



Rialtas na hÉireann
Government of Ireland

FLOOD RISK MANAGEMENT

Climate Change Sectoral Adaptation Plan

Prepared under the National
Adaptation Framework

Prepared by the Office of Public Works

www.opw.ie

EXECUTIVE SUMMARY

It is likely that climate change will have significant impacts on flooding and flood risk in Ireland due to rising sea levels, increased rainfall in winter, more heavy rain days and more intense storms. While it is important that causes of climate change are addressed, Ireland must also prepare to adapt to such changes.

The first Climate Change Sectoral Adaptation Plan for Flood Risk Management was produced by the OPW in 2015 under the mandate of the National Climate Change Adaptation Framework (DECLG 2012). This Plan has been prepared under the National Adaptation Framework (DCCA, 2018), and updates the 2015 Plan taking into account new information available on climate change and its potential impacts, developments in flood risk management since 2015 and the Guidelines for the preparation of the Sectoral Adaptation Plans (DCCA, 2018).

The purpose of this Climate Change Sectoral Adaptation Plan for Flood Risk Management is to:

- outline the potential impacts of climate change on flooding and flood risk management in Ireland;
- identify the objectives for an effective and sustainable approach to adaptation as part of flood risk management for the future,
- promote a coordinated approach to adaptation:
 - within the flood risk management sector and sustainable flood risk management measures in other sectors, and,
 - across the policies and actions of other Sectors including Local Authorities, and,
- recommend any further actions required to meet the objectives for adaptation.

Climate Impacts on Flooding, Flood Risk and Flood Risk Management

Ireland has suffered from some severe flood events over recent decades, including the winter of 2015-16 when many thousands of properties were flooded, cut-off or at risk from flooding. Significant work has been undertaken over recent years to assess the level of risk associated with flooding in Ireland, including through the:

- Preliminary Flood Risk Assessment (PFRA) that was a national screening for flood risk under current conditions at a national level to identify the areas of potentially significant flood risk
- The Catchment-based Flood Risk Assessment and Management (CFRAM) Programme that included detailed assessments of flooding and impacts for potential future climate change scenarios, as well as under current conditions for 300 communities around the country that are home to approximately two-thirds of the population and 80% of properties potentially at risk in Ireland from rivers and seas, the primary source of flooding in Ireland.

The CFRAM Programme has identified measures that, in combination with the measures already completed or that were previously at construction or under design, will provide protection to 95% of the properties at risk within the 300 areas. These measures are set out in the Flood Risk Management Plans (FRMPs) that were published in 2018, along with information on the properties and assets at risk.

Human activities are estimated to have already caused approximately 1.0°C of global warming above pre-industrial levels, and global mean sea level has risen about 20 cm since the beginning of the 20th century, and is rising at approximately 3.5 cm per decade at present. The Intergovernmental Panel on Climate Change (IPCC) has reported that for a 1.5°C rise in temperature, the global mean sea level could rise by up to approximately 1m by 2100, and projections of more intense Atlantic storms could potentially increase surge events and wave heights. Met Éireann has predicted that in Ireland the autumns and winters may become wetter, with a possible increase in heavy precipitation events of approximately 20%.

The assessments under the National CFRAM Programme indicate potentially very significant increases in the flood impact and the number of properties that could become at risk from flooding. The impact on both the extent and depth of flooding, as well as on the potential damages caused is however site specific and varies significantly from community to community. Flood relief schemes that are currently in construction or under design, or that are planned as set out in the FRMPs will however protect many of the properties that would otherwise become prone to flooding in future scenarios, or the schemes have, or will be, designed taking account of climate change and the need for adaptation.

Climate change will also impact on different aspects of the national flood risk management programme. These impacts, and the need to take adaptive action to address them, vary across the different programmes of work within flood risk management, with the highest priority impacts being on flood protection, spatial planning and development management. Non-structural flood risk management measures (e.g., preparedness measures) tend to be more inherently adaptable to changes in flood frequency and severity, and 'green' measures, such as natural water retention measures also facilitate adaptation while providing benefits to other sectors (e.g., improve water quality and biodiversity, contribute towards carbon mitigation).

