Predictive National Flood Risk Assessment

Flood Risk Index Assessment Methodology Report

May 2025

Contents

List of Tables

List of Figures

Glossary

Terms Used

Area of High Flood Risk Index (FRI) Score	Geographic area identified, based solely on the FRI assessment, which attract an FRI score equal to or greater than 250.
Area of Potentially Significant Flood Risk (APSFR)	Geographic area identified, based on the overall Preliminary Flood Risk Assessment, where a *potentially significant* risk of flooding exists in the Current scenario.
Area of Potentially Significant Future Flood Risk (APSFFR)	Geographic areas identified, based on the overall Preliminary Flood Risk Assessment, where a *potentially significant* risk of flooding exists in the Future scenario(s) (MRFS and/or HEFS).
Community	Cities, towns, villages or townlands where a collection of homes, businesses and other properties form the nucleus of, and are unified by, the local geography.
Exposure	The presence of a *receptor* (see below) within a flood *hazard* (see below).
Flood Extent	The extent of land that has been, or might be, flooded. Flood extent is often represented on a flood map.
Flood Risk	The combination of the probability of an area or receptor being flooded with the impact, or consequences, if that area or receptor were to flood.
Flood Risk Index Assessment	A quantitative, non-monetary assessment of flood risk based on the presence of *receptors* within an identified *hazard*.
Flood Hazard	The combined extent and probability of a flood that has the potential to cause harm or detrimental consequences.
Higher Risk Grid Squares	Grid squares assessed in the Flood Risk Index Assessment, which have an FRI score above the defined threshold of 15.
High-End Future Scenario (HEFS)	An Extreme future scenario with allowances for significant increased flow and/sea level rise due to climate change.
Mid-Range Future Scenario (MRFS)	A likely future scenario with allowances for increased flow and/sea level rise due to climate change.
Preliminary Flood Risk Assessment (PFRA)	The overall assessment considering historic floods, predictive assessments, and stakeholder engagement to identify those areas for which potentially significant flood risk exists.
Receptor	People, places, objects or activities that might suffer harm or damage in the event of a flood, such as a house, office, monument, hospital, road, agricultural land or environmentally designated site.

Significant	A qualitative, not quantitative, term used to represent *flood risk* that is of particular concern nationally. Section 5.3 of the report sets out guiding principles in defining locations that might potentially be at *significant flood risk*.
Vulnerability	The potential degree of damage to a *receptor* (see above), and the degree of consequences that would arise from such damage.

1 Introduction

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 those areas for which they conclude that potentially significant flood risks exist' as part of a 'Preliminary Flood Risk Assessment' (PFRA). The PFRA shall be reviewed, and if necessary updated, every six years.

In Ireland, the areas of potentially significant flood risk were designated as Areas for Further Assessment (AFA) during the National CFRAM Programme and the first cycle of implementation of the 'Floods' Directive.

The PFRA was undertaken as part of the first cycle of implementation of the 'Floods' Directive in 2011 and then completed in 2012 after public consultation. A total of 300 communities were designated as AFAs.

The PFRA was subsequently reviewed and updated in 2019, the second cycle. No new communities were designated, and 101 communities that had previously been designated as AFAs had their designation removed, primarily on the basis of further and more detailed assessment undertaken through the National CFRAM programme. This resulted in a revised list of 199 communities, or Areas of Potentially Significant Flood Risk (APSFR). The abbreviation AFA is now superseded.

The third cycle review of the PFRA includes an updated national review of all communities based on the current understanding of flood risk today and in the future. The third cycle review of the PFRA is to be undertaken and updated by 22 December 2024.

The PFRA is a 'high-level' investigation to identify, for each River Basin District and Unit of Management throughout the country, APSFRs based on 'available or readily derivable' information. The results of this initial assessment are used to focus subsequent, and more detailed, flood risk studies for Ireland.

The PFRA in Ireland is undertaken using three approaches:

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

The Predictive National Flood Risk Assessment (PNFRA) relates specifically to the predictive assessment of flood risk to inform in the third cycle review of the PFRA based on the Flood Risk Index Assessment (FRIA).

The FRIA consists of a non-monetised, numeric assessment of flood risk for a variety of sources of flooding at a national scale. It is a spatial assessment which primarily considers the presence of receptors within a flood extent, and their respective vulnerability. This FRIA methodology report (this report) has been prepared by the Office of Public Works (OPW), to outline the methods used to evaluate the potential current and future flood risk in Ireland to comply with the requirements of the 'Floods Directive'. The methodology report includes a review of previous methods used in the first (2012) and second (2019) cycle PFRAs, and updates where appropriate to reflect best use of available or readily derivable information. The outcome of the FRIA is to identify Areas of High Flood Risk Index Scores for both the Current Scenario and for potential future scenarios. As such, a list of Areas of High FRI Score is identified for the Current Scenario, the Mid-Range Future Scenario (MRFS), and the High-End Future Scenario (HEFS).

The findings of the PNFRA will be reviewed against historic flood events and shared with relevant stakeholders for consultation as part of the wider third cycle review of the PFRA. Once the review of the PFRA is complete, a finalised, updated list of APSFRs will be determined and published.

2 Flood Risk Index Assessment - Overview

2.1 Requirements of the Floods Directive

Within Articles 4 and 5 of the Floods Directive, the legislation sets out a variety of considerations which should be made in undertaking the PFRA and the identification of APSFRs. Not all of these considerations are directly relevant to the predictive assessment (PNFRA), and are covered elsewhere within the wider PFRA. Table 2-1 below provide a checklist for the requirements set out in the Floods Directive, the relative inclusion or exclusion of these, and a sign-post as to their respective inclusion.

Table 2-1 Checklist of the requirements of the Floods Directive as set out in Chapter II 'Preliminary Flood Risk Assessment'

Item	Article(s)	Included	Location	Commentary
Records and studies on long-term development	**4(2), 4(2)(d)**	**Yes**	Internal Technical Note	Assessment of the potential flood risk impacts to long-term development undertaken, including the effects of climate change.
Impacts of climate change	**4(2), 4(2)(d)**	**Yes**	FRIA	The FRIA has been undertaken for the current scenario and two future scenarios (MRFS and HEFS). Areas of High FRI Score are identified for all scenarios.
Maps of the river basin district	**4(2)(a), 6**	**Yes**	PFRA	Updated flood maps produced via the NCFHM (Coastal), NIFM (Fluvial) and GWFlood (Groundwater) projects respectively (see also floodinfo.ie).
Floods which have occurred in the past	**4(2)(b), 4(2)(c)**	**Yes**	PFRA	Assessment of past floods included within the main PFRA report and supports the identification of APSFRs.
Human Health	**4(2)(d)**	**Yes**	FRIA	Please refer to Section 4.5.1, 4.5.2 and 4.5.3 for detailed methodology.
Environment	**4(2)(d)**	**Yes**	FRIA	Please refer to Section 4.5.4, 4.5.5, and 4.5.6 for detailed methodology.
Cultural Heritage	**4(2)(d)**	**Yes**	FRIA	Please refer to Section 4.5.7, 4.5.8, and 4.5.9 for detailed methodology.
Economic Activity	**4(2)(d)**	**Yes**	FRIA	Please refer to Section 4.5.10 to 4.5.13 inclusive for detailed methodology.
Effectiveness of existing man-made flood defence improvements	**4(2)(d)**	**Yes**	PFRA	Benefitting areas identified in flood hazard mapping and factored into the identification of APSFRs.
International river basin districts	**4(3), 5(2)**	**Yes**	PFRA	Cross-border coordination undertaken as required in the flood risk assessment of river basin districts.
Identify those areas that potential significant flood risks exist	**5(1)**	**Yes**	FRIA and PFRA	Areas of High FRI Score identified based on the PNFRA, with review of past floods and consultation with relevant stakeholders feeding into the final list of APSFRs.

2.2 Introduction to Flood Risk Index Assessment

The Flood Risk Index Assessment for the third cycle review of the PFRA is broadly consistent with the original predictive assessment undertaken in the first cycle PFRA. It comprises three main elements including the definition of '**flood hazard**' areas and of '**flood receptors**' respectively. The third element involved combining these two data sets to evaluate '**flood risk**'.

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

  Flood hazard areas (or flood extents) 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.

  Pluvial flooding was not considered within the PNFRA, as no new national predictive flood hazard mapping has been produced at a scale or extent suitable for use in the PNFRA. Pluvial flooding was included within the wider review of the PFRA through the review of past floods and consultation with relevant stakeholders.

- '**Flood receptors**' are defined as people, places, objects or activities that might 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 consistent with Article 4 of the Floods Directive.

- '**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 were compiled and reviewed in a Geographical Information System (GIS). This approach 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 was only defined for receptors located within the flood hazard areas. Identified receptors outside the flood hazard area are not at flood risk.

The FRI assessment used this approach to undertake a non-monetised, numeric assessment of flood risk for a variety of sources of flooding based on a spatial assessment that primarily considers the presence of receptors within a flood extent, and their respective vulnerability.

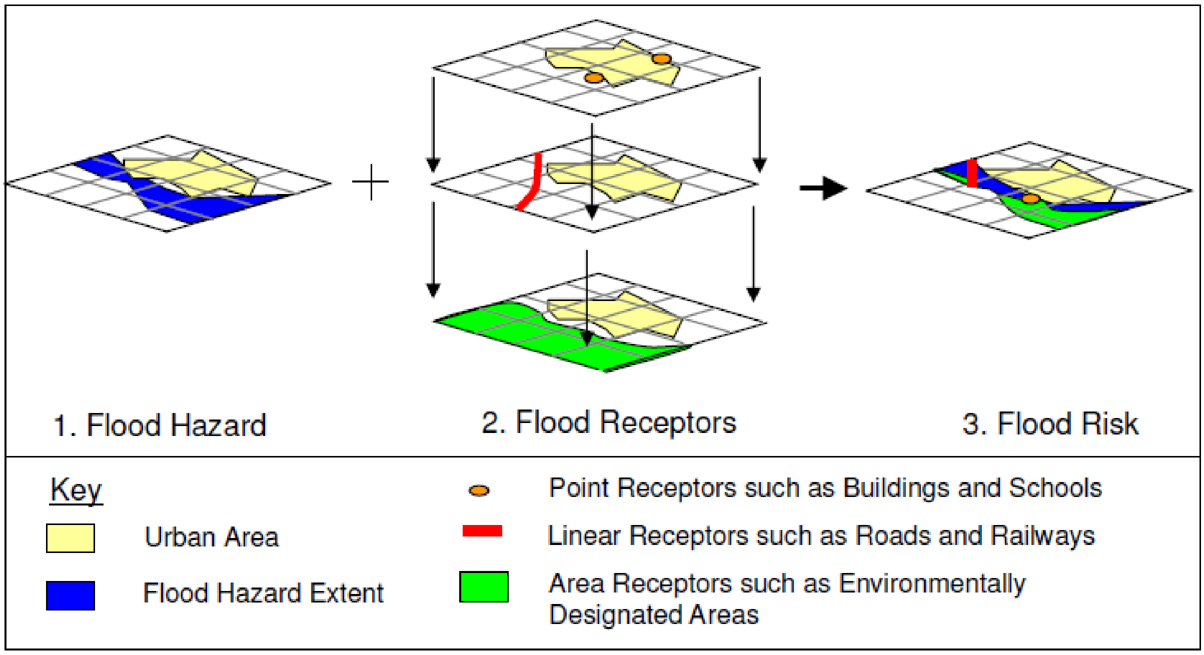

Figure 2-1; Schematic diagram illustrating the determination of flood risk through combining flood hazards and flood receptors

2.3 Report Structure for Flood Risk Index Assessment

The methodology report is structured to detail the approach to each of the three stages of the PNFRA:

- Section 3 details the identification of flood hazard areas
- Section 4 details the identification of flood receptors
- Section 5 details how flood risk was assessed and how Areas of High FRI Score have been identified

3 Flood Risk Index 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 – the flood hazard. 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 principal flood mechanisms.

Each of these flood hazard areas is indicatively representative of a specified probability of the flood event occurrence. The probability of the flood event occurrence is detailed as the annual exceedance probability (AEP), or the probability (expressed as a percentage) of a flood event occurring in any given year.

The following sections provide details of the best available national data sets used to define the flood hazard areas associated with each principal flood mechanism assessed in the PNFRA.

The PNFRA does not include an assessment of pluvial flooding, as no new predictive flood hazard mapping was available at a scale and extent suitable for use in the PNFRA. However, pluvial flood risk was considered within the review of the PFRA as a whole through the other two approaches outlined (see Section 1) – review of past flood events and consultation with relevant stakeholders.

3.2 Fluvial Flood Hazard Areas

Predictive flood maps were developed as part of the first cycle PFRA to enable a predictive assessment of flood risk. The maps developed for the first cycle PFRA were based on simple methodologies that were appropriate for a national screening exercise, enabling an indicative assessment of flood risk. Maps were produced for the national river network for all catchment areas greater than 1 km².

Following the first cycle PFRA, the National Catchment-based Flood Risk Assessment and Management (CFRAM) programme included the preparation of flood hazard and risk maps for the 300 AFAs (now APSFRs) and for reaches between the AFAs and reaches running downstream of an AFA to the open sea. The flood mapping produced under the CFRAM programme provides much more reliable information than the first cycle PFRA on flood extents and depths, through hydrological analysis and hydro-dynamic modelling making use of topographical and aerial survey to produce channel cross-sections and Digital Terrain Models (DTMs).

Under the National CFRAM Programme, a detailed assessment of risk provided economic justification of approximately 120 new flood protection options which were proposed in the Flood Risk Management Plans (FRMPs), along with a number of national non-structural measures. Many of these options include schemes for cities, towns and villages. A number of these schemes are now at various stages of development – either in planning, design, at construction or completed.

Further to the National CFRAM programme, National Indicative Fluvial Mapping (NIFM) has been produced to provide higher quality and accuracy flood mapping relative to the mapping prepared during the first cycle PFRA, for rivers outside the geographic extent of the CFRAM programme. Through a 2D hydraulic model, the NIFM data was produced for all watercourses in Ireland with a catchment area greater than 5 km² and not already mapped as part of the CFRAM programme.

Both the CFRAM (Fluvial) and NIFM data sets are used within the PNFRA. The fluvial flood mapping produced and used within the first cycle PFRA was not used in the third cycle PFRA. The data sets used to define fluvial flood hazard areas within the PNFRA are detailed in Table 3-1.

Table 3-1 Fluvial flood hazard data to be used in the PNFRA

Data Set	Publication Date	Probability	Further Details
National CFRAM Mapping	**2016**	5% AEP	Data set to be used nationally where available. Data was available for the Current Scenario, Mid-Range Future Scenario (MRFS), and High-End Future Scenario (HEFS). Flood depth, level, and extent data available. Flood depth and level data was not readily available for HEFS for some AEPs. Flood extent data was not available for 5% AEP HEFS for most locations.
		1% AEP	
		0.1% AEP	
National Indicative Flood Mapping	**2020**	5% AEP	Data set to be used nationally where available (catchment area > 5 km² and excluding areas covered by the CFRAM mapping). Data was available for the Current Scenario, Mid-Range Future Scenario (MRFS), and High-End Future Scenario (HEFS). Flood depth, level, and extent data available.
		1% AEP	
		0.1% AEP	

It is acknowledged that in some areas, new and updated hydraulic modelling is or will be available for the geographic areas covered by new flood relief schemes (developed during the detailed appraisal and design stage). Detailed hydraulic modelling developed for individual schemes was not used in the PNFRA. Whilst it is acknowledged that this likely represents best available data, subject to the date of production amongst other factors, this data is not readily derivable for use at an appropriate scale as part of a national screening exercise.

Furthermore, such data is almost exclusively only available for locations where flood protection options are either implemented or planned. It should also be noted that communities where a flood relief scheme is under construction or is planned will retain their status as an existing APSFR, and so updated mapping for these communities was not critical for the purpose of the PNFRA.

