability	3a. Significant Loss of Service	National, Short Duration
					Ports		Point	High Vulnerability	3a. Significant Loss of Service	Regional, Moderate Duration
				Airports	Airfields and Aerodromes		Point	Moderate Vulnerability	2. Damage to Matters of Value	Regional, Minor Damage
					Airports - National and Regional		Point	Extreme Vulnerability	3a. Significant Loss of Service	National, Moderate Duration
					Airports - International		Point	Critical Vulnerability	3a. Significant Loss of Service	International, Moderate Duration
	Agriculture & Land	Arable and Horticulture	Arable Farming, Greenhouses and Market Gardens	Arable and Horticulture		Area	VARIABLE	2. Damage to Matters of Value	VARIABLE	
		Livestock Pasture		Livestock Farming		Area	VARIABLE	2. Damage to Matters of Value	VARIABLE	
		Minerals	Mining	Mineral Works		Area	Low Vulnerability	2. Damage to Matters of Value	Regional, Minor Damage	
		Forestry		Forestry		Area	VARIABLE	2. Damage to Matters of Value	VARIABLE	
Cultural Heritage	Cultural Heritage	Built Heritage	Architectural Heritage		Local	Point	Low Vulnerability	2. Damage to Matters of Value	Local, Minor Damage	
			Architectural Heritage		Regional	Point	Low Vulnerability	2. Damage to Matters of Value	Regional, Minor Damage	
			Architectural Heritage		National	Point	Moderate Vulnerability	2. Damage to Matters of Value	National, Minor Damage	
			Architectural Heritage		International	Point	Critical Vulnerability	2. Damage to Matters of Value	International, Severe Degradation	
		Museums	Museums and Art Galleries	Museums and Art Galleries		Point	VARIABLE	2. Damage to Matters of Value	VARIABLE, see individual worksheet	
		Archaeological / Historical Monument Sites	National Monuments		Monuments (neither of the two classes)	Point	Low Vulnerability	2. Damage to Matters of Value	Local or Regional, Minor Damage	
			National Monuments		Monuments Subject to a Preservation Order	Point	VARIABLE	2. Damage to Matters of Value	VARIABLE, see individual worksheet	
			National Monuments		Monuments in State Care	Point	Low Vulnerability	2. Damage to Matters of Value	Local or Regional, Minor Damage	
			National Monuments		Monuments in State Care and Subject to a Preservation Order	Point	VARIABLE	2. Damage to Matters of Value	VARIABLE, see individual worksheet	
			National Monuments		UNESCO World Heritage Sites	Point	Critical Vulnerability	2. Damage to Matters of Value	International, Severe Degradation	
Environment	Natural Environment	Protected Lands / Areas		Special Area of Conservation		Area	VARIABLE	2. Damage to Matters of Value	VARIABLE	
				Special Protected Area		Area	VARIABLE	2. Damage to Matters of Value	VARIABLE	

B.2. Variable Receptor Vulnerabilities - Office of Public Works / Government Buildings