Sectoral Adaptation Plan for Flood Risk Management

This Plan sets out a long-term goal for adaptation in flood risk management, along with a set of objectives and adaptation actions aimed at achieving those objectives. The long-term goal adopted by the OPW on climate adaptation for flooding and flood risk management is:

Promoting sustainable communities and supporting our environment through the effective management of the potential impacts of climate change on flooding and flood risk.

To deliver on this goal, the OPW has identified the following adaptation objectives:

- **Objective 1:** Enhancing our knowledge and understanding of the potential impacts of climate change for flooding and flood risk management through research and assessment
- **Objective 2:** Adapting flood risk management practice to effectively manage the potential impact of climate change on future flood risk
- **Objective 3:** Aligning adaptation to the impact of climate change on flood risk and flood risk management across sectors and wider Government policy

A number of actions have been identified under each adaptation objective across the areas of activity in flood risk prevention, protection and preparedness and resilience, as well as in further research and capacity building. Flooding has the potential to affect all sectors and local authorities, and Coordination is critical towards ensuring a coherent and whole of government approach to climate resilience in relation to flooding and flood risk management.

To ensure progress and continual improvement in adaptation, the implementation of this Plan will be monitored and reviewed through current structures. This will be informed by indicators to enable a critical assessment and to measure progress. An annual review of progress will be undertaken to inform the Annual Sectoral Adaptation transition Statement for Flood Risk Management.



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MINISTER'S FOREWORD

In May last year, the OPW completed the most extensive and comprehensive study on flood risk ever undertaken in this country and through the National Catchment-based Flood Risk Assessment and Management (CFRAM) Programme has identified the flooding risk to 300 communities. The measures contained in the Flood Risk Management Plans prepared under the CFRAM Programme have been assessed and developed taking account of the impact that climate change would have on future flood risk, and how adaptable a proposed measure might be to cope with the potential impacts of climate change.

The Flood Risk Management Plans identify 118 flood relief schemes in addition to the 35 flood relief projects that are already in design and development under the existing capital programme. These schemes will be carried out over the next decade and will address the flood risk to a total of 23,500 properties underpinned by a €1billion funding investment provided in the National Development Plan 2018 - 2027. These schemes will be designed and constructed to standards which take account of potential future climate change impacts.

This plan has been prepared under the Climate Action and Low Carbon Development Act, 2015, and the National Adaptation Framework, 2018, in line with the Sectoral Planning Guidelines for Climate Change Adaptation and taking into account the submissions made during public consultation and the advice of the Advisory Council.

This Climate Change Sectoral Adaptation Plan for Flood Risk Management considers the impacts of climate change on flooding and flood risk, as well as on flood risk management and identifies 21 adaptation actions needed to ensure effective and sustainable management of flood risk into the future. These actions include ongoing research and assessment of the potential impacts of climate change for flooding and flood risk, the consideration of these impacts in the development and implementation of ongoing and future flood risk management measures, and coordination with other sectors and local authorities as part of a whole of Government approach to sustainable and effective flood risk management.



Kevin "Boxer" Moran, T.D.