Fluvial flood risk to catchment areas which are less than 5km² and not covered by the CFRAM programme was not assessed under the PNFRA due to an absence of readily available and derivable flood hazard data.

Full details of the methodology used to develop flood maps are available in various CFRAM Study Hydrology Reports and Hydraulic Reports, and in the NIFM Final Project Report, all available online at www.floodinfo.ie/publications.

3.3 Tidal Flood Hazard Areas

Detailed tidal modelling defining the flood hazard area for tidal flooding along the coast of Ireland has been undertaken in the past through the Irish Coastal Protection Strategy Study (ICPSS), completed in 2013, based on advanced numerical modelling of combined storm surges and tide levels to obtain extreme water levels along the coastline. The extreme water level data was projected inland and compared to a Digital Terrain Model (DTM) to generate the tidal flood hazard data. This data and mapping, where available, was used to inform the first cycle PFRA.

Following the first cycle PFRA, the National Catchment-based Flood Risk Assessment and Management (CFRAM) programme (see also 3.2) included the preparation of flood hazard and risk maps for the AFAs where tidal flood risk was identified only. This again used the ICPSS extreme water level data. The flood mapping produced under the CFRAM programme provides much more reliable information on flood extents and depths, through hydrological analysis and hydro-dynamic modelling making use of topographical and aerial survey to produce DTMs and applying a temporally varying water level at the coastal boundary to represent the tidal cycle.

Further to the National CFRAM programme, the Irish Coastal Wave and Water Level Modelling Study (ICWWS) was undertaken to update the estimated extreme water level data previously derived under the ICPSS. Similar analytical and numerical modelling techniques to those proven successful as part of the ICPSS were used, together with new data on historic tidal flood events which have occurred since the ICPSS. Improvement in modelling and statistical analysis due to the availability of additional bathymetry and meteorological data resulted in increased confidence in the ICWWS results in comparison with ICPSS with the model tolerance for estimated extreme water levels reduced from ±180mm to ±150mm relative to OD Malin (OSGM15).

As such, the ICWWS outputs represent the best available and most up to date extreme coastal water level data, which was subsequently used to produce updated flood hazard mapping in 2021 - National Coastal Flood Hazard Mapping (NCFHM). The NCFHM interpolated extreme water levels generated by ICWWS to produce a sea level surface, before resampling this dataset down to a 5m resolution. A Digital Terrain Model (DTM) was then used to project levels inland and generate flood maps, with the DTM being subtracted from the interpolated and resampled sea level surface. NCFHM does not include wave overtopping.

The data sets used to define tidal flood hazard areas within the PNFRA are detailed in Table 3-2.

Table 3-2 Tidal flood hazard data to be used in the FRIA

Data Set	Publication Date	Probability	Further Details
National Coastal Flood Hazard Mapping (NCFHM)	2021	5% AEP	Data set to be used nationally where available. Data was available for the Current Scenario, MRFS, and HEFS. Flood depth, level, and extent data available.
		1% AEP	
		0.1% AEP	

The mapping produced through the National CFRAM programme was based on the older ICPSS data, and so the NCFHM was used nationally for the PNFRA.

As with fluvial flood hazard areas, it is acknowledged that in many cases, new and updated hydraulic modelling is available for the areas covered by new flood relief schemes (developed during the detailed appraisal and design stage). Detailed hydraulic modelling developed for individual schemes was not used in the PNFRA. This was for the same reason as indicated in 3.2.

Full details of the methodology used for ICWWS and NCFHM are available in the Irish Coastal Wave and Water Level Modelling Study 2018 Phase 1 (Extreme Water Levels) Report and the National Coastal Flood Hazard Mapping 2021 Flood Mapping Methodology Report respectively, available online at www.floodinfo.ie/publications.

3.4 Groundwater Flood Hazard Areas

Predictive groundwater flood maps were developed as part of the first cycle PFRA to enable a predictive assessment of flood risk. The maps developed for the PFRA were based primarily using evidence collated from past studies, newspaper articles, historic maps, aerial photography and satellite imagery showing the extent of flooding during past events. No analysis or numerical modelling was undertaken. This evidence identified that the vast majority of groundwater flooding in Ireland occurs at turloughs located in karstified limestone environments.

In response to the extensive 2015/16 groundwater flooding, Geological Survey Ireland carried out the GWFlood Project, to advance understanding of karst groundwater flooding in Ireland. This project included the production of two flood maps – a historic groundwater flood map and a predictive groundwater flood map. The flood mapping produced focused on groundwater flooding associated with karstified bedrock. Non-karst groundwater flooding (e.g. permeable superficial deposits) was not studied within the GWFlood Project.

The data sets used to define groundwater flood hazard areas within the PNFRA are detailed in Table 3-3.

Table 3-3 Groundwater flood hazard data to be used in FRIA

Data Set	Publication Date	Probability	Further Details
National GWFlood Project mapping	2020	5% AEP	Data set to be used nationally where available. Data is available for the Current Scenario only at the time of analysis. Flood depth, level and extent data available.
		1% AEP	
		0.1% AEP	

It is acknowledged that the mapping available through the GWFlood Project data does not yet take account of potential impacts of climate change on groundwater flooding. A further project was initiated by GSI in January 2020 (GWClimate) with the objective of producing a predictive groundwater flood map considering the potential future impacts of climate change. This mapping was not available when the PNFRA was undertaken. For the purpose of the FRI assessment, groundwater flooding was not considered in the future scenarios.

Full details of the methodology used for the GWProject flood mapping are available in a separate report[1].

[1] Geological Survey Ireland (2020) GWFlood Project: Monitoring, Modelling and Mapping Karst Groundwater Flooding in Ireland. Revision 1.2.

3.5 Potential Impacts of Climate Change

At the time of the first cycle PFRA, whilst international and national research indicated that flooding was likely to worsen as a result of climate change, the information required to undertake a predictive analysis of the potential flood risk impacts of climate change was not available.

The second cycle review of the PFRA, with the availability of more robust data from both the National CFRAM Programme and the ICPSS on the potential impacts of climate change, included an assessment of likely impacts of climate change on flood risk. This determined that "the potential impacts of climate change can increase flood risk in Ireland very significantly in the future, particularly in coastal areas. These impacts will however evolve over a number of decades". It goes on to acknowledge the ongoing (at the time) work on the Sectoral Adaptation Plan for Flood Risk Management before concluding it is "not considered necessary to designate…, at this time, areas currently at low risk but that could be subject to significant risk under future scenarios."

The second Climate Change Sectoral Adaptation Plan for Flood Risk Management was published in 2019, and detailed an action (Plan Action 1B) to "Through reviews of the Preliminary Flood Risk Assessment and flood maps, informed by the most up-to-date research and projections of climate change, assess the potential impacts on flooding and flood risk across the country". With tidal and fluvial flood mapping available for future climate change scenarios (MRFS and HEFS), it was considered appropriate to include potential climate change impacts in the PNFRA through the definition of flood hazard areas and identification of Areas of High FRI scores for future scenarios as well as for the Current Scenario.

Section 5 identifies how flood risk was assessed to enable the identification of Areas of High FRI Score of all scenarios.

3.6 Potential impact of Long-term Development

No specific assessment of the potential impact of flooding on areas of long-term development was undertaken during the first cycle or second cycle review of the PFRA.

Project Ireland 2040 is the government's long-term overarching strategy to make Ireland a better country for all of its people. By 2040, the population of Ireland is projected to increase by approximately 1,000,000. This population growth will in turn require new homes and jobs, alongside amenities and enhanced regional connectivity.

Project Ireland 2040 National Planning Framework (NPF) guides development and investment over the coming years, including regional targets for population growth and employment opportunities. The NPF is underpinned by more detailed plans at a Regional (Regional Spatial and Economic Strategies) and Local (Development Plans and Local Area Plans) scale.

At the Local scale, spatial mapping is produced to 'zone' land according to current or proposed future use. New Development Plans and Local Area Plans link to Project Ireland 2040, coordinating and prioritising areas to meet national targets set out in the National Development Framework. Development Plans and Local Area Plans are updated in six-year cycles, providing the best available or readily-derivable information of long-term development in Ireland.

Data is available to view online via myplan.ie and has been provided by the Department of Housing, Local Government and Heritage for the purpose of the PNFRA.

Data available at the time of the PNFRA was last updated in 2018. These Development Plans and Local Area Plans used post-2006 population projections and allowed 50% more land to be zoned than was required to meet these projections. In hindsight, analysis indicated this was an overestimate of population projections. New plans, when produced, will use Project Ireland 2026 (and 2031) population projections and will include only a 25% headroom allowance. As such, whilst the current data available is based on superseded population projections, the fact this was overestimated indicates it is still a reasonable interpretation of long-term development in Ireland pending the new plans, and is currently the best available information.

The PNFRA included a national scale review of land identified for new and proposed development located in areas of flood risk now or potentially in the future. A spatial assessment was undertaken to identify the size and type of land zoned for future development that is located within flood risk areas.

Existing development which is subject to regeneration / redevelopment was not identifiable using readily available information so was excluded from the assessment of long-term development. The following land categories were used in the assessment of long-term development:

- O1 – Strategic reserve, White land;
- R1 – New/proposed residential;
- R4 – Strategic Residential Reserve.

Land zoned as ‘strategic reserve’ typically relates to longer-term development plans.

It was noted that, due to inconsistency in land zoning, this assessment may exclude some lands proposed for longer-term development. For example the proposed route for the Limerick Northern Distributor Road has been zoned as “N1.1 – Road” in myplan.ie, which adopts nationally consistent codes. However within the Clare County Development Plan it is zoned as “Infrastructure Safeguard”, land for the future provision of key infrastructural services.

In addition, it is noted that this review can only be undertaken where spatial mapping data is available in GIS compatible format. In some cases, spatial mapping data is not readily available for existing Development Plans or Local Area Plans. In other cases, new Development Plans or Local Area Plans are expected but were not published at the time of the assessment. As such, the review is only representative of a sample of plans and cannot be assumed to be a representation of Ireland as a whole. The review identifies the volume and location of plans that are included in the assessment.

It was not possible or appropriate to undertake a specific FRIA on long-term development as information is not readily available at the property specific level, nor should Areas of High FRI Score be designated based on receptors which do not yet exist. The assessment was instead published in tabular format, with the spatial distribution of the identified long-term development at flood risk provided at the local authority level. This data was not specifically used to inform the designation of APSFRs at it relates to possible future risk that will only develop in the decades to come, or may not arise should development over-time either not progress or be reassigned to other locations than this currently zoned.

4 Flood Risk Index Assessment – Flood Receptors

4.1 Introduction

The Floods Directive requires the PFRA to consider "significant adverse impacts" of flooding on "human health, the environment, cultural heritage and economic activity."[2]

In order to determine areas of flood risk across the country, data on flood risk 'receptors' was 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 were 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.
- **Environment:** For the PFRA, receptor data for the natural environment was obtained for areas of designated and protected habitats and species across Ireland.
- **Cultural Heritage:** These receptors cover sites of importance from the man-made and natural environment including architecturally or archaeologically significant sites, places of importance to cultural heritage, and principal museums and galleries.
- **Economic:** This covers infrastructure or assets with economic importance such as utility supplies, transport services and agricultural land. 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.

This section details the available and readily derivable data for each receptor and how this was used to assess the impact of flooding for each receptor type.

4.2 The Selection and Classification of Flood Receptors

The identification and classification of receptors potentially at risk from flooding was not substantially changed from the hierarchical classification structure adopted for use in the first cycle PFRA. This enabled a degree of consistency with previous assessments. Receptors were grouped into principal categories listed above and aligned to the Floods Directive at Level 1. Increasing granularity was provided through Levels 2 and 3, with specific receptor types detailed at Level 4. A list of receptors included in the PNFRA is detailed in Table 4-1.

[2] 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.

Table 4-1 List of Receptors and the Classification Structure used for the PNFRA

Receptor Classification				**Receptor**	**Input Data**
Level 1	**Level 2**	**Level 3**	**Level 4**		
Social (Human Health)	Human Health	Residential Properties	Death, Injury, Stress	Detached	**PRIME2 (building_poly, building type id)**, GeoDirectory (residential delivery points)
				Semi-detached	
				Terrace	
				Bungalow	
				Ground Floor Flat	
				Raised Flat	
		Dangerous Substances	Death, Injury, Illness	COMAH (formerly Seveso) sites	**RFI 174561 Locations of COMAH Establishments.10feb21 (Health and Safety Authority)**
	Community	Social Infrastructure	Education	Early Years Services	**ELC_Services (Department of Children, Equality, Disability, Integration and Youth)***
				Special Education	**Primary_2019_EnvironV4, School Type (Department of Education)**
				Pre-School	**Primary_2019_EnvironV4, Pre-School on site (Department of Education)**
				Primary	**Primary_2019_EnvironV4 (Department of Education)**
				Post Primary	**Post.Primary_2019_EnvironV2 (Department of Education)**
				Third Level	**Information from the Higher Education Authority (Higher Education Authority)****
			Emergency Services	Fire Station	**PRIME2 (building_poly, form_value)**
				Garda Station	**garda_stations (All Island Research Observatory, via data.gov.ie)**
				Civil Defence	**List of civil defence sites for OPW (Department of Defence)**
			Governance	OPW / Government Buildings	**PRIME2 (building_poly, func_value)**
			Care Homes	Nursing Homes	**nursing_homes (Health Service Executive)**
			Hospitals	Hospitals	**listofhospitalsinireland (Health Service Executive)**
			Health Centre	Health Centres	**listofhealthcentresinireland (Health Service Executive)**
			Community Services	Post Office	**PRIME2 (building_poly, func_value)**
Environment	Natural Environment	Protected and Designated Land / Areas		Special Area of Conservation (SAC)	**SAC_ITM_2019_12 (NPWS)**, CLC_IE_ITM (CORINE Land Cover, EPA)*** , PRIME2 (water_poly)
				Special Protected Area (SPA)	**SPA_ITM_2019_12 (NPWS)** , CLC_IE_ITM (CORINE Land Cover, EPA)*** , PRIME2 (water_poly)
				Natural Heritage Area	**NHA_ITM_2019_06 (NPWS)**, CLC_IE_ITM (CORINE Land Cover, EPA)*** , PRIME2 (water_poly)
				Proposed Natural Heritage Area	**pNHA_ITM_2015_11 (NPWS)**, CLC_IE_ITM (CORINE Land Cover, EPA)***, PRIME2 (water_poly)
		Pollution		Licensed Waste Facilities	**LicensedFacilities_Waste_21092020 [*Waste*] LicensedFacilities_IE_21092020 [*Industrial Emissions*] LicensedFacilities_IPC_21092020 [*Integrated Pollution Control*] (EPA)**
Cultural Heritage	Cultural Heritage	Built Heritage		Architectural Heritage	**NIAH161116 (Department of Housing, Local Government and Heritage)**
		Museums and Cultural Records		Museums, Archives and Art Galleries	**MuseumsCollectionsArchives (Heritage Council)**
		Archaeological / Historical Monument Sites		Site and Monument Record***	**SMR_NMS210126_excl_redundant_records (Department of Housing, Local Government and Heritage)**
				UNESCO World Heritage Sites	**UNESCO Sites in Ireland (Heritage Council)**
Economic Activity	Business	Commercial Properties	Economic Impact on Business Activity	Commercial Properties	**PRIME2 (building_poly, form_value, func_value)**, GeoDirectory (commercial_delivery_points)
	Infrastructure	Utilities	Power	Power Stations	**Power_Plants_-_Osi_National_250k_Map_of_Ireland-shp (All Island Research Observatory)**
				High-Voltage Substations	**PRIME2 (building_poly, func_value)**
			Water	Wastewater Treatment Plants	**UWWT_PlantCompliance_20022020 (EPA)**
		Transport	Road	Motorways	**PRIME2 (way_poly, func_value, eng_name)**
				National Primary Routes	**PRIME2 (way_poly, func_value, eng_name)**
				Regional Routes	**PRIME2 (way_poly, func_value, eng_name)**
			Rail	Railway Lines and Infrastructure	**IR Network (Irish Rail) Green_Line_Polyline / Red_Line_Polyline (TII)**
			Airports	Airfields and Aerodromes	**PRIME2 (building_poly, site_poly, form_value, func_value)**
				Airports - National and Regional	
				Airports - International	
	Agriculture and Land	Arable land		Arable land	**CLC_IE_ITM (CORINE Land Cover, EPA)***
		Permanent crops		Permanent crops	
		Pastures		Pastures	
		Heterogeneous agricultural areas		Heterogeneous agricultural areas	
		Natural grassland		Natural grassland	

*Early Start & Rutland Street List (Department of Education) amalgamated into the ELC_Services list provided by Department of Children, Equality, Disability, Integration and Youth

**Data readily available for publicly funded Higher Education Institute main campus locations only

***EPA National Land Cover project will provide improved definition of Irish land cover types and improved resolution (1Ha versus 25Ha), but is not yet readily available (due later in 2021).