Level 1	Level 2	Level 3	Level 4	Level 5 - Receptors	Receptor Sub-class	Basic Classification	Table Used to Define Receptor Vulnerability	Reason for Vulnerability Classification - Table
Social	Community	Social Infrastructure	Governance	OPW / Government Buildings	Garda Stations			
					Visitor Centres	Low Vulnerability	3b. Less Significant Loss of Service	Local, Moderate Duration
					Castle			
					Driving Test Centres	Low Vulnerability	3b. Less Significant Loss of Service	Regional, Short Duration
					Courthouses and Legal Services Buildings	Low Vulnerability	3b. Less Significant Loss of Service	Regional, Short Duration
					AHGI Offices	Low Vulnerability	3b. Less Significant Loss of Service	Regional, Short Duration
					Probation and Welfare Offices	Low Vulnerability	3b. Less Significant Loss of Service	Regional, Short Duration
					Environment Offices - Regional	Low Vulnerability	3b. Less Significant Loss of Service	Regional, Short Duration
					OPW Offices	Low Vulnerability	3b. Less Significant Loss of Service	Regional, Short Duration
					Monuments Depots / Museums Stores	Low Vulnerability	3b. Less Significant Loss of Service	Regional, Short Duration
					Agriculture Offices	Low Vulnerability	3b. Less Significant Loss of Service	Regional, Short Duration
					Agriculture Colleges	Low Vulnerability	3b. Less Significant Loss of Service	Regional, Short Duration
					Veterinary Labs	Low Vulnerability	3b. Less Significant Loss of Service	Regional, Short Duration
					Education Offices	Low Vulnerability	3b. Less Significant Loss of Service	Regional, Short Duration
					Census / Statistical Offices - Regional	Low Vulnerability	3b. Less Significant Loss of Service	Regional, Short Duration
					Vehicle Registration Offices	Low Vulnerability	3b. Less Significant Loss of Service	Regional, Short Duration
					Customs and Excise	Low Vulnerability	3b. Less Significant Loss of Service	Regional, Short Duration
					Government Offices	Low Vulnerability	3b. Less Significant Loss of Service	Regional, Short Duration
					Revenue Offices	Low Vulnerability	3b. Less Significant Loss of Service	Regional, Short Duration
					Coastguard Station	Low Vulnerability	4. Emergency Response and Recovery	Local, Negligible Loss of Service
					Marine Rescue Services	Low Vulnerability	4. Emergency Response and Recovery	Local, Negligible Loss of Service
					Social Welfare Offices	Moderate Vulnerability	3a. Significant Loss of Service	Regional, Short Duration
					Environment Offices - National	Moderate Vulnerability	3b. Less Significant Loss of Service	National, Short Duration
					Vehicle Registration Offices - National	Moderate Vulnerability	3b. Less Significant Loss of Service	National, Short Duration
					Census / Statistical Offices - National	Moderate Vulnerability	3b. Less Significant Loss of Service	National, Short Duration
					Irish Water Safety Office - National	Moderate Vulnerability	3b. Less Significant Loss of Service	National, Short Duration
					Creches	High Vulnerability	1. Risk to Life	Elevated Risk to Life
					Refugee Centre	High Vulnerability	1. Risk to Life 3a. Significant Loss of Service	Elevated Risk to Life Local, Long Duration Impact
					Civil Defence HQ	High Vulnerability	4. Emergency Response and Recovery	Regional, Partial Loss of Service
					National Schools	High Vulnerability	1. Risk to Life 3a. Significant Loss of Service	Elevated Risk to Life Local, Long Duration Impact
					Prison	Extreme Vulnerability	1. Risk to Life	Highly Elevated Risk to Life
					Military Barracks	Extreme Vulnerability	3a. Significant Loss of Service 4. Emergency Response and Recovery	National, Short Duration Impact National, Partial Loss of Service

B.3. Variable Receptor Vulnerabilities: Museums, Archives and Art Galleries

All sites listed are classified as:

Receptor Name	Basic Classification	Table Used to Define Receptor Vulnerability	Reason for Vulnerability Classification - Table
Ballina Arts Centre	Moderate Vulnerability	2. Damage to Matters of Value	Local, Severe Degradation
Ballyhugh Arts and Cultural Centre			Local, Severe Degradation
Bank of Ireland Arts Centre			Local, Long Impact
De Valera Library and Gallery		3b. Less Significant Loss of Service	Local, Long Impact
Dr. Douglas Hyde Interpretative Centre		2. Damage to Matters of Value	Regional, Moderate Damage
Dublin Writers Museum			Local, Severe Degradation
Ledwidge Cottage Museum			Regional, Moderate Damage
Lismore Castle Arts		3b. Less Significant Loss of Service	Regional, Moderate Damage
Mullingar Arts Centre			Regional, Minor Impact
National Museum of Irish Transport			Regional, Moderate Damage
National Wax Museum Plus		2. Damage to Matters of Value	Local, Long Impact
Poets Cottage		3b. Less Significant Loss of Service	Regional, Moderate Damage
Seanchai Kerry Literary and Cultural Centre			Regional, Moderate Damage
The Shaw Birth Place			National, Minor Damage
Yeats Society Sligo		2. Damage to Matters of Value	Regional, Moderate Damage
Yeats Tower (Thoor Ballylee)			Regional, Moderate Damage
Abbey Theatre Archive	High Vulnerability	2. Damage to Matters of Value	Regional, Severe Degradation
All Hallows Archives			Regional, Severe Degradation
Arklow Fine Art Gallery			Regional, Severe Degradation
Boole Library Archive Services			Regional, Severe Degradation
Butler Gallery			Regional, Severe Degradation
Chester Beatty Library			Regional, Severe Degradation
City Arts Archive			Regional, Severe Degradation
Clare County Archives			Regional, Severe Degradation
Cork City and County Archives			Regional, Severe Degradation
Crawford Art Gallery			Regional, Severe Degradation
Dublin City Gallery The Hugh Lane			Regional, Severe Degradation
Dublin City Library and Archive			Regional, Severe Degradation
Erasmus Smith Trust Archive			Regional, Severe Degradation
Fingal County Archives			Regional, Severe Degradation
Garda Síochána Museum and Archives			National, Moderate Damage
Glebe House and Gallery			Regional, Severe Degradation
Highlanes Gallery			Regional, Severe Degradation
Hunt Museum			Regional, Severe Degradation
Irish Theatre Archive			National, Moderate Damage
James Joyce Museum			National, Moderate Damage
Kerry Local History and Archives Department			Regional, Severe Degradation
Kilkenny Local History and Archives			Regional, Severe Degradation
King House Interpretive Galleries and Museum			Regional, Severe Degradation
Laos County Archive Service			Regional, Severe Degradation