Minister of State for the Office of Public Works and Flood Relief



GLOSSARY OF ABBREVIATIONS

AEP	ANNUAL EXCEEDANCE PROBABILITY
AFA	AREA FOR FURTHER ASSESSMENT
AR5	FIFTH ASSESSMENT REPORT (OF THE IPCC)
CARO	CLIMATE ACTION REGIONAL OFFICE
CFRAM	CATCHMENT-BASED FLOOD RISK ASSESSMENT AND MANAGEMENT
COM	COMMISSION OF THE EUROPEAN COMMUNITIES
DAFM	DEPARTMENT OF AGRICULTURE, FOOD AND THE MARINE
DCCAIE	DEPARTMENT OF COMMUNICATIONS, CLIMATE ACTION AND ENVIRONMENT
DCHG	DEPARTMENT OF CULTURE, HERITAGE AND THE GAELTACHT
DEFRA	DEPARTMENT OF THE ENVIRONMENT, FISHERIES AND RURAL AFFAIRS (UK)
DHPLG	DEPARTMENT OF HOUSING, PLANNING AND LOCAL GOVERNMENT
DPER	DEPARTMENT OF PUBLIC EXPENDITURE AND REFORM
DRCD	DEPARTMENT OF RURAL AND COMMUNITY DEVELOPMENT
EFAS	EUROPEAN FLOOD AWARENESS SYSTEM
ESB	ELECTRICITY SUPPLY BOARD
EPA	ENVIRONMENTAL PROTECTION AGENCY
EU	EUROPEAN UNION
FRA	FLOOD RISK ASSESSMENT
FRMP	FLOOD RISK MANAGEMENT PLAN
FSR	FLOOD STUDIES REPORT
FSU	FLOOD STUDIES UPDATE
GCOS	GLOBAL CLIMATE OBSERVATION SYSTEMS
GHG	GREEN HOUSE GAS

HEFS	HIGH-END FUTURE SCENARIO
ICPSS	IRISH COASTAL PROTECTION STRATEGY STUDY
ICWWS	IRISH COASTAL WAVE AND WATER LEVEL MODELLING STUDY
IFI	INLAND FISHERIES IRELAND
IPCC	INTER-GOVERNMENTAL PANEL ON CLIMATE CHANGE
JRC	JOINT RESEARCH CENTRE
MRFS	MID-RANGE FUTURE SCENARIO
NAF	NATIONAL ADAPTATION FRAMEWORK
NDP	NATIONAL DEVELOPMENT PLAN
NWRM	NATURAL WATER RETENTION MEASURE
OEP	OFFICE OF EMERGENCY PLANNING
OPW	OFFICE OF PUBLIC WORKS
OSPAR	OSLO/ PARIS CONVENTION (FOR THE PROTECTION OF THE MARINE ENVIRONMENT OF THE NORTH- EAST ATLANTIC)
PFRA	PRELIMINARY FLOOD RISK ASSESSMENT
RCP	REPRESENTATIVE CONCENTRATION PATHWAY
SAC	SPECIAL AREA OF CONSERVATION
SEA	STRATEGIC ENVIRONMENTAL ASSESSMENT
SI	STATUTORY INSTRUMENT
SPA	SPECIAL PROTECTION AREA
UNFCCC	UNITED NATIONS FRAMEWORK CONVENTION ON CLIMATE CHANGE

PART 1

Introduction

KEY MESSAGES

- Flooding is a natural process that can occur from a range of sources at any time in a wide variety of locations. Flooding can impact on people, communities, property, infrastructure, economy, environment and our cultural heritage.
- It is likely that severe weather events and sea level rise due to climate change will have a considerable impact on flooding and flood risk in Ireland.
- The first Climate Change Sectoral Adaptation Plan for Flood Risk Management was produced by the OPW in 2015 under the mandate of the National Climate Change Adaptation Framework (DECLG, 2012).
- This Plan has been prepared under the National Adaptation Framework (DCCAE, 2018), and updates the 2015 Plan taking into account new information available on climate change and its potential impacts, developments in flood risk management since 2015 and the Guidelines for the preparation of the Sectoral Adaptation Plans (DCCAE, 2018).
- The Plan considers the impacts of climate change on flooding and flood risk, as well as on flood risk management and what adaptation actions are required to ensure effective and sustainable management of flood risk into the future.
- The OPW and other responsible bodies are implementing a coordinated programme of work to manage flood risk in Ireland, addressing flood risk prevention, protection and preparedness in line with the national flood policy and the EU 'Floods' Directive.

1.1 Background to this Adaptation Plan

The Inter-governmental Panel on Climate Change (IPCC) stated in its Fifth Assessment Report (IPCC, 2014) that “warming of the climate system is unequivocal, and since the 1950s, many of the observed changes are unprecedented over decades to millennia. The atmosphere and ocean have warmed, the amounts of snow and ice have diminished, and sea level has risen” and that “recent climate changes have had widespread impacts on human and natural systems”.