A number of revisions were made to the list of receptors compared to the first cycle PFRA, to reflect improved understanding of flooding impacts together with critical infrastructure in a developed nation. Additional receptors (compared to the first cycle PFRA) are highlighted in green in Table 4-1. Key changes are summarised below.

- Residential properties (Human Health) were classified by property type (detached, terraced, etc) rather than leaving the property type unclassified. Property damage in any given flood event can increase by up to 83% (based on MCM Direct damage data) for a detached property compared to a terraced property.
- Establishments where dangerous substances are present (COMAH sites) were included within the Human Health category.
- Early years services, pre-school, special education, and post offices were included within the social infrastructure category to reflect the increased vulnerability and importance to significant numbers of the local community respectively.
- Eircom assets (Telecommunications) were **removed** from the list included in the first cycle PFRA. This reflected research into the damages of the 2007 floods in UK which found "There were few reports of telephone exchange and network equipment affected by flooding. Unless flood water enters property, resilience of telecommunications equipment to flooding was high"[3].
- Regional Routes (Transport) were included as they have the potential for more significant disruption than National Routes or Motorways in rural communities e.g. the R591 near Skull is in a flood hazard area, and would result in an increase in journey distance from 8km to 31km to access the nearest National Route (N71).

4.3 Quality Assurance of Input Data

A comprehensive data collection and review exercise was undertaken to identify, review and assure the best readily available and derivable information for each receptor type.

PRIME2 building footprints allowed the flood risk to property-based receptors to be assessed based on any part of the footprint being within the flood hazard area, rather than a single point associated with point receptors (as was done for the first cycle PFRA using Geodirectory data).

This required independent point receptor datasets e.g. primary schools, to be mapped against the building footprints to ensure that a footprint could be assigned to the respective point data.

Where a point lay outside the building footprint, an exercise was undertaken to assign the point receptor to the appropriate building footprint. For example, if the point for a primary school was located in the adjoining playground, the point would be moved to within the building footprint of the school to ensure accurate assessment.

This process was repeated for multiple datasets to significantly improve the robustness of the assessment. It was only undertaken for point receptors which were located within or close to the

[3] Environment Agency (2010), *The Cost of the summer 2007 floods in England*, Environment Agency, UK.

identified flood hazard areas (as those outside flood hazard areas would attract a Flood Risk Index score of 0, see Section 4.5).

In total, 71% of the property-based point receptors in independent datasets (excluding the Sites and Monuments Record and National Inventory of Architectural Heritage) were mapped directly to a building footprint. Approximately 10% (999) of the remaining point receptors were located within flood hazard areas, and the majority of these were reassigned to the appropriate building footprint using property names, addresses, Eircodes, and aerial photography to ensure the process was accurate.

Most of those point receptors that required reassigning were museums, nursing homes, and early learning centres. A buffer, creating an indicative circular building footprint, was applied to Wastewater Treatment Plants data as these could not be accurately assigned to a PRIME2 building footprint due to a lack of available address data.

The volume of Sites and Monument Records (SMR) and National Inventory of Architectural Heritage (NIAH) outside building footprints (145,000) was such that the reassignment process could not be completed proportionately. Receptors at flood risk which had a higher vulnerability were assigned to an appropriate building footprint, and a typology based buffer was assigned to the remaining receptors of lower vulnerability, in consultation with Fingal County Council (who adopted a similar methodology on a recent independent assessment), based on the class description and original type attributes for SMR and NIAH receptors respectively.

4.4 Evaluating the Impact of Flooding on Different Receptors

Given the diversity of receptors considered within the FRIA, a monetary assessment of damages would have been difficult to achieve with a high degree of confidence at a national scale using readily available information. As such, a 'semi-quantitative' method of evaluating the impact of flooding across all the receptor types was utilised.

This approach was broadly consistent with the first cycle PFRA and is discussed in further detail below.

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

Flood impact was represented as a function of the receptor 'importance' and 'potential damage' from flooding.

Importance was based on its function, scale of influence and ease of replacement.

Potential damage was based on 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 equated to higher levels of vulnerability to flooding for the receptor.

4.4.2 Stage (ii): The Basis for Assessing Receptor Vulnerability

To determine distinct levels of vulnerability, relating to the combined function of importance and potential damage, a vulnerability scale was used comprising of six categories. This table is listed in Table 4-2.

Table 4-2 List of vulnerability categories

Critical Vulnerability
Extreme Vulnerability
High Vulnerability
Moderate Vulnerability
Low Vulnerability
Very Low Vulnerability

A more important receptor that had the potential to suffer significant damage was classified towards the upper categories (Critical, Extreme). A less important receptor that was less prone to suffer from flood damage was classified towards the lower categories (Low, Very Low).

4.4.3 Stage (iii): Defining Vulnerability According to the Types of Flood Impact

When determining the nature of the impact of flooding on a receptor, it was acknowledged that different receptors would be impacted differently. For example, the impact of flooding on a residential property could result in a risk to human life and a damage to the property and the property contents. Whereas the impact on a wastewater treatment plant would relate to loss of service. For this reason, types of flood impact, or 'vulnerability derivation' tables (see Appendix A) were applied which cover the following types of impact:

- **Table 1 - Risk to Life**: This category included all receptors that human life may potentially occupy.
- **Table 2 - Damage to Matters of Value:** This category was applied to receptors that were themselves considered valuable in terms of cultural heritage, archaeological significance, environmental significance, or had contents that could be considered valuable from a societal, social or personal point of view.
- **Table 3a - Significant Loss of Service:** This category covered the loss of a service that was considered to be essential e.g. water supply, or complete loss of a main transport link.
- **Table 3b - Less Significant Loss of Service:** This category was applied to services where the impact of them flooding was still considered important, but not essential e.g. community centres.
- **Table 4 - Emergency Response and Recovery:** This category covered the impact of flooding on emergency services that could play a role in mitigation of risk to loss of life during extreme events.

Each vulnerability derivation table was assigned a number of probable impact levels cross referenced with the degree of receptor importance / designation to enable the assignment of a vulnerability class to each receptor. In all cases, the Vulnerability Class was Critical, Extreme, High, Moderate, Low, or Very Low. This was consistent with the first cycle PFRA, although the

"Very Low" classification was introduced to reflect the very low impact to some receptors under certain categories, whilst providing clarification that this does not equate to "No Vulnerability".

Where the vulnerability of a receptor was classified under a number of different tables, each table was documented and the 'highest' vulnerability classification was assigned to that receptor. The following example highlights how the vulnerability level for a specific receptor was determined. The full list of tables to derive receptor vulnerability is detailed in Appendix A – Tables to Derive Receptor Vulnerabilities.

Example of Vulnerability Classification - Gárda station

A gárda station is completely inundated by floodwaters. Due to the fact that many gárda stations in the country are occupied 24/7, it is safe to assume that there is a risk to life from this flood event. Given the nature of the service provided by the station, there is also a risk to partial loss of service in the form of emergency response and recovery, which this asset provides to a local community.

While it is accepted that there is a risk to life in this example, it is also understood that the population of this particular receptor will not be classified as vulnerable or having reduced mobility. For that reason, a vulnerability classification of 'Low' is assigned to this receptor from **Table 1: Risk to Life**, as seen highlighted in purple below.

In terms of the risk to loss of service, a gárda station will suffer from a partial loss of service from a local influence and therefore will be assigned a 'Moderate' vulnerability classification from **Table 4: Emergency Response and Recovery**, as seen highlighted in blue below.

Taking the 'higher' level vulnerability classification of the two, the local gárda station will have a final vulnerability classification of 'Moderate'.

Vulnerability Derivation Table 1: Risk to Life

Probable Impact	Vulnerability Classification
Significant Risk to Loss of Life	Critical
Highly Elevated Risk to Loss of Life	Extreme
Elevated Risk to Loss of Life	High
Moderate Risk to Loss of Life	Moderate
Low Risk to Loss of Life	Low
Very Low Risk to Loss of Life	Very Low

Vulnerability Derivation Table 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
Minimal Loss of Service	High	Moderate	Low

Negligible Loss of Service	Moderate	Low	Very Low

4.4.4 Global Weighting Research

An additional qualitative verification of the vulnerability classifications was undertaken to reflect nationally representative research undertaken as part of the CFRAM programme. This research was designed to determine global weightings that reflect the perceived importance of objectives for reducing economic, social and environmental / cultural heritage risks in flood management. The weightings represent the perceived importance of predetermined objectives and sub-objectives, set out for the purpose of assessing the effectiveness of a proposed flood relief option, from a societal point of view.

This evidence-based, quantitative research was used to ensure the vulnerability classifications were unbiased and considered the broader societal point of view.

As these objectives were broadly in keeping with the receptor categories of the FRIA, it was accepted that the perceived importance of the objectives assigned under the CFRAM global weightings could be assessed against the respective FRIA Vulnerability Classification.

Table 4-3 documents the link between the multi-criteria analysis (MCA) objectives and the PNFRA sub-categories.

Table 4-3 MCA Global Weightings against FRIA receptor categories

MCA Objective	MCA Sub-Objectives	Arithmetic Mean	Geometric Mean	Category Rank	Included in FRIA	PNFRA Sub-Category
Minimising Economic Risk	Minimise economic risk to homes and businesses	0.387	0.405	1	Y*	Residential / Commercial Properties
	Minimise risk to utility infrastructure	0.242	0.241	2	Y	Utilities, Ports and Airports
	Manage risk to agriculture	0.204	0.189	3	Y	Agriculture and Land
	Minimise risk to transport infrastructure	0.167	0.165	4	Y	Road and Rail
Minimising Social Risk	Minimise risk to human health and life of residents	0.452	0.464	1	Y*	Residential Properties
	Minimise risk to high vulnerability properties	0.278	0.286	2	Y**	Social Infrastructure
	Minimise risk to social infrastructure and amenity	0.152	0.139	3	Y**	Social Infrastructure
	Minimise risk to local employment	0.118	0.111	4	Y	Commercial Properties
Minimising Environmental / Cultural Risk	Provide no impediment to the achievement of water body objectives and, if possible, contribute to the achievement of water body objectives	0.279	0.279	1	Y	Pollution / Dangerous Substances
	Avoid detrimental effects to, and where possible enhance, Natura 2000 network, protected species and their key habitats	0.254	0.265	2	Y	Protected and Designated Land / Area
	Protect, and where possible enhance, visual amenity, landscape protection zones and views into / from designated scenic areas within the river corridor	0.134	0.131	3	Y	Protected and Designated Land / Area / Architectural Heritage / Archaeological and Historical Monument Sites
	Avoid damage to or loss of features, institutions and collections of architectural value and their setting and improve their protection from extreme floods.	0.130	0.124	4	Y	Architectural Heritage / Museums, Archives, and Galleries / Archaeological and Historical Monument Sites

It was evident from Table 4-3 that the proposed methodology for FRIA has complete coverage of all objectives assessed within the research. The highest ranking objectives by some measure were:

- Minimise risk to human health and life of residents;
- Minimise economic risk to homes and businesses.
-

The specific method of assessment for these receptors is detailed in Section 4.4.1 (Residential Properties) and 4.4.8 (Commercial Properties).

Given the perceived importance by society, an increased emphasis was placed on risk to life and loss of service tables when categorising the vulnerability classification for the FRIA. The key amendments made were:

- Risk to Loss of Life table was extended to include ‘Moderate’ and ‘Low’ risk to life. In the first cycle PFRA, receptors were only classified as vulnerable if there was an ‘Elevated’ risk to life. This amendment allows the risk in receptors populated part-time only, or with smaller populations, to be considered.
- Damage to Matters of Value table (applies to Cultural Heritage assets) was amended so “Severe Degradation” was re-set to align with “Moderate Damage”. This amendment was aligned to the importance placed on assets of heritage value detailed above, relative to other receptors.
- Loss of Service tables were reviewed, particularly in the context of local business and duration of up to one month. However the ‘Moderate’ vulnerability assigned in the first cycle PFRA was considered appropriate with no further amendment.

4.5 Analysis of Flood Receptors

Flood Receptors were analysed by determining a **Flood Risk Index (FRI) score**, consistent with the approach in the first cycle PFRA. For each flood receptor, the **FRI score** was assessed as the product of *Exposure* and *Vulnerability* where:

- *Exposure* was the presence of a flood receptor within a flood hazard area;
- *Vulnerability* was a measure of the impact of flooding on that receptor.

For all receptors, the magnitude of risk was factored into the *Exposure* assessment through the Annual Exceedance Probability (AEP). A receptor located within a 5% AEP flood extent was multiplied by 5; a receptor located within a 1% AEP flood extent was multiplied by 1, and a receptor located within a 0.1% AEP flood extent was multiplied by 0.1.

The FRI score for each receptor was calculated based on the most significant source of flood risk and was not cumulative. A receptor located within the 5% AEP coastal flood extent and the 1% AEP fluvial flood extent would have been multiplied by 5, and would not have attracted a score for both sources (coastal and fluvial) of flooding. The exposure to multiple sources of flood risk was considered when estimating numbers of receptors at risk from each source assessed – coastal, fluvial, and groundwater.

For residential properties only, a damage adjustment factor was incorporated as evidence based data on damages was available to more accurately assess the change in damages with probability of flooding (see Section 4.5.1).

The method to determine *Exposure* and *Vulnerability* varied for each receptor type and is set out in this section.

4.5.1 Social (Human Health) - Residential Properties

Residential properties at flood risk were used as the first of three measures of the social (human health) impact of flooding. The measure relates to the risk to life to the resident, anxiety and stress faced by the resident and/or property owner due to financial loss, and both short-term and long-term mental health impacts.

Exposure

The first cycle PFRA predictive assessment assessed residential properties as individual address points, typically represented as a single point in the centre of the property. The property was only identified as being at flood risk if this point was within the flood hazard area. The third cycle PFRA predictive assessment (FRIA) assessed residential properties as polygons representing the building footprint.

In the example shown in Figure 4-1 below, five residential properties can be observed. Using the updated method adopted for the third cycle PFRA, all five of these properties (each consisting of one address) were identified as being at flood risk (flood extent inundates part of building footprint), whereas in the first cycle PFRA none would have been at flood risk (based on the single point being outside the flood extent).

Figure 4-1; Indicative predictive assessment illustrating limitation of point receptors in determining flood risk

In the FRIA, the PRIME2 dataset was used to assess *Exposure* based on the building footprint (PRIME2 Building Poly) of each residential property. The residential property (GeoDirectory “building_use”) was identified as being at flood risk if any part of the footprint was located within the flood hazard area. Each individual address (GeoDirectory “residential delivery points”) was included in the assessment i.e. a single detached apartment building containing six ground floor apartments (residential delivery points) was counted as six apartments, not one detached property.