Receptor Name	Basic Classification	Table Used to Define Receptor Vulnerability	Reason for Vulnerability Classification - Table
Lewis Glucksman Gallery	High Vulnerability	2. Damage to Matters of Value	Regional, Severe Degradation
Limerick City Gallery of Art			Regional, Severe Degradation
Limerick Studies Archives			Regional, Severe Degradation
Longford County Archives and Local Studies			Regional, Severe Degradation
Louth County Archives Service			Regional, Severe Degradation
National Museum of Ireland - Country Life			National, Moderate Damage
National Print Museum			National, Moderate Damage
National Transport Museum			National, Moderate Damage
Offaly Local Studies and Archives Service			Regional, Severe Degradation
Patrick Kavanagh Centre			National, Moderate Damage
Royal Hibernian Academy			Regional, Severe Degradation
Russell Library Archives			Regional, Severe Degradation
South Tipperary Archives Service			Regional, Severe Degradation
The Douglas Hyde Gallery			Regional, Severe Degradation
The Model			Regional, Severe Degradation
Waterford City Archives			Regional, Severe Degradation
Waterford County Archives Service			Regional, Severe Degradation
Waterford Municipal Art Gallery			Regional, Severe Degradation
Westmeath Local Studies and Archives			Regional, Severe Degradation
Wexford County Archive Service			Regional, Severe Degradation
Áras an Uachtaráin	Critical Vulnerability	2. Damage to Matters of Value	National, Total Loss
Bolton Library			
Book of Kells			
Geological Survey of Ireland Archives			
Irish Architectural Archive			
Irish Defence Forces Military Archives			
Irish Film Archive			
Irish Museum of Modern Art			
Irish Traditional Music Archive			
National Archives of Ireland			
National Gallery of Ireland			
National Library of Ireland			
National Museum of Ireland - Archaeology			
National Museum of Ireland - Decorative Arts and History			
National Museum of Ireland - Natural History			
National Museum of Ireland - Reserve Collection Site 1			
National Museum of Ireland - Reserve Collection Site 2			
National Museum of Ireland - Reserve Collection Site 3			
National Photographic Archive			
The National Archives			
UCD Archives			

Appendix C. Details of Receptor Data Sets

This appendix highlights specific aspects and limitations regarding some of the receptor data sets, which are important when considering the APSR results. The data sets represent the best 'available or readily derivable' data sources which could be obtained and applied in the APSR analysis. However, several key issues have been highlighted for specific receptor types in the following sections to assist with consultation with stakeholders on the PFRA results.

C.1. Social Receptors

C.1.1. OPW / Government Buildings

A summary of the classifications for the sub-categories of buildings in the OPW properties list has been included in Appendix B.2. It is acknowledged that some of the lists of sites under each sub-category may not necessarily be complete. For example, only one prison is included on this version of the property list. However, these sites have been taken from the latest available list of OPW properties (data revision from December 2009) and this forms the 'available and readily derivable' data set of government owned and operated properties around the country.

The vulnerability classifications for two of the receptor sub-classes in the table in Appendix B.2 have been 'greyed-out'. Although Garda stations are included in the OPW properties list, the station locations and flood vulnerabilities are already included in a separate dataset, as shown in Appendix B.1. In addition, any castles included on the OPW properties list would also be accounted for under the National Monuments register (see Appendix C.3.1).

C.2. Economic Receptors

C.2.1. Airports, airfields and aerodromes

Vulnerability levels for airports, aerodromes and airfields across Ireland have been assigned according to the type of flights operating from each site. Table C.1 shows the assigned vulnerability levels for the major international and national airports. All other airfields and aerodromes have been assigned as moderate vulnerability according to the potential damage to matters of value.