Projections for climate change include:

- continued sea level rise,
- potentially more severe Atlantic storms, which could generate more significant storm surges and extreme waves,
- increase in the number of heavy rainfall days each year, and,
- wetter winters.

The potential impacts from these projections include increasing flood risk for communities and infrastructure along rivers, estuaries and the coast with accelerating rates of coastal erosion; threatening coastal habitats and environment.

It is recognised that there remains uncertainty in relation to the rate and scale of change in climate impacts. However even with this uncertainty and mitigation measures taken to date, it is prudent to consider the potential impacts from climate change and plan for adaptation measures to help ensure a more resilient society in the future, and it will typically be more cost-effective to plan for adaptation now and implement early actions than to retrofit unplanned adaptation measures and/or suffer the increased damages that are expected due to increasing flood risk.

Under Section 5 of the Climate Action and Low Carbon Development Act, 2015, the Minister for Communications, Climate Action and Environment published the National Adaptation Framework (NAF) in January 2018 (DCCAE, 2018), which complements the National Mitigation Plan published in July 2017 (DCCAE, 2017). The NAF specifies the national strategy for the application of adaptation measures in different sectors and by local authorities in their administrative areas in order to reduce the vulnerability of the State to the negative effects of climate change and to avail of any positive effects that may occur. The NAF identifies Flood Risk Management as one of the priority sectors, and the Office of Public Works (OPW) as the Lead Department for the adaptation plan for the sector.

The purpose of this Climate Change Sectoral Adaptation Plan for Flood Risk Management is to:

- outline the potential impacts of climate change on flooding and flood risk management in Ireland;
- identify the objectives for an effective and sustainable approach to adaptation as part of flood risk management for the future,
- promote a coordinated approach to adaptation:
 - within the flood risk management sector and sustainable flood risk management measures in other sectors, and,
 - across the policies and actions of other Sectors including Local Authorities, and,
- recommend any further actions required to meet the objectives for adaptation.

1.2 Flooding and Flood Risk

Flooding is a natural phenomenon defined as a temporary covering by water of land not normally covered by water, and is a natural process that can happen at any time in different locations.

Flooding can occur from a range of sources, individually or combined, including:

- coastal flooding (from the sea or estuaries),
- fluvial flooding (from rivers or streams),
- pluvial flooding (from intense rainfall events and overland flow),
- groundwater flooding (typically from Turloughs in Ireland), and
- other sources, such as from blocked culverts.

Flooding can be positive for the environment, such as where many wetland habitats and species depend on periodic flooding for their conservation. Flooding can however also cause damage, loss or harm in a number of ways, including:

- impacts on people and society, including physical injury, illness, stress and even loss of life,
- damage to property, such as homes and businesses,
- damage to and loss of critical infrastructure, such as water supply or roads,
- impacts on the environment, such as damage or pollution of habitats, and
- damage to our cultural heritage, such as monuments and historic buildings.

Flood hazard is the potential threat posed by flooding to people, property, the environment and our cultural heritage. The degree of hazard is dependent on a variety of factors that can vary from location to location and from one flood event to another.

Flooding only presents a risk when people, property, the environment and our cultural heritage can be potentially damaged. Therefore, for any given flood event the flood risk will vary by location and community. Flood risk is calculated from the combination of the probability of flood events of different magnitudes and the degree of the potential impact or damage that they can each cause.

The probability or frequency of a flooding event is expressed in a number of ways. Significant flood events such as those that occurred in winter 2015/2016 are floods that have a 1 in a 100 or 1% chance of being equalled or exceeded in any given year (referred to as the 1% Annual Exceedance Probability (AEP) flood). Expressed in another way, a flood that might occur, on average and over a long period of time, once every hundred years (the 100-year flood).

Further information in relation to flooding and flood risk is available at **Appendix A**.