All demolished, derelict, vacant, and under construction (GeoDirectory "demolished", "vacant", etc) properties were excluded from the assessment to provide an accurate assessment of flood risk at the point in time. It was assumed that flooding to these property types would cause less stress and anxiety (not owned / occupied) and less damage (no household items). Any future change in status of occupancy, completed construction or re-development of those properties would be reflected in future cycles of the PFRA in line with the Floods Directive requirements. All holiday homes were included in the assessment as it was assumed that the property owner would still suffer anxiety and stress, and household items would still be contained within the property.

In all cases, *Exposure* was measured by the total number of residential delivery points at risk of flooding i.e. flooded or not flooded.

Exposure – Damage Adjustment Factor

A damage adjustment factor was included for use in assessing residential properties, to reflect evidence based data[4] that direct and indirect damages are not directly proportionate to the probability of flooding. That is to say a property at twice as much risk will not incur twice as much damage, therefore using probability of flooding alone would have been misrepresentative.

The cumulative total of Weighted Annual Average Damages (Table 4.5 of the Multi-Coloured Handbook[4]) was used to determine the Damage Adjustment Factor (DAF). Annual damages associated with the human related intangible impacts of flooding was set as equivalent to the direct damages as per current economic appraisal of capital flood relief schemes in Ireland. A baseline factor of 1.0 was applied to the damages associated with a 1% AEP flood event.

The determination of the DAF is illustrated in Table 4-4. For example, based on Annual Total Damage, a property at risk in a 5% AEP flood event would attract approximately 13 (12.83) times as much damage than a property at risk in a 1% AEP flood event (not 5 times as with the first cycle PFRA). Therefore, instead of multiplying by 5 (% AEP) as with other receptors, the Damage Adjustment Factor would multiply the property by 2.57 x 5 (i.e. 12.85), to reflect the non-linear damage relationship.

Table 4-4 Damage Adjustment Factor for Residential Properties

Probability of Flooding (AEP)	Annual Direct Damages (€*)	Annual Indirect Damages (€)	Annual Total Damages (€)	Percentage Adjustment (%)	Damage Adjustment Factor**
5%	€1,296	€1,296	€2,592	1283%	2.57
1%	€101	€101	€202	100%	1.00
0.1%	€12	€12	€24	12%	1.19

*All values based on MCH Table 4.5 (2020/21 prices), exchange rate of 1.179 applied (January 2021)

**Damage Adjustment Factor is the required "Adjustment", to 2 decimal places, therefore Percentage Adjustment ÷ Probability of Flooding (% AEP)

[4] Penning-Rowsell et al (2020) Flood and Coastal Erosion Risk Management Handbook for Economic Appraisal 2020, Flood Hazard Research Centre, Middlesex University, UK.

Exposure – Identification of Raised and Ground Floor Flats

MCM does not specifically distinguish between raised and ground floor flats, as damages are assigned based on depth above a defined threshold level. For the FRIA, raised flats were assessed to ensure properties being surrounded by floodwater were included.

Geodirectory data attributes confirm how many residential addresses (delivery points) are attached to an individual property, together with the total footprint of that property. Various options were considered to estimate the number of raised flats within a property and these are discussed below.

(1) Assume the property is a single detached property i.e. no flats. This was considered inaccurate and likely to significantly under-estimate flood risk as a block of flats may include large numbers of ground floor flats;

(2) Assume all residential addresses are on the ground floor. Whilst this will be accurate in some cases, this was considered too simplistic and may significantly over-estimate the true flood risk at a property where multiple floors exist (over-estimation of ground floor flats);

(3) Assume the total residential addresses were evenly split between ground floor and raised floor. Whilst it was considered likely this would provide a more accurate representation than assuming all ground floor flats (option 2), it was again considered too simplistic. Given the presence of open access in receptions, and likelihood of multiple floors in many cases, it was considered likely to over-estimate the true flood risk in many cases (over-estimation of ground floor flats);

(4) Manually assess the number of raised flats based on aerial photography, floor plans, etc. Whilst this would greatly improve accuracy, in many cases the information required is not readily available and the time taken for the assessment would be significant and disproportionate at a national scale.

(5) Estimate the total number of ground floor flats based on the property footprint and an average flat size. A simple rule could be established and applied at a national scale.

Having ruled out options (1) – (4), the most accurate and proportionate option was agreed to be (5), which would achieve an appropriate balance between accuracy and proportionality.

A sample of properties with multiple residential addresses was identified and evaluated to estimate the actual number of ground floor flats based on floor plans, architect records, and aerial photography. Following this, a 'best fit' flat area was determined to derive an estimated number of ground floor flats (based on the total property footprint).

Comparing the actual number of flats with the estimated number of flats identified that an assumed flat area of 75 square metres yielded the most consistent relationship with all sample properties being accurate to within 25% and nearly half yielding exact matches. The merit of reducing the total footprint first to account for external walls, open space, and stairs / elevators was evaluated but it was found this did not result in increased accuracy.

It is acknowledged that the method adopted has significant limitations, but it was considered the best approach given readily available and derivable information.

Vulnerability

The first cycle PFRA did not distinguish the vulnerability of one residential property type from another due to flooding. All address points were applied the same weighting. This concept remains unchanged in the FRIA (see also Section 4.3), in that each residential property was assigned the same Vulnerability Class.

However, for the FRIA, each property was assigned a Vulnerability Factor based on the property type (GeoDirectory – “building type id”). This was to reflect evidence based data[4] that direct property damages vary significantly with property type. Indirect damages are more commonly associated with the probability of flooding, rather than the property type, and as such are covered within the Damage Adjustment Factor.

Direct damage data was extracted from the MCM for each property type, assuming long duration flooding (>12 hours) with no warning. Data for both saltwater and stormwater flooding was assessed with the difference found to be negligible in the context of the FRIA. The average damage over a range of flood depths was used. A baseline factor of 1.0 was applied to the least vulnerable property (i.e. Terrace).

The determination of Vulnerability Factors is illustrated in Table 4-5. For example, a detached property at risk would attract, on average, 71% more damages in a given flood event than a terraced property at risk in the same flood event across a range of flood depths (171% compared to 100%). Therefore, instead of multiplying by 1.0 (as in the first cycle PFRA), the Vulnerability Factor would multiply the property by 1.71 to reflect the property type.

Table 4-5 Vulnerability Factor for Residential Properties

Property Type	Average Direct Damages (€*)	Percentage Adjustment (%)			Vulnerability Factor
		Minimum**	Average	Maximum**	
Residential Sector Average	€51,147	117%	121%	124%	1.21
Detached	€72,817	158%	171%	180%	1.71
Semi-Detached	€47,934	111%	114%	118%	1.14
Terrace	€42,094	100%	100%	100%	1.00
Bungalow	€72,962	152%	171%	184%	1.71
Ground Flat	€43,152	93%	103%	109%	1.03
Raised Flat	*Not Applicable*				0.52***

*All values based on MCH Direct Damage Data, Long Duration, No Warning (2020/21 prices) converted to euro rates applicable to Ireland by applying a ‘PPP’ factor (1.179) derived from the relative OECD Purchasing Power Parity values for the UK and for Ireland.

**Represents Minimum and Maximum Percentage Adjustment evident across a range of flood depths to demonstrate sensitivity

***Raised flats are included in the assessment. but with a reduced (50%) Vulnerability Factor compared to Ground Flats. In the context of Human Health, occupants will still suffer due to disrupted commuting, education, and access to community services.

Flood Risk Index Score

An example calculation for the following is provided below:

- A residential property (i.e. Vulnerability Class = 1 (Low Vulnerability);
- Semi-detached holiday home;
- Located within the 5% AEP flood extent.

Flood Risk Index (FRI) Score =

Σ Exposure (E) x Damage Adjustment Factor (DAF) x Vulnerability Factor (VF) x Vulnerability Class (VC)

FRI =		*5 (E is 5% AEP)*
	x	*2.57 (DAF for 5% AEP)*
	x	*1.14 (VF for semi-detached)*
	x	*1 (VC for low vulnerability)*
	=	<u>14.6</u>

4.5.2 Social (Human Health) – Sites containing Dangerous Substances

Sites at flood risk which contain dangerous substances were used as the second of three measures of the social (human health) impact of flooding.

Sites containing dangerous substances relate to the potential impact on human health of dangerous substances being released into the natural environment as a result of flooding. The Control of Major Accident Hazard (COMAH) Regulations identify establishments where dangerous substances are present (COMAH sites). COMAH sites were previously commonly referred to as Seveso sites.

Exposure

COMAH sites were not specifically assessed within the first cycle PFRA.

In the FRIA, the list of COMAH sites was cross-referenced with the PRIME2 dataset to enable the identification of the building footprint. The COMAH site was identified as being at flood risk if any part of the footprint was located within the flood hazard area.

Any building footprint identified as being a COMAH site was excluded from any further assessment i.e. commercial properties to avoid the risk of duplication.

In all cases, *Exposure* was measured by the total number of COMAH sites at risk of flooding i.e. flooded or not flooded.

Vulnerability

Each COMAH site was assigned an appropriate Vulnerability Class given the probable impact of flooding on that site. A unique vulnerability derivation table was adopted for COMAH sites. This was broadly based on **Table 1: Risk to Life** but additional granularity provided to factor in:

- The toxicity of the substance released into the environment (to both human health and the environment itself);
- The quantity of substance released into the environment.

The toxicity of a substance is reflected in 21 unique 'Hazard Categories' under the COMAH Regulations. Dangerous substances are categorised based on the type of substance present and the hazard associated with it. The hazard categories were reviewed to identify those substances which were hazardous to human health or the environment in their natural state in the context of flooding. For example, a flammable gas would need a further reaction to be hazardous, whereas a substance released which is fatal in its raw state if swallowed would be hazardous in the context of flooding.

The following hazard categories are included in the FRIA on this basis (the remaining hazard categories were excluded):

- H1 Acute Toxic Category 1
- H2 Acute Toxic Category 2
- H3 STOT Specific Target Organ Toxicity
- E1 Hazardous to the Aquatic Environment Category 1
- E2 Hazardous to the Aquatic Environment Category 2
- O1 Substances or mixtures which react violently with water
- O2 Substances and mixtures which in contact with water emit flammable gases
- O3 Substances or mixtures which in contact with water liberate toxic gas

The quantity of a substance is reflected in the Upper and Lower tier system in the COMAH Regulations. For example, a site may qualify as Upper tier based on 200t of an E2 substance, or 100t of an E1 substance. In this case whilst the E1 substance is potentially more toxic to the environment, the E2 substance is held in higher quantities, and so all Upper tier sites are equally important in the context of the FRIA.

Table 4-6 sets out how a Vulnerability Class will be assigned in line with the above approach.

Table 4-6 Vulnerability derivation table for COMAH sites

Probable Impact	**Degree of Receptor Importance**	
	Upper Tier	**Lower Tier**
Hazardous to Health <u>and</u> Environment, (H1, H2, or H3 <u>and</u> E1 or E2)*	**Critical**	**Extreme**
Hazardous to Health (H1, H2, or H3)	**Extreme**	**High**
Hazardous to Environment (E1 or E2)	**Extreme**	**High**
Hazardous to Other (O1, O2, or O3)**	**High**	**Moderate**

*The potential risk was considered to be cumulative, so the release of a substance which is dangerous to both Health and the Environment was deemed to have greater consequences than a substance which is only dangerous to one of these, particularly when considering the safety of the emergency response.

**The Vulnerability Class for "Other" was lower than Environmental and Health as this relates to the emission of gases or an immediate violent reaction when a substance comes into contact with water. The reduced vulnerability was based on reduced concentration (air compared to water), reduced geographic coverage (in the case of an immediate reaction), and the requirement for a secondary reaction (with fire) to realise the hazard (in the case of flammable gases).

Flood Risk Index Score

An example calculation for the following is provided below:

- A COMAH site exceeds the Upper tier threshold for E2 (Environment) and the Lower tier threshold for O1 (Other). No substance is stored that falls under the 'Health' category i.e. Vulnerability Class = 250 for 'Extreme' (Environment) > 2.5 for 'Moderate' (Other);
- The COMAH site is located within the 5% AEP flood extent of the River Boyne.

Flood Risk Index (FRI) Score =

Σ Exposure (E) x Vulnerability Class (VC) where E is the Probability of Flooding (PoF) in % AEP

FRI	=	*5 (PoF is 5% AEP)*
	x	*250 (VC for extreme vulnerability – environment, highest of the two i.e. Lower Tier 'Other' would have a VC of 'Moderate')*
	=	*1,250*

4.5.3 Social (Human Health) – Social Infrastructure

Social infrastructure or community services at flood risk were used as the third of three measures of the social (human health) impact of flooding.

Social infrastructure and community services relates to the disruption caused to the wider community due to a higher risk to life in certain cases due to occupancy or increased susceptibility for certain receptors (e.g. hospital) and reduced access to essential or critical services. For example, a school closure could impact hundreds of households, even if no residential properties suffer from direct flooding.

Exposure

As with residential properties, the first cycle PFRA assessed social infrastructure as individual address points, typically represented as a single point in the centre of the asset. The property was only identified as being at flood risk if this point was within the flood hazard area.

In the FRIA, the PRIME2 dataset was again used to assess the building footprint (PRIME2 Building Poly) of each asset, with each asset identified as being at flood risk if any part of the footprint was located within the flood hazard area.

Datasets have been collated from the relevant authorities which typically provide a more robust and up to date identification of social infrastructure receptors than PRIME2 i.e. Schools from Department of Education, Civil Defence from Department of Defence, etc (see Table 4-1). These were used and cross-referenced with the PRIME2 data to assign a building footprint to the identified points. In the case of government buildings and fire stations, PRIME2 data was used (PRIME2 func_value, form_value) to identify receptors.

Any building footprint identified as being a social infrastructure was excluded from any further assessment i.e. commercial properties, residential proeprties to avoid the risk of duplication.

In all cases, *Exposure* was measured by the total number of assets at risk of flooding i.e. flooded or not flooded.

Vulnerability

The first cycle PFRA categorised each individual social infrastructure into a Vulnerability Class. This concept remains unchanged in the FRIA (see also Section 4.4), in that each asset was assigned an appropriate Vulnerability Class given the probable impact of flooding on that asset (permanent damage, loss of service, etc).

The Vulnerability Class of each asset, assigned in the first cycle PFRA, was reviewed to reflect both changes to society and a subjective review of relative importance compared to other receptors (see also Section 4.4.4). A summary of amendments is detailed below:

- Fire Stations. Downgraded to Moderate vulnerability, from High. This was on the basis that the Loss of Service was considered to be negligible. Fire Stations are inherently resilient to flooding through reduced risk (high threshold vehicles), and capacity to mitigate risk (pumping).
- Health Centres. Maintained as Moderate vulnerability, however reassessed as ‘Moderate’ duration and ‘Local’ importance under the ‘Significant Loss of Service’ classification criterion.

Early years services, special education and post offices were also added to the receptor list for social infrastructure. This factored in observations during the Covid-19 pandemic (2020-21) and the relative importance of childcare and delivery services to the community, together with the increased susceptibility of young children or children with a disability. Vulnerability Classes for these assets were assigned as below:

- Early years services and special education. Classified as Extreme vulnerability. Assessed as ‘Highly Elevated Risk’ under the ‘Risk to Life’ classification criterion and ‘Moderate’ duration and ‘Local’ importance under the ‘Significant Loss of Service’ classification criterion.
- Post Offices. Classified as Moderate vulnerability. Assessed as ‘Moderate’ duration and ‘Regional’ importance under the ‘Less Significant Loss of Service’ classification criterion.

It should be noted that in some cases, early years services and special education classes are located within primary or post-primary schools (both High Vulnerability). In these cases, the respective primary or post-primary school was not double-counted i.e. treated once as an early years service or special education facility (Extreme Vulnerability), and not duplicated as a primary or post-primary school.

Flood Risk Index Score

An example calculation for the following is provided below:

- A primary school (with no early years services or special education) i.e. Vulnerability Class = 25 (High Vulnerability);
- Located within the 0.1% AEP flood extent.