Table C.1: Vulnerability Levels Assigned to International and National Airports

Airport	Main Function	Vulnerability Level	Table Used to Assign Receptor Vulnerability	Reason for Vulnerability Classification
Knock	National / Regional Airport	Extreme	3a. Significant Loss of Service	National, Moderate Impact
Donegal				
Gallway				
Kerry				
Sligo				
Waterford				
Dublin	International / National Principal Airport	Critical	3a. Significant Loss of Service	International Moderate Impact
Cork				
Shannon				

C.2.2. Agricultural Areas, Mineral Works and Forestry

The best available and readily derivable data regarding agricultural areas across Ireland was found to be the Corine land cover mapping. The Corine Land Cover 2000 project in Ireland forms part of the land cover mapping for the whole of Europe, as coordinated by the European Environment Agency¹⁸. This data set spatially defines the principal land cover classes related to land use or natural vegetation and landscape features and is based on satellite imagery.

There are three main land cover categories defined in the Corine data set that are relevant for the description and analysis of the agricultural land in the PFRA. These are listed below, together with the proportion of the country defined as each land cover type.

- Arable, non-irrigated land, 7.66%
- Pastures, 51.45%
- Complex cultivation patterns (small areas of diverse annual crops, pasture and / or permanent crops, 1.74%

The data set has limitations in terms of the resolution of the data set and the classification of some areas of land. However, the data set was judged to be the best available to define the distribution of arable and pastoral farming areas.

In addition to pastoral and arable farming, areas of commercial forestry have been identified. This land use category is intended to be distinct from areas of forest or woodland that are environmentally protected. Consultation with the Department of Agriculture indicated that the 'Forestry07' data set is representative of the distribution of forestry areas around the country and this data has been used to assess flood risk for commercial forestry areas.

C.3. Cultural Heritage Receptors

C.3.1. Architectural Heritage

This data set was obtained from the Department of Environment, Heritage and Local Government and is taken from the National Inventory of Architectural Heritage (NIAH). The designations of local, regional, national and international importance for each of the sites are taken from the 'Rating' class included in the NIAH database and described in the NIAH Handbook¹⁹. No edits have been made to the NIAH classifications of individual sites for the PFRA, particularly considering that the data set does not include details of the type of building at each of the listed locations. However, it was found that ratings were missing in the database for 869 out of 34000 sites. In the absence of any further information, these sites have been assumed to be of Local Importance and therefore of Low Vulnerability in the PFRA analysis.

¹⁸ Corine 2000 – Ireland Land Cover Update (ERA-Maptec Ltd and EPA, 2004)

¹⁹ The National Inventory of Architectural Heritage Handbook (Department of Environment, Heritage and Local Government, June 2006)
<http://www.buildingsofireland.ie/Resources/NIAHHandbook/Thefile,170,en.pdf>

The numbers of sites located within each rating category in the NIAH database are as follows: Local: 1965; Regional: 31063; National: 686; International: 6.

C.3.2. Museums, Archives and Galleries

A national list of museums, archive stores and art galleries was obtained from the Irish Museums Association (IMA)²⁰, which is a voluntary organisation promoting the interests of museums throughout Ireland. The IMA maintains a list of museums and related organisations, which, although may not be comprehensive, represents the best available data for these sites across Ireland. The original full list consists of approximately 450 sites with postal addresses rather than geographical coordinates included for each site. In order to define a receptor data set for the PFRA, the full list was reduced according to the following criteria:

- Any sites listed as 'National' or 'Irish' to try to ensure that any site that is readily identified as the foremost national centre for a particular type of information is included.
- Any sites designated for film or photographic stores. These were included due to the specific vulnerability of the storage media to flood damage.
- Any sites designated by title as 'Archives'. It is acknowledged that this includes a range of types of archive and an attempt has been made to consider the importance of the archive store in the vulnerability classification.
- Any sites referenced as 'Art Galleries' or 'Museums'.
- An attempt was also made to include locations and details of reserve stores for some of the key museum and gallery sites. However, the National Museum was the only organisation where a request for this information was made which was willing to supply this data.

The sites selected for this 'short list' of museums, archives and art galleries are listed in Appendix B.3 together with the flood vulnerability levels that have been assigned in each case.

High level indicative details on each of the sites were obtained, where possible, from the respective organisations' homepages on the internet. This was information was used to gain an initial appreciation of the function and contents of each site and therefore the potential impact of flooding in each case. Consultation on the importance and flood vulnerability of each site was not possible during the programme of the initial PFRA, but this will form an important part of future updates to the PFRA and the more detailed CFRAM projects.

The following notes help explain how some of the specific vulnerability levels have been determined for the PFRA.