1.3 Background to Flood Risk Management in Ireland

1.3.1 National Flood Risk Policy

Historically, flood risk management focused on land drainage for the benefit of agricultural improvement. With increasing urbanisation, the Arterial Drainage Act, 1945, was amended in 1995 to permit the Office of Public Works (OPW) to implement localised flood relief schemes to provide flood protection for cities, towns and villages.

In line with changing national and international approaches on how to efficiently manage flood risk, a review of national flood policy was undertaken in 2003-2004. The review was undertaken by an Interdepartmental Review Group, led by the Minister of State at the Department of Finance with special responsibility for the OPW. The Review Group prepared a report that was considered by Government, and subsequently approved and published in September 2004.

The 2004 policy was accompanied by many specific recommendations, including

- the OPW is responsible for leading and coordinating the implementation of national flood risk management policy,
- structural (i.e. engineered) flood relief measures continue to play an important role in flood management but with an increased emphasis to be placed on non-structural measures (e.g. flood forecasting, sustainable planning, etc.), and,
- the OPW, with input from other relevant State bodies, where necessary, to develop a programme to implement the detailed recommendations of the report.

Three specific recommendations of the report led to the development and implementation of the National CFRAM Programme. These recommendations are:

- focus on managing flood risk, rather than relying only on flood protection measures aimed at reducing flooding,
- taking a catchment-based approach to assessing and managing risks within the whole-catchment context, and
- being proactive in assessing and managing flood risks, including the preparation of flood maps and Flood Risk Management Plans (FRMPs).

1.3.2 EU 'Floods' Directive 2007

The adoption of the national flood risk policy direction aligned with the subsequent requirements of the EU 'Floods' Directive (2007/60/EC). Protecting the community from the risk and impact of flooding is at the heart of the EU 'Floods' Directive. This Directive requires Member States to undertake a screening exercise, the Preliminary Flood Risk Assessment, to identify areas at potentially significant flood risk, and then for these areas to map the flood extent and assets at risk in these areas and to identify measures to manage and reduce this flood risk to be set out in Flood Risk Management Plans. The implementation of the 'Floods' Directive needs to be coordinated with the implementation of the EU Water Framework Directive. The preparation of the flood maps and the FRMPs was undertaken in Ireland through the CFRAM Programme.

The EU 'Floods' Directive was transposed into Irish law by the European Communities (Assessment and Management of Flood Risks) Regulations 2010, S.I. No. 122 of 2010 and amended by the European Communities (Assessment and Management of Flood Risks) (Amendment) Regulations 2015, S.I. No. 495 of 2015.

1.3.3 The National Preliminary Flood Risk Assessment

The Preliminary Flood Risk Assessment (PFRA) is a requirement of the EU 'Floods' Directive that is aimed at identifying through a national screening exercise the Areas of Potentially Significant Flood Risk, or Areas for Further Assessment (AFAs) as they were referred to in Ireland. The AFAs are the areas where, under the 'Floods' Directive, detailed flood maps need to be produced and for which flood risk management measures need to be assessed to reduce and manage the risk.

In Ireland the first cycle PFRA involved:

- Reviewing records of floods that have happened in the past (the historic assessment);
- Undertaking analysis to determine which areas might flood in the future, and what the impacts might be (the 'predictive' assessment); and,
- Consulting with the Local Authorities, Government Departments, other public agencies and members of the public.

The assessment has considered all types of flooding such as from rivers, the sea and estuaries, heavy rain and groundwater, and also from man-made sources, such as the failure of built infrastructure. It has included the impacts flooding can have on people, property, businesses, the environment and cultural heritage.

The first cycle PFRA identified 300 AFAs. Under the CFRAM Programme and other location-specific projects, detailed flood hazard and risk assessments were subsequently undertaken for these areas, as described below.

The 'Floods' Directive is cyclical and as part of the second and subsequent cycles, the OPW and other relevant authorities are required to review, and if necessary update, the PFRA in relation to the potential sources of flooding they have responsibilities for. This review builds on the work of previous cycles, taking into account floods that may have occurred at the time of the reviews.