Flood Risk Index (FRI) Score =

Σ Exposure (E) x Vulnerability Class (VC)

FRI =		*0.1 (E is 0.1% AEP)*
	x	*25 (VC for high vulnerability)*
	=	<u>2.5</u>

4.5.4 Environment – Sites containing Dangerous Substances

Sites at flood risk which contain dangerous substances were used as the first of two measures of the environmental impact of flooding.

Sites containing dangerous substances relate to the potential impact on the environment of dangerous substances being released into the natural environment as a result of flooding. Specifically, these include substances which are hazardous to the aquatic environment (those catrgorised as E1 or E2, see Section 4.5.2). The Control of Major Accident Hazard (COMAH) Regulations identify establishments where dangerous substances are present (COMAH sites). COMAH sites were previously commonly referred to as Seveso sites.

The way in which the *Exposure*, *Vulnerability*, and *Flood Risk Index score* of COMAH sites was assessed is presented in Section 4.5.2.

4.5.5 Environment – Waste Facilities

Waste facilities will be used as the second of two measures of the environmental impact of flooding. The measure relates to the potential temporary or permanent damage to the surrounding environment due to uncontrolled release of waste.

Exposure

The first cycle PFRA did not assess licensed waste facilities.

A register of Licensed Waste Facilities is available from the Environmental Protection Agency (EPA). The register details facilities categorised as Waste, Industrial Emissions, and Integrated Pollution Control. In the FRIA, the Licensed Waste Facilities will be cross-referenced with the PRIME2 dataset to identify the associated building footprint (PRIME2 Building Poly). Each facility will then be identified as being at flood risk if any part of the footprint is located within the flood hazard area.

The waste facility receptors were cross-referenced with the PRIME2 dataset to enable the identification of the building footprint where appropriate. In these cases, the waste facility receptor is identified as being at flood risk if any part of the footprint is located within the flood hazard area. In some cases, the waste facility is geographically referenced to the centroid of a wider site. This would rarely be within a building footprint, given the size of sites and the volume of storage or yard space typically associated with many waste facilities. Where this occurred, points were assigned to the nearest building on the site (where one is present).

In all cases, *Exposure* will be measured by the total number of COMAH sites at risk of flooding i.e. flooded or not flooded.

Vulnerability

The Licensed Waste Facility register does not include sufficient information to allow the susceptibility of individual sites to be assessed. As such, all sites will be assigned a "Moderate" vulnerability classification to reflect the potential risk posed to the environment.

Flood Risk Index Score

An example calculation for the following is provided below:

- A **Licensed Waste Facility** (i.e. Vulnerability Class = 2.5 (Moderate Vulnerability);
- Located within the 1% AEP flood extent.

Flood Risk Index (FRI) Score =

Σ Exposure (E) x Vulnerability Class (VC)

FRI = *1 (E is 1% AEP)*
x *2.5 (VC for moderate vulnerability)*
= 2.5

4.5.6 Environment – Protected and Designated Land / Area

Protected and designated environmental sites were considered for use in the assessment of the environmental impact of flooding. This was on the basis of identifying the potential temporary or permanent damage to species or habitat supported by the protected or designated site.

Protected and designated sites considered for inclusion in the assessment were:

- Special Areas of Conservation (SAC), designation under the EU Habitats Directive (1992)
- Special Protection Areas (SPA), designation under the EU Habitats Directive (1992)
- Natural Heritage Areas (NHA), designation under the Wildlife Amendment Act (2000)
- Proposed Natural Heritage Areas (pNHA), non-statutory designation under the Wildlife Amendment Act (2000)

The first cycle PFRA assessed environmental sites independently to the cellular approach adopted for other receptors. This approach allowed the flood risk and associated impact to each individual designated site to be identified. The first cycle PFRA also assessed flood risk based on the proportion of a site prone to flooding, designed to reflect the fact that the specific location of species is generally not known.

Pilot Study

A pilot study was undertaken as part of the FRIA to review potential methodologies, and the value of the associated outputs in the context of the PFRA.

A key limitation of the first cycle PFRA assessment was that the designated sites are each unique in the habitats and species that they support. Furthermore the habitats within each designated site are not uniform. There are multiple habitats and land types which are either protected in their own right, or support species in different ways. The vulnerability of habitats and species to flooding is also not uniform. For example, a waterbody or wetland would typically be less vulnerable to flooding than grassland habitat. In addition, species which rely on that waterbody or wetland may be more or less vulnerable to flooding.

It was therefore considered necessary to have reliable information on both the type of habitat and species within a designated area, together with the spatial distribution within that designated area. Whilst some records exist, it was not readily available and derivable at a national scale, and it was considered that the dynamic nature of species in particular would also result in inaccuracies.

The pilot study did experiment with using Corine land cover mapping and cross-referencing this with designated areas to assist in mapping the spatial distribution of different land types. Information on the designated sites was then used to identify those habitats and species within the designated areas which were considered more vulnerable to flooding.

The area of land types which may either directly or indirectly support vulnerable species were then estimated, and the percentage of that land type which was at flood risk was subsequently determined.

On review of the pilot study, it was considered that the outputs generated were low confidence and could not be used to assist in identifying area of potentially significant flood risk given the scale and accuracy of the information which was readily available and derivable. A similar methodology would require robust, site-specific, and spatially distributed data for each designated area.

As such, Protected and Designated Land / Area was excluded from the Flood Risk Index Assessment.

4.5.7 Cultural Heritage – Architectural Heritage

Architectural heritage sites were used as the first of three measures of the cultural heritage impact of flooding. The measure relates to the potential temporary or permanent damage to architecture designated for its heritage value.

Data on architectural heritage was obtained from the Department of Environment, Heritage and Local Government and was taken from the National Inventory of Architectural Heritage (NIAH).

Exposure

The first cycle PFRA assessed all architectural heritage sites as individual address points, typically represented as a single point in the centre of the site. The site was only identified as being at flood risk if this point was within the flood hazard area.

The National Inventory of Architectural Heritage (NIAH) dataset was used to identify architectural heritage sites. In the FRIA, the size and type of the NIAH dataset was such that a slightly different approach to exposure compared to other receptors was used.

The type of NIAH asset (NIAH "original type") indicates that data varies significantly i.e. from signal posts to airports. In some cases, therefore, it was not considered appropriate to assign a receptor to an entire building footprint. Equally, some NIAH receptors are located outside of building footprints, and so a uniform methodology of assigning all NIA receptors to building footprints would have been erroneous. In addition, the size of the dataset (43,000+ receptors) was such that it was not proportionate to manually reassign point receptors to an appropriate building footprint.

The NIAH receptors were first cross-referenced with the PRIME2 dataset to enable the identification of the building footprint where appropriate. In these cases, the NIAH receptor was identified as being at flood risk if any part of the footprint was located within the flood extent.

For those receptors located outside a building footprint and at flood risk, a screening process was used to identify the receptors which were more vulnerable (NIAH, "Rating"). Those receptors which were deemed of International or National importance were manually reassigned to the appropriate building footprint, where a building footprint was appropriate to represent the type of NIAH asset.

For the remaining receptors, the point data was used with a buffer applied based on typology within the "Original Type" field, which details the kind of receptor. This approach was consistent with that adopted by Fingal County Council when undertaking the Fingal Cultural Heritage and Climate Change Risk Assessment[5] project. Heritage assets were applied a buffer of between 1m and 150m, creating an indicative footprint, depending on the type of asset – castles, walled gardens, etc applied a larger buffer; post box, lamp, etc applied a smaller buffer.

As with the NIAH receptors with a building footprint, if any part of the buffered area was located within the flood hazard area the receptor was assumed to be at flood risk.

It should be noted that the FRIA may classify and score a receptor under both "Cultural Heritage" and other categories ("Human Health, Economic"). For example, Dublin Airport is an active International Airport (Economic Activity), and the main terminal building (Terminal 1) is also a designated architectural heritage site (Cultural Heritage).

In these instances, the score under both categories was included (duplication allowed), as the receptor was correctly identified under more than one category.

[5] Land Use Consltants (2021) Fingal Cultural Heritage & Climate Change Risk Assessment, Fingal County Council

Vulnerability

The first cycle PFRA categorised each individual Architectural Heritage receptor into a Vulnerability Class. This concept remained unchanged in the PNFRA, in that each asset was assigned an appropriate Vulnerability Class given the probable impact of flooding on that asset (permanent damage, loss of service, etc).

The NIAH dataset (NIAH "Rating") includes a regional, national, or international rating of the architectural significance of the structure. This rating evaluates sites to be of sufficient architectural heritage importance to be considered in an international context (International), make a significant contribution to the architectural heritage of Ireland (National), or of their region (Regional), or offer some vintage that contribute to architectural heritage but do not merit being placed on the Record of Protected Structures (RPS), for example, if they have lost much of their original fabric (Local). NIAH "Rating" was used to identify the Vulnerability Class. Only structures included in the RPS were included i.e. Local and Record Only ratings were not be included in the PNFRA. Following consideration in, and review of, a pilot study, vulnerabiltiy classifications were established as follows:

- "**International**" rating = Extreme (250), severe degradation to an internationally important asset (see Appendix A – Permanent Damage to Matters of Value);
- "**National**" rating =Moderate (2.5), minor damage to a nationally important asset (see Appendix A – Permanent Damage to Matters of Value A);
- "**Regional**" rating = Low (1), minor damage to a regionally important asset (see Appendix A – Permanent Damage to Matters of Value)

The susceptibility of a structure to flooding, in the context of cultural heritage, is dependent on a variety of factors including the age of the structure, type of structure, condition, material use, and depth of flooding. This data was not readily available and derivable to enable a robust assessment of susceptibility and as such was excluded from the FRIA.

The susceptibility of individual structures should be assessed on a case-by-case at detailed appraisal if an asset ends up being within an area designated as an APSFR and is subject to further investigation. This may not only include direct damage, but also access to the structure.

It should be noted that the Vulnerability Class of "International" rated heritage assets was reduced to "Extreme" in the FRIA (previously "Critical" in the first cycle PFRA). This is in line with the discussion of Section 4.4.4, where assets of heritage value are deemed of less importance from a societal view compared with other receptors. The "Critical" classification was considered to be disproportionate with this research, and when considered alongside the total FRI score generated by multiple receptors within entire communities.

Flood Risk Index Score

An example calculation for the following is provided below:

- St Patrick's Catholic Church – A **National** Church/Chapel (i.e. Vulnerability Class = 2.5 (Moderate Vulnerability);
- Located within the 1% AEP flood extent.

Flood Risk Index (FRI) Score =

Σ Exposure (E) x Vulnerability Class (VC)

FRI = *1 (E is 1% AEP)*
x *2.5 (VC for moderate vulnerability)*
= 2.5

4.5.8 Cultural Heritage - Museums, Archives and Galleries

Museums, archives and art galleries were used as the second of three measures of the cultural heritage impact of flooding. The measure relates to the potential temporary or permanent damage to the respective collections.

A national list of museums, archives and art galleries were obtained from the Irish Museum Association (IMA), which is the voluntary organisation promoting the interests of museums throughout Ireland.

Exposure

The list of museums used in the first cycle PFRA contained 450 sites identified by postal addresses rather than geographical coordinates. That list was then filtered to include only sites that met certain criteria i.e. 'National', 'Irish' in the title (see Vulnerability).

For the PNFRA, the IMA dataset now includes geographical coordinates to assist identification. The list was cross-referenced with the PRIME2 dataset to identify the building footprint (PRIME2 Building Poly) of each site. The asset was identified as being at flood risk if any part of the footprint was located within the flood hazard area.

All sites (521) listed on the IMA database were included in the PNFRA, rather than filtering this list by set criteria as per the first cycle PFRA.

Vulnerability

The specific interest under this criterion was the importance and content of the museum, rather than any architectural value (which is covered under 4.5.5 Architectural Heritage). That is to say, hypothetically, that a photography museum housed in a 16th century cathedral would have the same value as one housed in a shed.

For the first cycle PFRA, the following criteria were used to filter the list of 450 museums, archives, and art galleries before assigning a 'Vulnerability Class':

- 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'.

This ‘short list’ of sites were subsequently categorised into a Vulnerability Class based on individual (manual) assessment.

Data was still not readily available which classifies the relative importance of each listed site. This is largely subjective and comes down to interpretation. The only readily available data is the name of the museum and a description of the asset.

For example, the “National Transport Museum of Ireland”” is described as “*The National Transport Museum is operated by the Transport Museum Society of Ireland Ltd. They are a voluntary and not for profit group. Their main activities include the preservation and restoration of road commercial vehicles, including Trams.”* Applying the above criteria from the first cycle PFRA, the museum would be shortlisted as it has “National” in the title, however manual assessment applied only a ‘Moderate Vulnerability’ due to the lower susceptibility of the contents to flooding.

For the PNFRA, the following criteria were used to provide an indicative ‘Vulnerability Class’, based on relative importance at a national or regional level. A manual assessment was subsequently undertaken based on the name and description to agree the appropriateness of the ‘’Vulnerability Class’, amending this as required.

- Nationally important museums, archives and collections were classified as ‘Critical’ vulnerability given that these sites are nationally important and flood damage could result in total loss of the items or data involved. Sites with ‘Irish’ or National’ in the title were used to categorise these museums;
- In certain cases, where the contents were deemed less susceptible to flooding, ‘Critical’ vulnerability nationally important museums were downgraded to ‘Extreme’ vulnerability.
- County and regional museums, archives and collections were classified as ‘High’ vulnerability given the regional level of importance of these sites. Any site with a county name in the title were used to categorise these museums.
- All other museums, archives and collections were classified as ‘Moderate’ vulnerability given the local level of importance of these sites.

It was acknowledged that certain assets i.e. Bolton Library would receive an incorrect indicative assessment, however this was picked up in manual verification. This approach is considered proportionate for the PNFRA considering the number of sites likely to be at flood risk (521 sites listed by IMA in total, only 88 of which were located within flood hazard areas).

Flood Risk Index Score

An example calculation for the following is provided below:

- National Photographic Archive, Dublin i.e. Vulnerability Class = 2,500 (Critical Vulnerability, National importance, highly susceptible to flooding, irreplaceable contents);
- Located within the 0.1% AEP flood extent.

Flood Risk Index (FRI) Score =

Σ Exposure (E) x Vulnerability Class (VC)

FRI =		*0.1 (E is 0.1% AEP)*
	x	*2,500 (VC for critical vulnerability)*
	=	250

4.5.9 Cultural Heritage - Archaeological / Historical Monument Sites

Archaeological sites and Historical Monuments were used as the third of three measures of the cultural heritage impact of flooding. The measure relates to the potential temporary or permanent damage to archaeology designated for its heritage value, or to historically important monuments.

Data on archaeological sites and historical monuments was obtained from the National Monuments Service (NMS) Sites and Monuments Record (SMR) dataset. The SMR dataset is a manual containing a list of certain and possible monuments.

Exposure

The first cycle PFRA assessed all archaeological/historical monument sites as individual address points, typically represented as a single point in the centre of the site. The site was only identified as being at flood risk if this point was within the flood hazard area. Due to the complexity and nature of the receptor, a separate report[6] was generated for this category providing greater detail on how the receptors were assessed.

In the PNFRA, the Sites and Monuments Record (SMR) dataset (NMS “CLASSDESC”) was used to identify if a site should be assessed as a point receptor or as an area receptor. The PRIME2 dataset was used to assess the footprint (PRIME2 Building Poly) of each site that has been classified as an area receptor. The coordinates of point receptors, as identified in the SMR dataset, were used to geographically locate point receptors. Categorisation of the receptors is presented in Table 4-5.

The SMR dataset was used to identify archaeological heritage sites. In the FRIA, the size and type of the SMR dataset was such that a slightly different approach to exposure compared to other receptors was used.