- Most of the nationally important museums, archives and artefacts are classified as 'critical vulnerability'. These sites are nationally important and flood damage could result in a total loss of the items or data involved. Exceptions to this rule include the National Transport

²⁰ The Irish Museums Association, <http://www.irishmuseums.org>

Museum and the National Wax Museum where either the degree of impact or the importance of the site is lower than for the other major sites on the critical vulnerability list.

- All county archives are defined as 'high vulnerability' considering a regional level of importance and a severe degradation impact. It has been assumed that there would not be a total loss of data and information due to disaster contingency plans that may be in place to back data up off-site. Clearly this generic rule will require further consultation with the organisations concerned to ensure that this is decision is appropriate, considering the specific data and storage medium at each site.
- A similar decision was made to determine the flood vulnerability of art galleries and similar sites. The majority of these sites have been classed as 'high vulnerability' considering the regional importance of the site and severe degradation of the exhibits and the buildings at each site. Clearly, for the PFRA, details regarding the importance and value of the contents of some of the galleries could not be fully accounted for and therefore further consultation will be important to pick-up any exceptions to this general rule.

C.3.3. National Monuments

Data for designated monument sites were obtained from the Department for Environment, Heritage and Local Government (DEHLG). These site records, including information on the type of structure in addition to the site location, have been classified by DEHLG according to the type of designation. The designation levels cover sites under 'state care', 'preservation orders' or both of these classifications.

The vulnerability assessment of monuments is described under a separate report.

C.3.4. UNESCO World Heritage Sites

UNESCO (the United Nations Educational, Scientific and Cultural Organisation) has defined a World Heritage Site List (WHS), which identifies sites that it considers as having "outstanding universal value".²¹

Although the national monuments data set includes a monument 'type' against each location on the list, the site names and full descriptions are not available. In order to ensure that the UNESCO sites are included in the receptor analysis, the details of these sites have been added to the list of national monuments. As shown in the table in Appendix B.1, UNESCO sites have been assigned as 'Critical Vulnerability' given their international importance and the potential for severe degradation of the site during flood events.

The classification system on the UNESCO list divides the sites between locations that are on the existing WHS list and a provisional list where applications for the inclusion of the sites on the full list have been submitted but no formal decision has been made at present.

A summary of the sites included on these two lists is provided in Table C.3. On the proposed list, Clonmacnoise is entered twice different site descriptions, although this location has only been included once in the receptor analysis.

²¹ UNESCO World Heritage Sites, <http://whc.unesco.org/en/list>

The entry for The Burren has been shaded in grey in the table to show that it has not been used in the analysis. The description on the UNESCO site record shows the site as an area of exposed limestone landscape covering 72,000 hectares and therefore the vulnerability of this type and area would not be significant within the context of the PFRA. In addition, the designated area for the North West Boglands has not been included in the receptor list for the UNESCO sites. These sites are designated for their natural habitat value and as an illustration of their environmental history and therefore would be accounted for under the receptors covering the environmental designations.

Table C.3: UNESCO Sites - Existing and Proposed World Heritage Site Lists

Sites on List		Lat / Long Reference	Irish Nat Grid	
Description			Easting	Northing
Archaeological Ensemble of the Bend of the Boyne		N53 41 30.012 W6 27 0	301572	272989
Skellig Michael		N51 46 18.984 W10 32 18.996	24825	60722

Proposed List		Lat / Long Reference	Irish Nat Grid	
Description	Location		Easting	Northing
Early Medieval Monastic Sites	Clonmacnoise	N53 19 40 W7 58 43	201033	230689
	Durrow	N53 16 22 W7 48 01	213415	222771
	Glendalough	N53 0 37 W6 17 25	312316	196802
	Inis Cealtra	N52 48 46 W8 26 35	169880	184958
	Kells	N53 43 33 W6 52 45	273968	275878
	Monasterboice	N53 46 48 W6 24 12	304350	282054
The Burren	The Burren	N53 03 08 W9 03 43	128838	200668
The Céide Fields and North West Mayo Boglands	The Céide Fields	N54 16 48 W9 22 15	110759	337663
	North West Mayo Boglands	N54 14 12 W9 43 11	87919	333337
The Historic City of Dublin	Dublin	N53 20 39 W6 16 3	315437	234033
The Monastic City of Clonmacnoise and its Cultural Landscape	Clonmacnoise	N53 19 40 W7 58 43	201033	230689
The Royal Sites of Ireland	Cashel	N52 31 17 W7 53 16	207467	140928
	Dún Ailinne	N53 7 3 W6 45 50	282042	207904
	Hill of Uisneach	N53 29 16 W7 31 43	229088	248961
	Rathcroghan Complex	N53 46 46 W8 15 18	179924	283447
	Tara Complex	N53 35 9 W6 33 42	291872	259622
Western Stone Forts	Dun Aonghusa, Aran	N53 7 33 W9 46 5	81769	209869
	Cahercommaun	N53 0 53 W9 4 14	128198	196503
	Caherconree	N52 12 11 W9 51 14	72653	106618
	Benagh	N52 6 00 W9 37 60	46050	111589
	Staigue	N51 48 19 W10 0 57	61039	63260