1.3.4 The Irish Coastal Protection Strategy Study

The Irish Coastal Protection Strategy Study (ICPSS) is a national study that was commissioned in 2003 with the objective of providing information to support decision making about how best to manage risks associated with coastal flooding and coastal erosion. The Study was completed in 2013 and provides strategic current scenario and future scenario (up to 2100) coastal flood hazard maps and strategic coastal erosion maps for the national coastline. This major study provides invaluable and essential information required to inform policy in this area, particularly for local authorities in relation to the proper planning and development of coastal areas. The ICPSS hazard mapping produced is available on the OPW website (<https://www.opw.ie/en/flood-risk-management/floodanderosionmapping/icpss/>).

The Irish Coastal Wave and Water Level Modelling Study (ICWWS) was commissioned in 2011 with the objective of providing information to facilitate the assessment of flood risk due to wave overtopping around the coast of Ireland. The Study was completed in 2013 and provides detailed nearshore water level and wave condition information for the current and future scenario (up to 2100) at 63 locations identified as being susceptible to wave overtopping and where this may contribute to significant coastal flooding both now and in the future.

In 2018, the OPW commissioned a further Study to update the extreme water level and wave analysis completed as part of the ICPSS and ICWWS by incorporating any additional data that is now available from tide gauges and records of more recent storm events. The objectives of this Study are to update the predicted extreme water levels for all previous ICPSS coastal locations and the predicted extreme water level and wave climate information for the areas identified as being susceptible to wave overtopping, under current and multiple future scenarios. The Study also includes the development of detailed models of specified major flood relief scheme locations to inform the detailed assessment and design of these schemes.

1.3.5 The CFRAM Programme

Completed in 2018, the objectives of the CFRAM Programme were to:

- identify and map the existing and potential future flood hazard and flood risk in the areas at potentially significant risk from flooding, called Areas for Further Assessment (AFAs), as identified through the PFRA,
- identify feasible structural and non-structural measures to effectively manage the assessed risk in each of the AFAs, and,
- prepare a set of FRMPs, and associated Strategic Environmental and Habitats Directive (Appropriate) Assessments that set out the proposed feasible measures and actions to manage the flood risk in these areas and their river catchments.

The CFRAM Programme covered those areas, in each county, where, based on initial analysis, the flood risk was determined to be potentially significant. The 300 communities studied are home to two thirds of the population and 80% of properties potentially at risk in Ireland from rivers and seas, the primary source of flooding in Ireland. Ninety of these communities are coastal areas. While the CFRAM Programme assessed flood risk in all our large urban areas, approximately one quarter of communities assessed had populations of less than 500 people and half had less than 2,000 people.

In consultation with Local Authorities, the OPW embarked on extensive and detailed analysis to fully assess the risk of flooding in each of these areas. This was completed through six CFRAM Projects covering 29 River Basins (**see Figure 1-1**), and other location-specific projects. To ensure best practice and a national consistency of approach, the OPW established a National Technical Coordination Group that established common standards, methods and approaches to assessing and planning to manage flood risk.