The type of SMR asset (SMR “CLASSDESC”) indicated that data varies significantly i.e. from altars and burial mounds to castles and sea walls. In some cases, therefore, it was not considered appropriate to assign a receptor to an entire building footprint. Equally, some SMR receptors are located outside of building footprints, and so a uniform methodology of assigning all SMR receptors to building footprints would have been erroneous. In addition, the size of the

[6] Mott McDonald (2011) Preliminary Flood Risk Assessment: Methodology for Classifying the Vulnerability of National Monuments from Flooding in The Republic of Ireland, Office of Public Works. Revision D.

dataset (141,000+ receptors) was such that it was not proportionate to manually reassign point receptors to an appropriate building footprint.

The SMR receptors were first cross-referenced with the PRIME2 dataset to enable the identification of the building footprint where appropriate. In these cases, the SMR receptor was identified as being at flood risk if any part of the footprint was located within the flood hazard area. SMR receptors with erroneous geographical referencing i.e. shown in Irish Sea, were excluded from the assessment in the absence of readily available information to accurately correct this data.

For the remaining receptors, the point data was used with a buffer applied based on typology within the “Class Description” field, which provided detail of the receptor type. This approach was consistent with that used to assess exposure for Architectural Heritage (see 4.5.5). Heritage assets were applied a buffer of between 1m and 25m, creating an indicative footprint, depending on the type of asset – castle, courthouse, etc applied a larger buffer; altar, grave, etc applied a smaller buffer.

As with the SMR receptors within a building footprint, if any part of the buffered area was located within the flood hazard area the receptor was assumed to be at flood risk.

Vulnerability

As Ireland does not have legislation in place which requires monuments to be designated by their importance, the first cycle PFRA introduced a method of designating importance by asset type[6].

The method was based on the criteria used for Scheduling monuments used in the UK and classified the degree to which each type of monument was important. The criteria included: period, rarity, documentation, group value, survival/condition, fragility, diversity and potential.

In relation to the methodology for classification of potential damage to monuments from floods, which was the second component of assessing the flood vulnerability, the PFRA used a number of rules which relate specifically to the type of flooding experienced in Ireland, the likelihood that the monument would have flooded previously (and therefore proved itself robust to flood damage) and the material from which the monument was constructed.

Given the methodology developed for classification of importance of monuments in the first cycle PFRA was recent in the context of archaeology and history, and founded in established international criteria, it was considered appropriate to use the same methodology for the FRIA. It was also noted that an assessment of flood events in the period of 2012 to 2018 undertaken for the second cycle PFRA identified only five flood events which had any impact on cultural heritage sites nationally. Re-developing established methodology given this level of flood risk was not considered proportionate for the FRIA. All monuments added or amended since the first cycle PFRA were included or reassessed accordingly and in line with the methodology.

UNESCO sites were included in the SMR dataset and were classified as ‘Critically Vulnerable’ given their international importance and the potential for severe degradation of the site during flood events. Examples of classifying the vulnerability of national monuments to flooding is provided in Table 4-7 below.

Table 4-7 Example receptor types for use in the PNFRA based on NMS Class Description

Monument Classification	Total	Description	Importance	Potential Damage	Vulnerability Class
Almshouse	9	A house endowed by a benefactor devoted to the shelter of the poor. These date from the late medieval period (c. 1400 to the 16th century AD) onwards.	National 2*	Severe 12*	Extreme
Altar	29	A structure of stone in the form of a table or block used as the focus for a religious ritual, but not part of a church. This class term is also used for features named 'Altar' on Ordnance Survey maps where there is no surviving visible trace above ground. These can be of any date from prehistory onwards.	Regional 2*	Minor 7*	Low
Barn	2	A building used primarily for storing hay, grain, farm equipment or as a shelter for livestock. These date from the medieval period (5th-16th centuries AD) onwards.	National 2*	Moderate 10*	High
Burial mound	80	An earthen or earthen and stone mound which contains burials. This classification is applied specifically to burial mounds which are medieval or later in date. For prehistoric examples see barrows.	National 1*	Minor 8*	Moderate

*Number relates to the reason for the classification. The numbers relate to the rules for classification of importance, Section 3.1 and 4 in the Methodology for Classifying the Vulnerability of National Monuments from Flooding in The Republic of Ireland[6]

Flood Risk Index Score

An example calculation for the following is provided below:

- Burial Mound i.e. Vulnerability Class = 2.5 (Moderate Vulnerability, see Table 4-8);
- Located within the 5% AEP flood extent.

Flood Risk Index (FRI) Score =

Σ Exposure (E) x Vulnerability Class (VC)

FRI = *5 (E is 5% AEP)*
x *2.5 (VC for moderate vulnerability)*
= 12.5

4.5.10 Economic Activity – Commercial Properties

Commercial properties at flood risk was used as the first of three measures of the economic impact of flooding. The measure relates to the direct impact caused to businesses due to damaged goods, equipment, and infrastructure.

Exposure

As with residential properties, the first cycle PFRA assessed commercial properties as individual address points, typically represented as a single point in the centre of the property. The property was only identified as being at flood risk if this point was within the flood hazard area.

In the PNFRA, the PRIME2 dataset was used to assess the building footprint (PRIME2 Building Poly) of each non-residential property. The property was defined as commercial by the GeoDirectory dataset (GeoDirectory "building_use" classified as 'C': Commercial or 'B': Business) and was identified as being at flood risk if any part of the footprint was located within the flood hazard area.

All demolished, derelict, vacant, and under construction properties (GeoDirectory "demolished, vacant, etc) were excluded from the assessment to provide an accurate assessment of flood risk at the point in time. It was assumed that flooding to these assets would cause less stress and anxiety (not owned / occupied) and less damage. Any future change in status of occupancy, completed construction or re-development of those properties would be reflected in future cycles of the PFRA in line with the Floods Directive requirements.

In cases where the building had an address type of multi occupancy non-residential building or multi occupancy mixed use building (GeoDirectory "commercial delivery points"), each individual commercial delivery point was included in the assessment.

In some cases, non-residential properties were assessed independently as discussed and presented elsewhere in this report. Where that was the case, that receptor was not duplicated in the assessment of commercial properties i.e. it was only scored once. This was the case for properties that score under Sites containing Dangerous Substances (4.5.2), Social Infrastructure (4.5.3), Museums, Archives, and Collections (4.5.6), and Utilities and Airports (4.5.9).

In all cases, *Exposure* was measured by the total number of assets at risk of flooding i.e. flooded or not flooded.

Vulnerability

The first cycle PFRA did not distinguish the vulnerability of one non-residential property type from another due to flooding. All address points were applied the same weighting.

In the PNFRA, this approach was changed as non-residential properties can now be categorised by property type (PRIME2, "form_value" and "func_value"). The importance of each non-residential property and its susceptibility to flooding varied based on property type and size. This was to reflect evidence based data that direct commercial property damages vary significantly with property type[4].

A Vulnerability Class was assigned to each property type, and considered both the typical size of that property type (larger properties would typically attract higher damages than smaller properties), and the importance (e.g. hotels would typically attract more damage and disruption than a tourist office).

Where the building had multiple commercial delivery points, only the first commercial delivery point was assumed to be the primary use in the assessment. All remaining commercial delivery points were included but assigned a “Low” Vulnerability Class. This was to avoid over-estimating the damage where a building has multiple uses. For example, a single building footprint may include a hotel, but additional commercial delivery points may exist for a coffee shop and laundry in the same building footprint. It would have been erroneous to allocate the “Hotel” property use to all three addresses.

Flood Risk Index Score

An example calculation for the following is provided below:

- A non-residential building is occupied by four commercial delivery points;
- The building is classified as a Cinema i.e. Vulnerability Class = 25 (High Vulnerability);
- Located within the 5% AEP flood extent.

Flood Risk Index (FRI) Score =

Σ Exposure (E) x Vulnerability Class (VC)

FRI_{Cinema}	=	*5 (E is 5% AEP)*
	x	*25 (VC for high vulnerability)*
	x	*1 (Commercial delivery point)*
	=	*125*
FRI_{Other}	=	*5 (E is 5% AEP)*
	x	*1 (VC for low vulnerability)*
	x	*3 (remaining commercial delivery points, originally 4)*
	=	*15*
FRI_{Total}	=	*125 + 15*
	=	*140*

4.5.11 Economic Activity – Utilities and Airports

Utilities and airports at flood risk were used as the second of three measures of the economic impact of flooding. The measure relates to the travel disruption and loss of service caused to the wider community due to reduced access to transport infrastructure or critical services. For example, flooding to a substation resulting in a power outage to hundreds of properties.

Exposure

As with residential properties, the first cycle PFRA assessed utilities and airports as individual address points, typically represented as a single point in the centre of the asset. The asset was only identified as being at flood risk if this point was within the flood hazard area.

Ports were also assessed as part of the first cycle PFRA. However for the PNFRA it was considered that the port as a whole is not very susceptible to flooding given the need for this infrastructure to be resilient due to the inherent risk of the port location. Individual buildings or receptors at risk within the port were assessed under each receptor respectively. For example, Dublin Port incorporated several COMAH sites, railway infrastructure, etc. Utility infrastructure assessed included water treatment plants, electricity substations, and power plants.

In the FRIA, the PRIME2 dataset was used for airports and electricity substations to assess the building footprint (PRIME2 Building Poly) of each asset, with each asset identified as being at flood risk if any part of the footprint was located within the flood hazard area. Airports were assumed to flood if the main terminal building or other key airport building was flooded.

Datasets have been collated from the relevant authority which typically provide a more robust and up to date identification of other utility receptors than PRIME2 i.e. Environmental Protection Agency (EPA). These were used and cross-referenced with the PRIME2 data to assign a building footprint to the identified points in the case of power plants. This approach could not be undertaken for wastewater rteatment plants as data points were typically located outside a building footprint and no address data was available to allow manual verification or re-location. An appropriate buffer was applied to the point dataset instead.

In all cases, *Exposure* was measured by the total number of assets at risk of flooding i.e. flooded or not flooded.

Vulnerability

The first cycle PFRA categorised each individual utility, port, or airport into a Vulnerability Class. This concept remained unchanged in the PNFRA, in that each asset was assigned an appropriate Vulnerability Class given the probable impact of flooding on that asset (permanent damage, loss of service, etc). The Vulnerability Class of each asset, assigned in the first cycle PFRA, was reviewed to reflect both changes to society and a subjective review of relative importance compared to other receptors. Amendments to the assigned Vulnerability Classes are detailed below:

- International airports remained as “Critical” vulnerability.
- National and Regional (Domestic) airports were downgraded from “Extreme” to “High” vulnerability. This was on the basis that National and Regional airports were not considered “Critical” when suitable and affordable road and rail alternatives exist throughout Ireland.
- Power Plants and Electricity Substations remained unchanged as “Critical” and “High” vulnerability respectively.
- Waste Water Treatment Plants remained unchanged as “Moderate” vulnerability.
- Telephone Exchanges were removed from the list of receptors due to high resilience and reduced demand (alternative established online communication methods).

Flood Risk Index Score

An example calculation for the following is provided below:

- A domestic airport with flooding to the main airport building (i.e. Vulnerability Class = 25 (High Vulnerability);
- Located within the 0.1% AEP flood extent.

Flood Risk Index (FRI) Score =

Σ Exposure (E) x Vulnerability Class (VC)

FRI =		*0.1 (E is 0.1% AEP)*
	x	*25 (VC for high vulnerability)*
	=	*2.5*

4.5.12 Economic Activity – Road and Rail

The road and rail network at flood risk was used as the third of three measures of the economic impact of flooding. The measure relates to the indirect impact caused to citizens, commuters, and businesses in Ireland due to temporary disruption.

Exposure

The first cycle PFRA concluded that it was not possible, based on existing available or readily derivable information at the time, to undertake a predictive analysis of risk that was of sufficient reliability for use in the PFRA. This was related to elevated assets whose true level had not been resolved in the national DTM and therefore were incorrectly being identified as at flood risk (i.e. bridges, embankments).

For the purpose of the FRIA, roads and railways located within a flood hazard area were assumed to be at flood risk. The above limitation was acknowledged and the associated receptor may be shown to be at flood risk even if it was elevated above the flood level. No available and readily derivable national dataset exists on road and railway levels. However, the lack of information related to road levels was likened to the lack of information related to property threshold levels. A property may be within the flood extent but with an elevated threshold (steps to floor level), just as a road may be elevated above the flood level.

Datasets were provided by Transport Infrastructure Ireland (TII) and Irish Rail which detailed the networks for the Luas and railway respectively. Railways were illustrated in PRIME2, however following review in the pilot study it was evident that this dataset included historic and disused railways, where there are negligible impacts of flooding to the economy. Railway receptors were characterised by polyline features in GIS.

In PRIME2, roads were detailed as both polylines and polygons, with the added benefit of the polygon dataset being that, in many cases, the road name was attributed to each polygon for motorways, national roads, and regional roads. For the purpose of analysis, the polygon (way_poly) dataset was used but was considered in the same way as polyline receptors.

A road or railway was assumed to be flooded, if any part of that road or railway was flooded. It was considered that as there is typically minimal horizontal gradient change across a road or railway; fluvial, tidal, or groundwater flooding encroaching on one side was likely to impact on the opposite side. In addition, “bottle-neck” disruption may occur regardless of whether the full width of the road was flooded (vehicles diverting into the centre of a two-lane road, distraction and proximity of nearby hazards).

In many cases, multiple segments of the same road or railway were flooded. Where possible, each road was individually identified (PRIME2, "eng_named_european_route", "eng_named_national_road"). Where the same road (i.e. N69) was flooded in multiple locations, it was only counted once in each grid square. Flooding to the same road was allowable in adjoining grid squares, as the associated damage and disruption was more likely to be unique or the cumulative impact more significant.

Vulnerability

Direct impact on roads relates to infrastructural damage. Whilst, on the face of it, flooding to major roads was considered to be a greater risk, research into the 2007 floods in the UK found that "motorways suffered proportionately less damage due to higher standards of design and maintenance compared with minor roads"[3]. It is, however, important to note that by the same measure, the cost to repair the same damage will be higher for a major road than a minor road (particularly considering the increased urgency of the need). For this reason, direct damage was not explicitly used to differentiate vulnerability of roads (major roads = more resilient, but higher repair cost; minor roads = less resilient, lower repair cost).

Temporary disruption (indirect damages) is linked primarily to the duration of flood, traffic volumes, and diversion length. Flood duration data was not available and readily derivable at this stage and so this factor cannot be built into the FRIA.

Traffic volume data was not readily available, however the road categorisation (Motorway, National road, Regional road, Local road) was used as a reasonable substitution for this. A major road was typically more likely to receive higher traffic volumes. Whilst a National road in a city may experience higher traffic volumes than a National road between rural towns, the latter may have greater strategic importance. As such, no distinction was made between urban and rural roads.

Whilst it was possible to undertake spatial analysis of the road network to consider diversion length, it was not considered proportionate or appropriate to do so when there was such uncertainty on whether a road is truly flooded and for how long (the other limitations discussed with regard to this receptor). For example, if a road only floods periodically for a couple of hours, the diversion length would be less relevant to the overall assessment of flood risk.

A Vulnerability Class was assigned to each affected asset based on the road categorisation (Table 4-9). Following consideration in, and review of a pilot study into the proposed FRIA methodology, all motorways and railways were assigned a Vulnerability Class of 'Moderate', as flooding was more likely to result in long queues of stationary traffic and/or no viable diversion due to distance between junctions.

Table 4-8 Vulnerability Class for roads and railway

Infrastructure Type	Vulnerability Class
Motorway	Moderate
National road	Moderate
Regional road	Low
Other roads	Very Low
Railway	Moderate

Flood Risk Index Score

An example calculation for the following is provided below:

- Two sections of a National road are located within the same Grid Square A;
- Each section floods in three places in the 5% AEP flood event;
- One section of the same road also floods in one place in the adjoining Grid Square B in the 1% AEP flood event.