C.4. Environmental Receptors

C.4.1. Environmental Designated Areas

Although flooding occurs naturally from fluvial and tidal inundation of land, the impact of flooding has been considered for the PFRA for environmentally designated areas across Ireland, where specific habitats and species have been identified as being important. The European designated sites (Natura 2000 sites) are covered by the Special Area of Conservation (SAC) and Special Protection Area (SPA) designations. The Natura 2000 network is the centrepiece of EU nature and biodiversity policy. It is an EU-wide network of nature protection areas established under the Habitats Directive. The aim of the network is to assure the long-term survival of Europe's most valuable and threatened species and habitats.

For each SAC and SPA, a vulnerability class has been assigned based on an evaluation of the vulnerability of the constituent habitats and species that are designated within each area. Full details of this process are outlined in a separate report.

Appendix D. Analysis of Linear and Area Receptors

D.1. Introduction

Section 5 explains how an initial set of APSRs has been derived by assessing the distribution of point receptor data in flood hazard areas. However, this method of analysis can not be easily applied for linear and area receptor types. The following two sections describe how linear and area receptors are being analysed for flood risk for the PFRA.

D.2. Definition of APSRs – Linear Receptors

Roads and railways are the two linear receptors have been identified for the PFRA.

As shown in the receptor list in Appendix B.1, two levels of roads have been considered, covering motorways and national primary routes. These are the road routes where the 'loss of service', due to flooding of a length of the road, would have a significant impact nationally and potentially on the coordination of emergency response during flood events. For the PFRA, data on the routes of the more minor roads has not been analysed for flood risk.

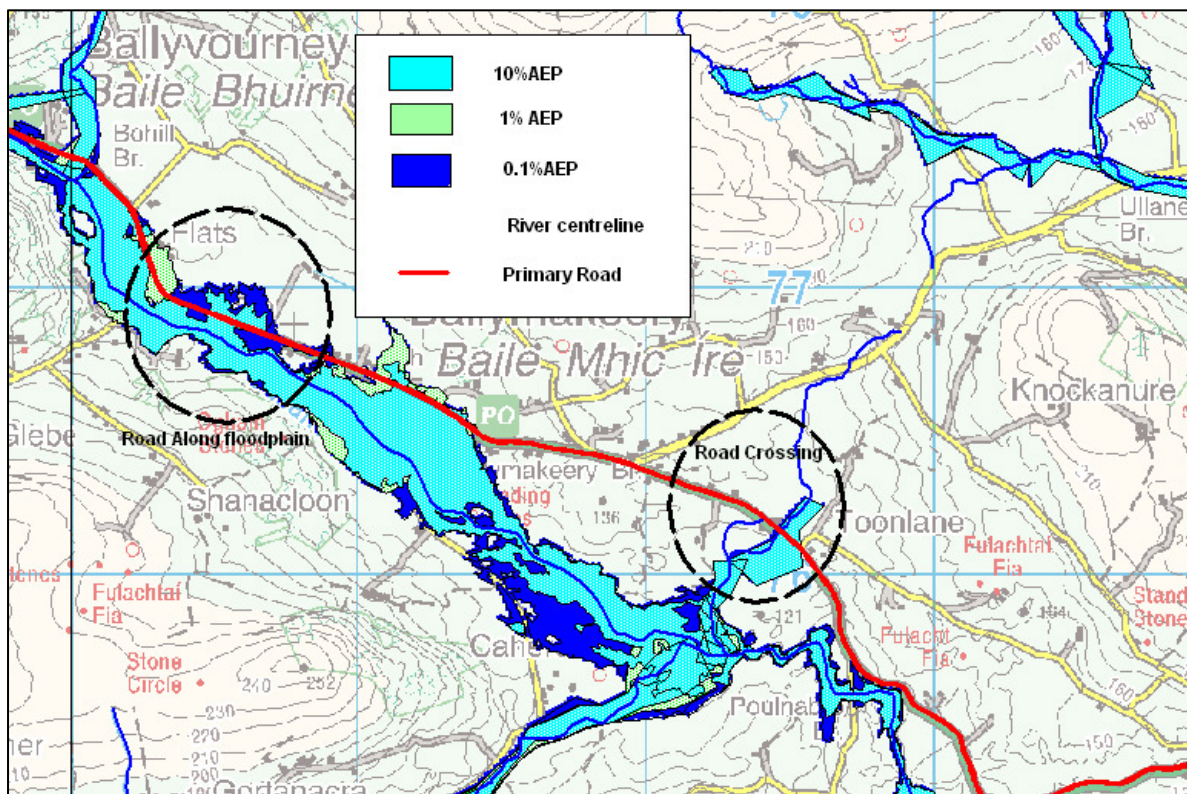
For railways, only the lines have been included in the flood risk assessment. Railway stations tend to be elevated above the surrounding ground surface level and so they have been excluded from the flood risk analysis.