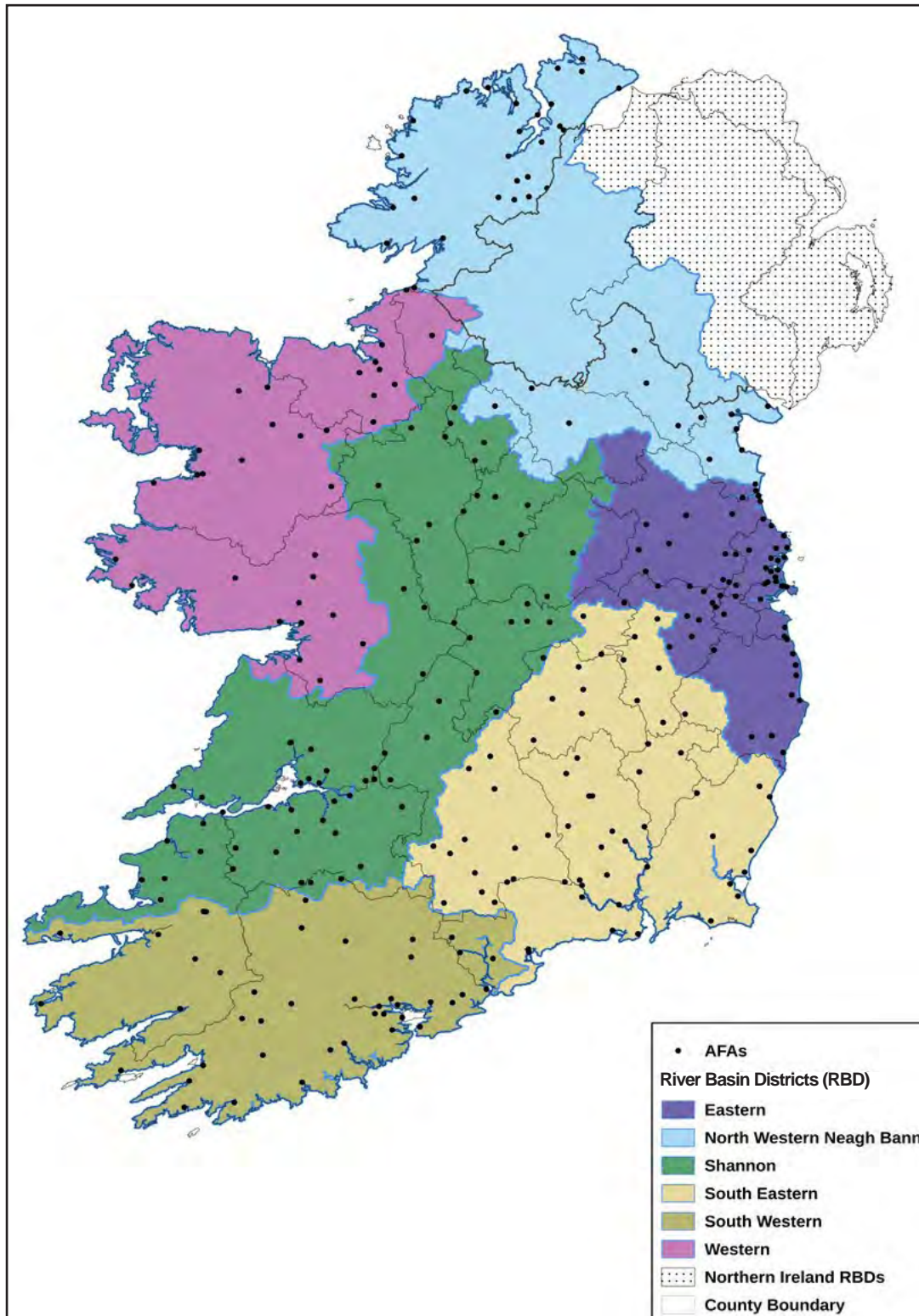


Figure 1-1: Six CFRAM Study Areas and 300 AFAs

The detailed work involved engineering analysis of the river systems, estuaries and coastal areas, including their hydrology and involving detailed hydraulic modelling. This included surveying and modelling of 6,700 km of watercourse and 9,400 km² of floodplain. The work and analysis was significantly informed by consultation with elected representatives, State Agencies, representative organisations and stakeholders, and members of the public.

Through the CFRAM Programme and other location-specific projects, the OPW has assessed and mapped the flood extents, hazard and risk for the 300 communities assessed for a range of flood events from frequent, minor flood events (1 in 10 year event) up to, very rare (1 in 100 year event) to extreme events (1 in 1,000 year event). The flood maps were developed for two future scenarios taking account of the potential impacts of climate change as well as for current conditions.

These maps and assessments provide valuable information for the OPW, local authorities and other sectors in planning for adaptation against increasing flood risks due to climate change, as well as informing future planning decisions, emergency response planning and helping communities and people to plan for and respond to a flood event.