Flood Risk Index (FRI) Score =

Σ Exposure (E) x Vulnerability Class (VC)

FRI (A)	=	*5 (E is 5% AEP)*
	x	*2.5 (VC for moderate vulnerability)*
	=	125
FRI (B)	=	*1 (E is 1% AEP)*
	x	*2.5 (VC for moderate vulnerability)*
	=	2.5

4.5.13 Economic Activity – Agriculture and Land

Agricultural land at flood risk as considered for use in the assessment of the economic impact of flooding. This was on the basis of assessing the direct impact caused to loss of crops and productivity in the agricultural sector.

Agriculture and land considered for inclusion in the assessment, consistent with the first cycle PFRA, were:

- Arable, non-irrigated land
- Pastures
- Complex cultivation patterns including small areas of diverse annual crops, pasture and/or permanent crops
- Commercial forestry

Pilot Study

A pilot study was undertaken as part of the FRIA to review potential methodologies, and the value of the associated outputs in the context of the PFRA.

A key limitation of the first cycle PFRA assessment was the exclusion of agriculture and land in close proximity to the watercourse, due to the practicalities of farming this land and increased frequency of flooding of this land. In the pilot study, this was resolved by introducing five metre buffer to represent land which cannot practically be farmed due to hedgerow, marginal vegetation, fencing, or maintenance access requirements. All other land, established using Corine land cover mapping, in the above categories was included in the assessment. This approach is illustrated in Figure 4-3 below where the yellow highlighted area would be excluded from the PNFRA in this example.

Figure 4-2; Example assessment of agricultural land at flood risk (brown), ensuring watercourses and marginal corridors (yellow) are excluded from the assessment

However whilst this provided a reasonable level of confidence in the land type and spatial distribution of that land, the main factors influencing damage to agricultural land from flooding are:

- the type of land use (arable more damaging than grassland);
- the seasonality (summer more damaging than winter); and,
- the duration of flooding (greater damage with duration).

For example, a summer flood with a duration of one week may be far more damaging to agricultural land than a winter flood of six weeks. Similarly, a flood which lasts one week will typically be more damaging than a flood that lasts for a few hours.

The readily available and derivable flood hazard data does not include any information on seasonality or duration of flooding. There is also an absence of flood hazard data associated with more frequent flood events (e.g., annual or multi-annual) which often have a greater impact on the long-term viability of agricultural land than more rare, extreme flood events.

For these reasons, on review of the pilot study, it was considered that the outputs generated were low confidence as they were not able to give due consideration to seasonality, flood duration, or higher frequency flood events – important factors in the context of agricultural land.

As such, Agriculture and Land was excluded from the Flood Risk Index Score.

5 Predictive National Flood Risk Assessment – Identification of Areas of Flood Risk

The main objective of the PNFRA was to undertake a predictive assessment of flood risk to support the identification of Areas of Potentially Significant Flood Risk (APSFRs) across Ireland in line with the 'Floods Directive'.

As set out in Section 1, the PNFRA itself does not conclude with the identification of APSFRs, which is instead the conclusion of the review of the PFRA as a whole. Following the PNFRA, consultation with relevant stakeholders and a review of past flooding events were subsequently undertaken to help verify areas that were deemed to be at risk of flooding based on the predictive assessment in isolation, leading to a finalised list of APSFRs.

This section details the method that was used to assess the data on predictive flood extents and the vulnerabilities of receptors in the predictive assessment to inform the designation of APSFRs.

5.1 Flood Risk Index

The 'Flood Risk Index' scoring system, as introduced in Section 2, was developed in the first cycle PFRA to combine the vulnerabilities of the different receptors depending on the severity of the flood concerned.

The basis for the Flood Risk Index (FRI) system is shown in Table 5.1. This approach allowed every receptor located inside a flood extent to be assigned a Flood Risk Index score, the magnitude of which depends primarily on the vulnerability class and the probability of flooding. For each vulnerability class, the FRI score varied according to the probability of the flood event concerned. The multiplying factor, based on the Annual Exceedance Probability, was a reflection in the difference in percentage probability of the flood extents.

For example, a receptor classified with Extreme Vulnerability to flooding would receive a score of 1,250 if it was located inside the 5% AEP flood extent (250 x 5), but only a score of 25 if it was located within the lower probability 0.1% AEP flood extent.

For residential properties, available and readily derivable information was used to provide a more accurate representation of the relationship between flood event probability and impact on a receptor (see Section 4.5.1), with Vulnerability Factors and Damage Adjustment Factors introduced to reflect this.

Table 5-1 Determination of Flood Risk Index score for Receptors

Vulnerability Class	Vulnerability Class Factor	Probability of Flooding (Annual Exceedance Probability)		
		5%	1%	0.1%
Critical	2500	12,500	2,500	250
Extreme	250	1,250	250	25
High	25	125	25	2.5
Moderate	2.5	12.5	2.5	0.25
Low	1	5	1	0.1
Very Low	0	0	0	0

5.2 Identifying Areas and Communities at Flood Risk

The method set out in this document as far as Section 5.1 demonstrates how Flood Risk Index scores for each receptor located inside the flood extents were determined. However, instead of limiting the review of flood risk to individual receptors, an area-based flood risk analysis was developed to determine areas, or communities, where the cumulative flood risk to a number of different receptors could be assessed. It should be noted that this method of assessment relates only to the predictive assessment of the PNFRA. The final designation of ''Areas of Potentially Significant Flood Risk' also depends on stakeholder consultation and a review of historic flood events.

First Cycle PFRA Method

In the first cycle PFRA, a 500m x 500m grid system was developed across the country in GIS with the cumulative Flood Risk Index score for each grid square determined. Adjacent squares (horizontally, vertically, and diagonally) were then amalgamated into sets of grid squares and assigned a score which was the cumulative sum of all amalgamated grid squares. Each amalgamation was identified as an amalgamated area. Where individual grid squares included receptors at risk, but no adjacent squares contained receptors at risk, these were assessed as standalone based on their FRI score in the same way as the amalgamated areas.

Areas where the level of flood risk was 'significant' were determined based on the total Flood Risk Index score for the amalgamated area, and at a 'settlement scale', to reflect the limitations of the methodology and flood hazard data. For the first cycle PFRA, an amalgamated area was deemed to be potentially at 'significant' flood risk if the Flood Risk Index score was 250 or higher.

First Cycle PFRA Review

A review of the first cycle FPRA methodology for identifying area of risk was undertaken to consider whether it was still appropriate for use in the third cycle PFRA. In reviewing the appropriateness of the first cycle PFRA methodology for use in the FRIA, the following observations were made:

- **Amalgamation of grid squares -** The amalgamation of individual grid squares allows a more robust identification of communities or areas at risk (multiple grid squares), with individual receptors having reduced influence;
- **Amalgamation of grid squares -** Despite the above point, it was also noted that the amalgamation of individual grid squares would typically favour larger urban areas, where the geographic coverage alone may result in higher cumulative FRI scores (due to a higher number of grid squares), even if the level of flood risk (FRI score) in each amalgamated grid square was modest. A smaller community, even if the flood risk (FRI score) in each amalgamated grid square was higher, has greater potential for being overlooked (due to a lower number of grid squares);
- **Flood Risk Index Threshold -** The application of a single numeric FRI threshold (250 in the first cycle PRA) meant all areas or communities at risk were treated in the same way. Whilst two areas may have scores of 25,000 and 250, both were deemed to be potentially at ‘significant’ flood risk. There was no differentiation between them. A ranking system or multiple threshold would allow more differentiation in the level of flood risk;
- **Total FRI score -** The application of a threshold for the total FRI score, rather than individual categories (Human Health, Environment, Cultural Heritage, Economic Activity), ensures communities which score just below a category threshold in all categories are not prematurely screened out;
- **Like-for-like FRI comparison -** It was noted that due to changes in assessment methodology, flood receptor data, and flood hazard data, there would not be a like-for-like comparison between FRI scores in the first cycle PFRA and the third cycle PFRA. The same community receiving a higher FRI score in the third cycle PFRA would not necessarily mean an increase in risk, but could be associated with a change in methodology or available receptor or flood hazard data.
- **Consistency in methodology –** Whilst a like-for-like comparison was not possible, consistency in the way areas or communities are identified as beign at flood risk would be advantageous as it would allow comparison in terms of ranking and number of areas identified, and would also reduce the risk of the same community no lnoge rbeing identified solely base don a change in the methodology used.

PNFRA Options

A number of options for the identification of areas or communities at flood risk were tested as part of a pilot study. These were specifically designed to build upon the first cycle PFRA methodology and the review undertaken.

The review identified a desire to ensure a level of consistency with the first cycle PFRA methodology, whilst acknowledging this would not be a like-for-like comparison due to changes to the underlying data and scoring methodology. The merits of the amalgamation of grid squares and the use of a cumulative FRI score were referenced in this context.

In addition, the review identified the potential for the previous methodology to favour larger urban areas through a sprawl effect, relative to a smaller community which had a high but concentrated level of flood risk.

In all cases, amalgamations which exceeded the defined FRI threshold would be identified as an **Area of High Flood Risk Index (FRI) score**.

For the FRIA, the identification of 'Areas of High Flood Risk Index score' were assessed under a staged approach developed based on the findings of the pilot study discussed above. This centred around firstly screening out areas (grid squares) where flood risk was not deemed significant (total FRI score of less than 15). Following this screening, adjacent grid squares (horizontally, vertically, and diagonally) were amalgamated and assigned a total FRI score which was the cumulative sum of all amalgamated grid squares. Those amalgamations with a total FRI score of 250 or greater were identified as Areas of High FRI score.

A more detailed description of the amalgamation process developed is discussed and illustrated below.

Stage 1 - Calculate Total Flood Risk Index Score

The Flood Risk Index score was calculated for each individual grid square as a cumulative total of all receptors within that square (Figure 5-1).

Where a property-based receptor was located within two or more grid squares, the receptor FRI score was assigned to the square within which the majority of the building footprint was located. An FRI score was calculated for each source of flood risk (fluvial, coastal, and groundwater) for each receptor. The total FRI score combined the highest FRI score for each individual receptor. The FRI score was calculated for the Current Scenario, Mid-Range Future Scenario, and High-End Future Scenario where flood hazard data was available and readily derivable.

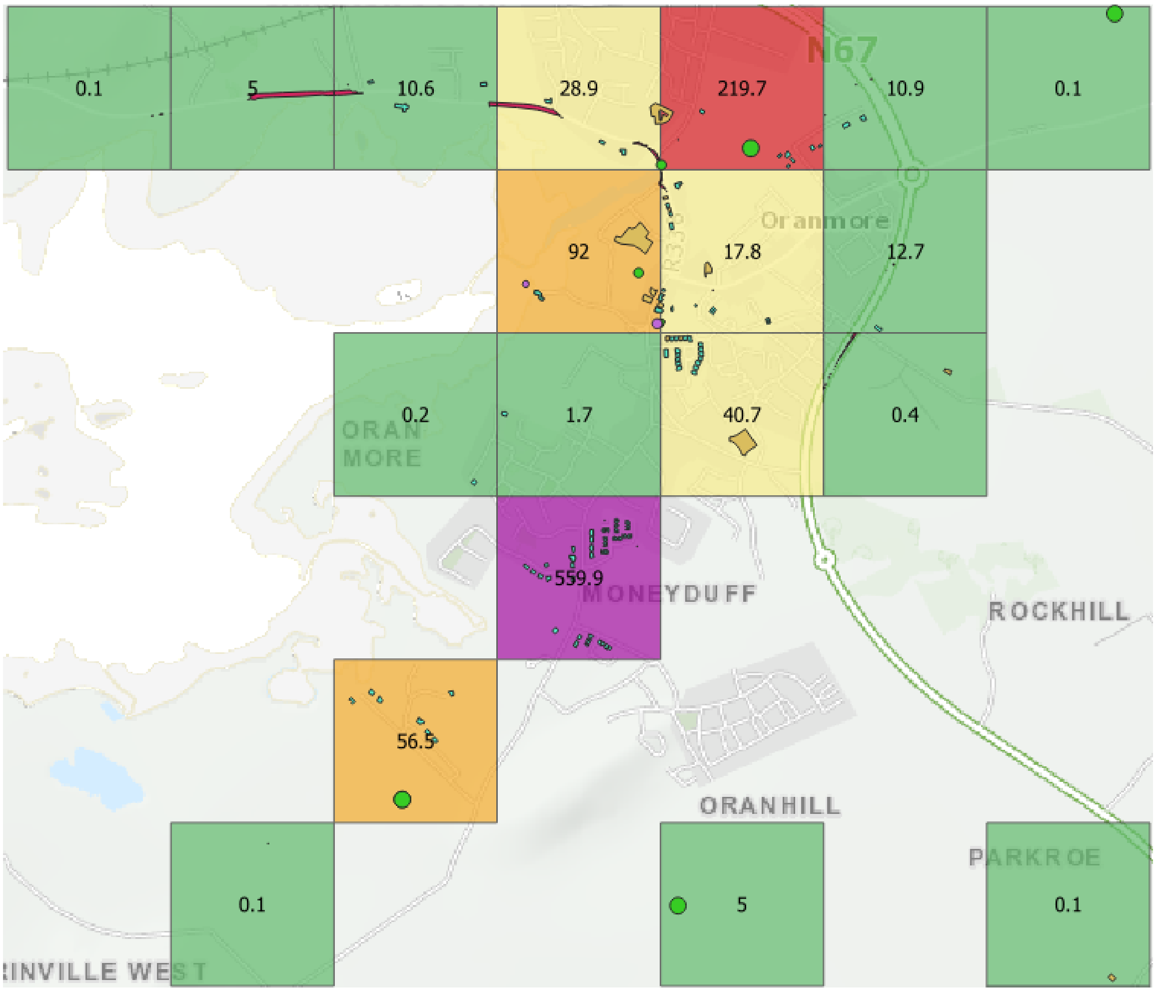

Figure 5-1; Calculation of the Total Flood Risk Index Score in Oranmore, Current scenario

Stage 2 - Screen out areas where flood risk is 'Not Significant'

Following the calculation of the total FRI score for all scenarios, grid squares which have a total FRI score of less than 15 were screened out and removed from further assessment as the flood risk was deemed to be not significant (Figure 5-2). The threshold was identified following analysis of five pilot study areas. The screening process was undertaken for all scenarios independently.