During the PFRA work, it became quickly apparent that assessing the occurrence of road and railway lines in flood hazard areas in GIS would identify many lengths of these linear receptors as being at risk that are in fact not at risk due to the presence of bridges. There is no readily available or derivable national data set of bridge deck levels to check the span of the bridge at each site and to use to try to ascertain whether the approach lengths of road and railway, together with the deck levels of the bridge, are at risk.

Figure D.1 shows examples of a road running both across a floodplain and along a valley with long lengths of road inside the flood extents. For the former scenario (the right-hand annotated circle in the figure) it is not possible from the available data to determine the height of the bridge deck and the bridge ramps in relation to the peak flood levels. The other annotated circle on the map indicates a different sort of risk where substantial lengths of road are within the hazard areas and could be subject to flooding during extreme events, although it is not known if these lengths are raised above the flood levels (e.g. on embankments that may not be resolved in the national DTM).

It is therefore concluded that it is not possible, based on existing available or readily-derivable information, to undertake a predictive analysis of risk that is of sufficient reliability for use in the PFRA. The assessment of these risks will therefore be discussed further by the OPW with the relevant authorities.

Figure D.1: Examples of roads located across and along floodplains



D.3. Definition of the APSRs – Area Receptors

There are two principal types of area receptors in this analysis covering agricultural cultivation and environmentally designated areas. In order to evaluate the distribution of these two types of area receptors against the flood hazard areas, a different set of techniques has been used to the methods described for point receptors in Sections 6.3 and 6.4.

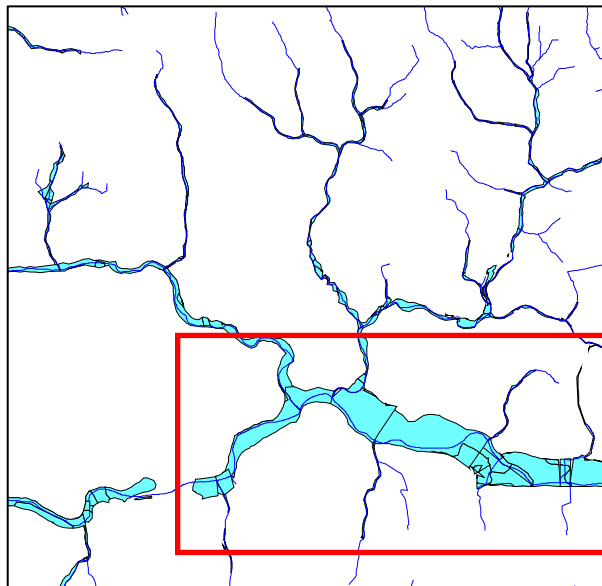
D.3.1. Agricultural and Forestry Areas

Flooding occurs naturally along many watercourses in the country. The aim of the PFRA, as described in the preceding sections of this report is to define areas of 'Potentially Significant Risk' from flooding. In any given natural watercourse there is likely to be out-of-bank flooding during extreme events for the majority of the watercourse length. Indeed, the 'normal depth' method that has been used to generate predictive flood hazard areas along watercourses (see Section 4.2) has generated continuous flood extents through the river networks around the country even if some parts of these extents only show a 'minimum' flood width of the order of 10m.

To define the receptor data for agricultural land use, including arable and pastoral cultivation, data from the European Environment Agency 'Corine Land Use' mapping²² has been used. This data set based on land cover data from satellite imagery is the best available national data set for land use across the country. Further details on the data classes used for the agricultural, mineral workings and forestry receptors are included in Section C.2.2.

Figure D.2 shows the distribution of agricultural land at flood risk from events up to the 0.1% AEP event through part of the river network in the country (indicated by the light blue polygons in the image). For most of the river network shown in the image, the flood extents are limited to 'corridors' of land running along the centrelines of the watercourses. However, the area inside the red box in the image shows channels where the flood extents are wider and a greater proportion of the agricultural land along the valleys is shown as being inundated by flood water.

Figure D.2: Agricultural land inundated by flood water along a sample part of the national river network



In order to try to identify areas of significant flood risk to agricultural land, Mott MacDonald and OPW have developed an automated process to identify areas similar to the flood extents highlighted in the red box in Figure D.2, and to determine the risk for these areas on the basis of the area of agricultural land at flood risk per unit length of river reach. This method identifies larger and more 'significant' areas of agricultural flood risk where further analysis may be warranted under the CFRAM Studies.

D.3.2. Environmentally Designated Areas

Appendix C.4.1 contains summary details of the approach used to define flood vulnerability classes for the SACs and SPAs (designated areas under the EU nature and biodiversity policy), which is detailed in a separate report.

²² See Footnote 18 on Page 30

Appendix E. Analysis of the Impact of Flooding at Pollution Risk Sites

Section 2(d) of Chapter II, Article 4 of the Floods Directive requires the PFRA, depending on the needs of the Member State, to cover an assessment of the potential adverse consequences of floods for human health and the environment, in addition to the impacts on cultural heritage and economic activity.

The methods described in this report provide a framework for the evaluation of flood risk on human health / activities and the environment from the inundation of water from either fluvial or tidal sources. The risk to the receptors is a function of the probability of the site being flooded and the vulnerability of the receptor to flooding.

However, there is an additional type of risk that could result from the flooding of a site containing hazardous substances. In this case, there is not only a risk to the site storing the dangerous substances, but also potentially for any receptors downstream that are also located inside flood hazard areas and are vulnerable to polluted flood water.

Two specific classifications of sites containing hazardous substances have been assessed under this study.

- **IPPC Sites:** Integrated Pollution Prevention Control (IPPC) licenses, under the protection of the Environment Act from 2003, aim to prevent or reduce emissions to air, water and land, to reduce waste and to promote energy efficiency. The sites covered include categories of industry or agricultural activities either manufacturing or using specific, potentially hazardous substances.²³
- **Seveso Sites:** These are sites designated under the Control of Major Accident Hazards Including Dangerous Substances Regulations of the European Community (Directive 1996/82/EC). These regulations are also known as the Seveso II Directive.

The Directive (1996/82/EC) focuses on the protection of the environment and covers requirements relating to the safe management of dangerous substances, as defined by the regulations. The Directive places requirements on the operator regarding the storage of the substances and the procedures following a major accident.²⁴

A GIS shapefile showing the locations of the IPPC sites was available from the Environmental Protection Agency website. A similar shapefile for the Seveso sites was not readily available and so these sites were digitised from the site address lists on the Health and Safety Authority website.

Clearly under the scope of the PFRA it is not possible to assess any specific measures that may have been taken to mitigate any risk of pollution at IPPC or Seveso sites during a flood event.

In evaluating the downstream risk from the flooding of these sites, it is also beyond the scope of the PFRA to complete any detailed studies regarding the potential concentrations or dispersal of the substances.

²³ See the Environmental Protection Agency website at <http://www.epa.ie/whatwedo/licensing/ippc/>

²⁴ See the Health and Safety Authority website at http://www.hsa.ie/eng/Your_Industry/Chemicals/Control_of_Major_Accident_Hazards/

Instead, the following approach has been adopted to identify the wider impact of flooding either IPPC or Seveso sites.

- All IPPC and Seveso sites located within the fluvial flood extents have been identified;
- The watercourses and therefore the related hazard areas downstream of these 'at-risk' IPPC and Seveso sites have been identified;
- Any receptors located within these downstream flood areas have been determined;
- These receptors have been reviewed to identify potential pollution risks that would impact on human health or the natural environment. This specifically covers the following receptor categories: drinking water abstraction sites and environmental protection areas (including SACs and SPAs).

There would also obviously be further impacts on the ecology of river reaches or lakes / reservoirs that are located downstream of the pollution source, although the assessment of these is also outside the scope of the PFRA.

More detailed local analyses would be required to improve the accuracy of the risk and vulnerability assessments and to account for any mitigation measures already in place at the IPPC and Seveso sites, to determine if any of these types of sites constitute a potentially significant flood risk.