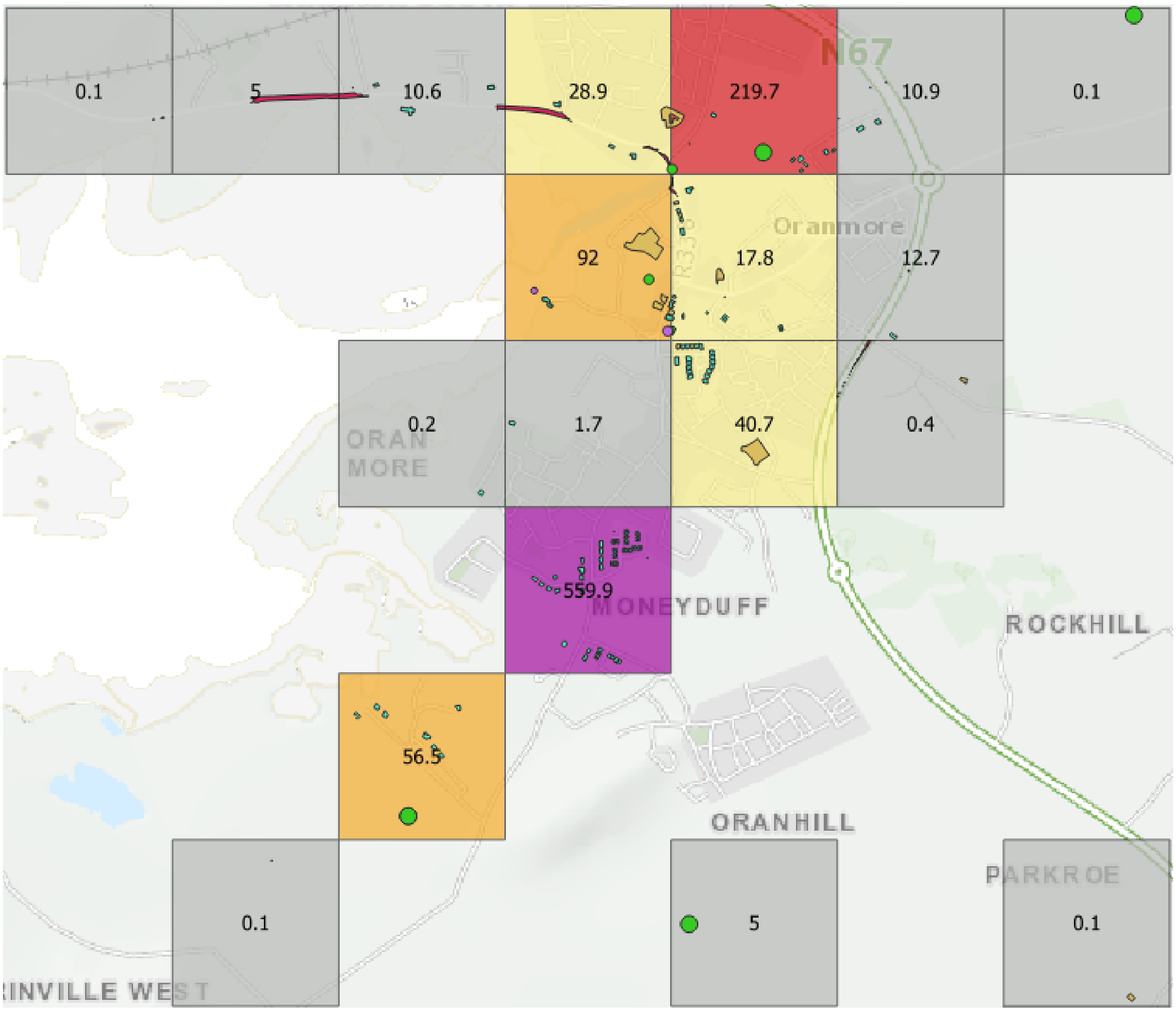

Figure 5-2; Screening out of grid squares (grey) where the flood risk is 'not significant' (FRI score less than 15) in Oranmore, Current scenario

Stage 3 – Amalgamate grid squares

The remaining grid squares, those that each had a Total FRI Score of greater than 15 were grouped into an amalgamation. An amalgamation consisted of all adjoining grid squares (horizontally, vertically, or diagonally).

The Total FRI score for each amalgamation was calculated using the cumulative total FRI score of all amalgamated squares. There were no minimum or maximum number of grid squares set in the amalgamation. The amalgamation process was undertaken independently for each scenario.

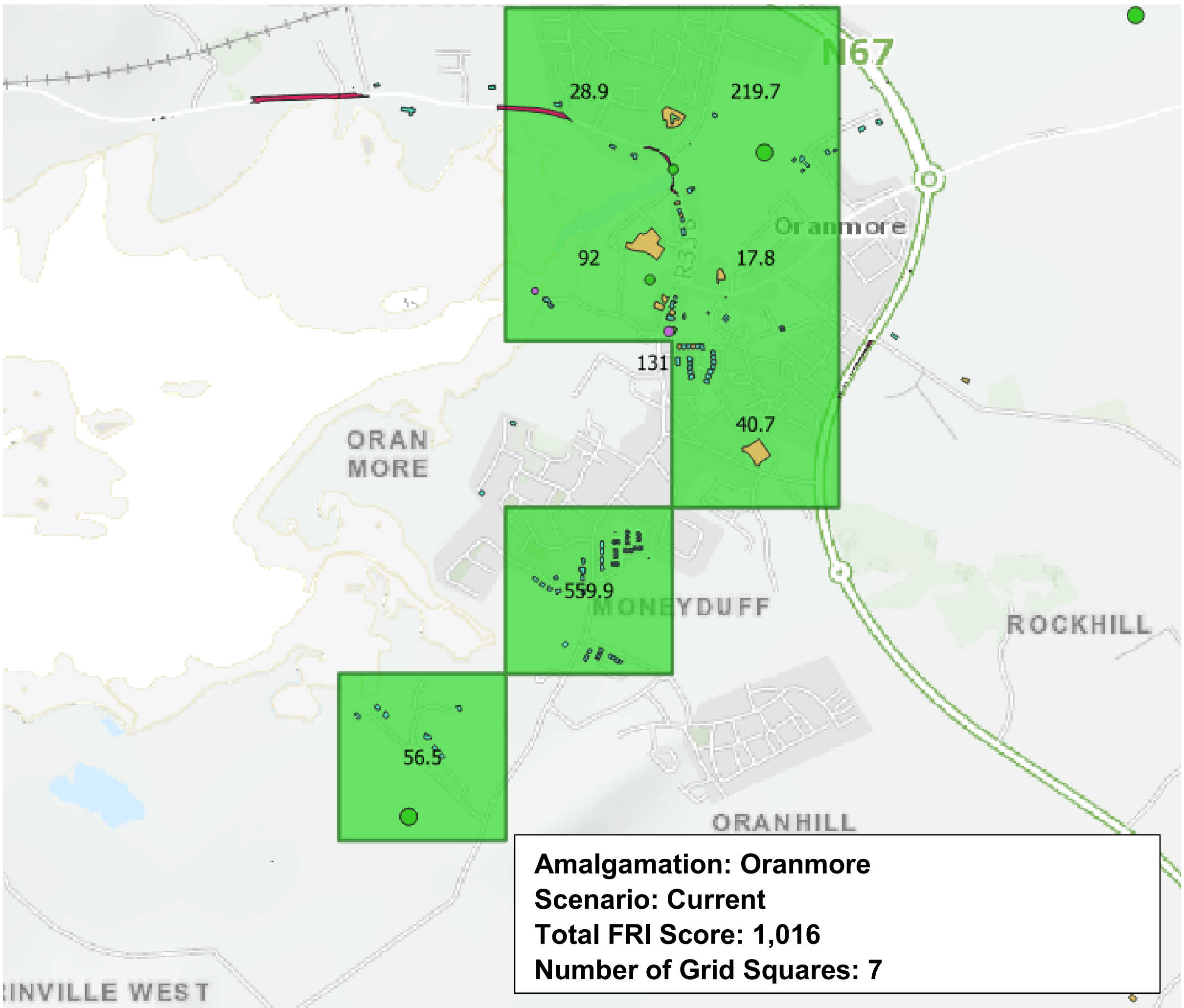

Figure 5-3; Amalgamated area (green) at Oranmore, Current Scenario based on adjoining grid squares above the identified threshold.

Stage 4 - Manually verify amalgamations

The process of identifying areas and communities at flood risk at a national scale must be automated as it would have been disproportionate and inconsistent to undertake it manually. However, it is not appropriate to finalise this process without some level of manual verification to ensure the proposed areas or communities were rational and logical. The purpose of this exercise was not to amend the assessment undertaken, but to review the geographical spread and consider the value in grouping amalgamations.

One reason to do so was where two amalgamations were separated by high ground (no flood risk) but were hydraulically linked. As such, it would be appropriate to group them as further assessment to identify options to manage flood risk would be better done in unison.

Similarly, an existing designated APSFR (from the second cycle PFRA) may currently be subject to further detailed appraisal (as part of a flood relief scheme). In this circumstance, if two new provisional Areas of High FRI score were located within the same existing second cycle PFRA APSFR boundary, it would be appropriate to group them. This circumstance was evident in multiple locations, including Ballinasloe where two provisional Areas of High FRI score were both located within the existing APSFR designation (Figure 5-4).

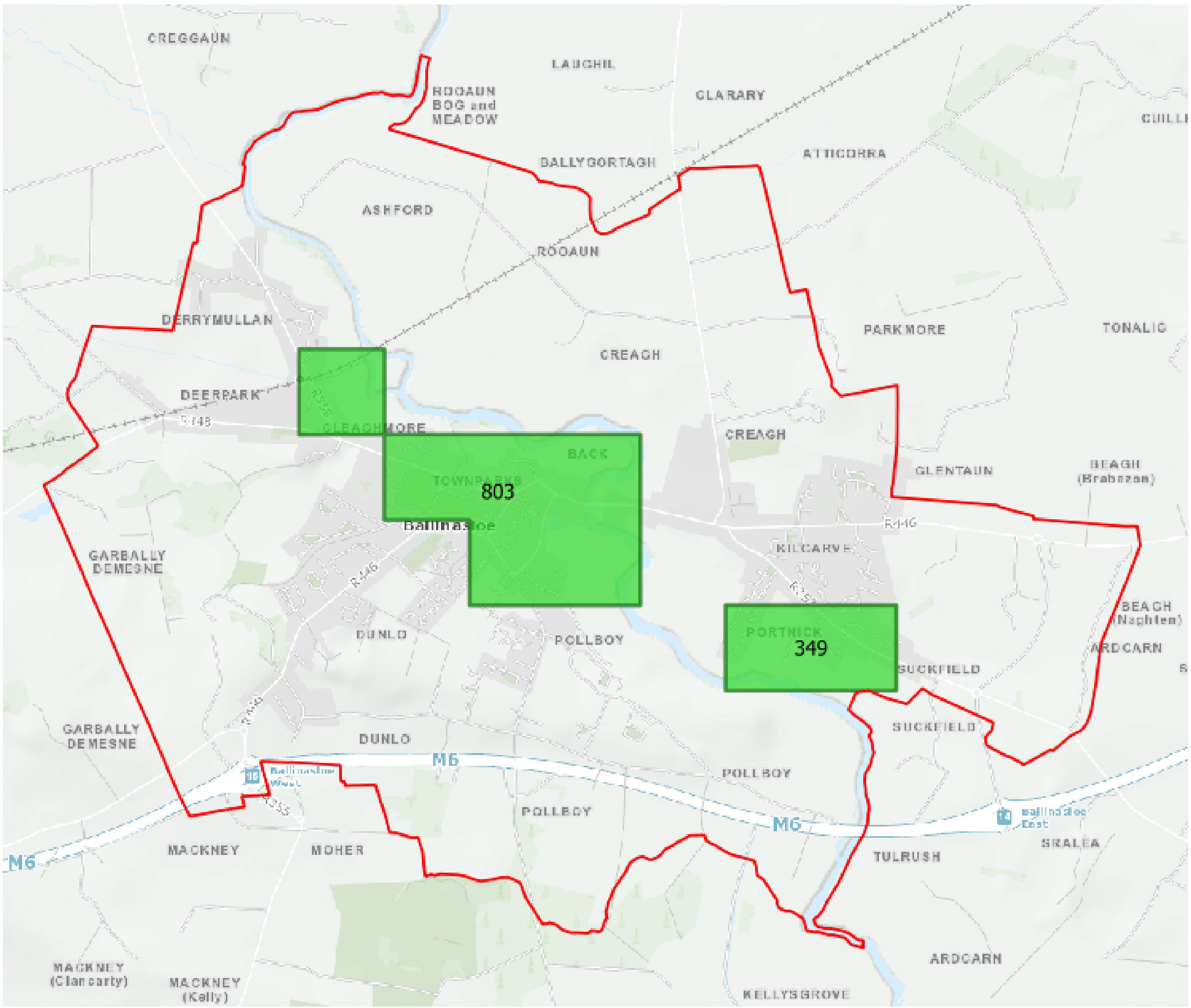

Figure 5-4; Two amalgamations (green) located within the boundary of the existing "Ballinasloe" APSFR would be grouped.

Stage 5 - Identify Areas of High FRI score

Following the amalgamation of grid squares and grouping of individual amalgamations where appropriate to do so, Areas of High FRI score were identified based on the Total FRI score of the grouped amalgamations.

Those amalgamations, or grouped amalgamations, with a total FRI score of 250 or greater were identified as Areas of High FRI score. Multiple amalgamations below this threshold could not be assessed as a single grouped amalgamation in order to meet the identified threshold.

A series of stakeholder workshops were subsequently held to present and consult on the identified Areas of High FRI score, and to compare these with both the local understanding of flood risk in the area together with any historic flooding that had occurred in the area.

Consideration of Climate Change

In the first and second cycle PFRA, the impact of climate change was not considered in the designation of Areas of Potentially Significant Flood Risk (APSFRs).

In the third cycle PFRA, the process of identifying Areas of High FRI score was repeated for both the Mid-Range Future Scenario and High-End Future Scenario. This generated an understanding of potential future increases in flood risk through:

- A national assessment of the potential increase in flood risk due to climate change through quantification of both the number of Areas of High FRI score and cumulative FRI scores;
- Quantification of the potential increase in flood risk (based on a comparison of FRI score across scenarios) communities already at flood risk;
- Identification of communities which may be at risk in the future that were not currently considered to be at flood risk.

5.3 Designating Areas of Potentially Significant Flood Risk

As part of the PNFRA, the appropriate definition for areas at flood risk was discussed, including in the context of the Floods Directive. The terminology used also needs to consider the various stage of the PFRA (and beyond) to provide clarity on when and how areas of flood risk are determined.

In chronological order, the terms used in the FRIA and in the wider third cycle review of the PFRA are discussed below. All terms relate to the Current scenario unless stated.

Grid Square of Potential Flood Risk

A **Grid Square of Potential Flood Risk** is used to describe any 500m x 500m grid square where at least one receptor is assessed to be a flood risk i.e. contributes an FRI score of greater than 0. By definition, a **Grid Square of Potential Flood Risk** will be any grid square where the total FRI score is greater than 0.

Grid Square where Flood Risk is deemed Not Significant

A **Grid Square where Flood Risk is deemed Not Significant** is used to describe any **Grid Square of Potential Flood Risk** where the total FRI score is less than 15 (see Section 5.2). A **Grid Square where Flood Risk is deemed Not Significant** can be described as a grid square where flood risk potentially exists, but was not assessed to be *significant* in line with the EU 'Floods' Directive.

Provisional Amalgamation

A ***provisional*** **Amalgamation** relates to the output of the automated process to amalgamate **Grid Squares of Potential Flood Risk** (see Section 5.2) in the Flood Risk Index Assessment described in this document. The *provisional* identification relates to this being a preceding step prior to manual verification.

Amalgamation

An **Amalgamation** relates to the final output of the amalgamation of **Grid Squares of Potential Flood Risk**, including manual verification to group ***provisional*** **Amalgamations**. **Amalgamation** will always be formed from one or more **Grid Square of Potential Flood Risk**.

Area of High Flood Risk Index score

An **Area of High Flood Risk Index score** is any amalgamation with a total Flood Risk Index score of 250 or higher. Each **Area of High Flood Risk Index score** was subject to an Economic Damage Assessment for each and every scenario that it exceeds the threshold of 250.

Area of Potentially Significant Flood Risk

On completion of the third cycle review of the PFRA, including public consultation, a final list of **Areas of Potentially Significant Flood Risk** will be published, in line with the requirements of the EU ‘Floods’ Directive. The uncertainty behind the designation (provisional, possible) will be removed from the terminology and signifies the conclusion of the PFRA. It is noted that the terminology related to uncertainty of flood risk (potentially) is retained pending further more detailed assessment i.e. beyond the national scale.

6 Summary

This methodology report sets out the approach to, and predictive assessment of, flood risk in Ireland at a national scale. It relates to a Flood Risk Index Assessment which concluded with the identification of Areas of High Flood Risk Index score. It sets out how readily available and derivable data was used within the predictive assessment, and the assumptions and limitations of the assessment where relevant.

Appendix A – Tables to Derive Receptor Vulnerabilities

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

The full set of these tables are shown below.

Table 1: Risk to Life

Probable Impact	Vulnerability Classification
Significant Risk to Loss of Life	Critical
Highly Elevated Risk to Loss of Life	Extreme
Elevated Risk to Loss of Life	High
Moderate Risk to Loss of Life	Moderate
Low Risk to Loss of Life	Low
Very Low Risk to Loss of Life	Very Low

Table 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
Negligible Damage	Low	Low	Very Low	Very Low

Table 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

Table 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	Very Low

Table 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