The CFRAM Programme has identified measures that, in combination with the measures already completed or that were previously at construction or under design, will provide protection to 95% of the properties at risk within the 300 areas. These measures are set out in the FRMPs that were published in 2018, along with information on the properties and assets at risk.

The flood maps and the FRMPs are available to view through the OPW flood portal; www.floodinfo.ie.

1.3.6 Dutch Peer Review of Ireland's Flood Risk Management

Approximately 10 years after the publication of the Report of the Flood Policy Review Group (2004), the OPW, in conjunction with the Government of the Netherlands, commissioned a peer review of flood risk management in Ireland. The review was undertaken by experts of the Dutch Risk Reduction Team.

The main finding of the review was that the approach and strategies for flood risk management in Ireland complies with international best practice and is well on track. The Dutch team benchmarked Ireland's policy against international best practice and reported the critical achievements to date including:

- that we have profiled the main flood risk areas, through the CFRAM programme,
- significant Government investment to reduce flood damage,
- introduction in 2009 of guidelines on the consideration for flood risk in planning and development management, and
- our progress in responding to flooding events.

1.4 Current Flood Risk Management Practice

The OPW, as the lead agency for flood risk management, is coordinating the delivery of measures towards meeting the Government's National Flood Risk Policy across three areas, or 'pillars' of flood risk management, supported by data collection and strategic flood risk assessments. This work contributes towards a number of the sustainable development goals, namely Goal 3 'Good Health and Well-being', Goal 11 'Sustainable Cities and Communities', and Goal 13 'Climate Action' (UN, 2015a).

A brief summary of each of these activities is outlined below, with reference to the above policy initiatives and legislation, to provide an overview of the context and current flood risk management work in Ireland. Further details on the activities are provided in **Appendix B**, and from the OPW website; www.opw.ie. The work of the OPW, through the CFRAM Programme, contributes towards

a number of priorities identified under the Disaster Risk Reduction Framework, namely Priority 1 'Understanding disaster risk, Priority 3 'Investing in disaster risk reduction for resilience, and Priority 4' Enhancing disaster preparedness for effective response and to "Build Back Better" in recovery, rehabilitation and reconstruction' (UN, 2015b).

1.4.1 Prevention

The National Flood Policy Review of 2004 identified flood risk prevention (i.e., the avoidance of creating new flood risks) as a critical aspect of flood risk management. In 2009, the OPW and the Department of Housing, Planning and Local Government (DHPLG) published guidelines under Section 28 of the Planning Act to assist planners in taking flooding into consideration in planning and development management (DECLG/OPW, 2009).

These Guidelines provide a clear framework for sustainable planning taking a risk-based approach whereby flood-sensitive development should avoid flood-prone areas, based on classifications of land-use vulnerability and flood zones. On an exceptional basis, town centre development in flood prone areas may be appropriate (subject to a justification test), providing the risk is managed.

1.4.2 Protection

Flood Relief Schemes

Since 1995, the OPW has completed 43 major schemes by the end of 2018, with a further 35 from the existing capital programme (i.e., prior to the publication of the FRMPs) currently at various stages of design, planning or construction. The completed major schemes have cost a total of €350m, provide protection to over 9,500 properties with an overall benefit of approximately €1.7bn. The design and implementation of flood relief schemes is subject to environmental assessment in accordance with relevant legislation as necessary.

The FRMPs, produced through the CFRAM Programme, identified a further 118 schemes to be progressed. The progression of these schemes is supported by the Government's National Development Plan (NDP) 2018 – 2027, which includes a total funding allocation of €940m over the lifetime of the Plan to underpin the delivery of the existing flood relief capital works programme and the additional prioritised flood relief schemes recommended in the Flood Risk Management Plans. The annual allocation for flood defence measures will increase to €100m by 2021 demonstrating the priority placed by the Government on addressing Ireland's flood risk and reflecting also the flooding policy priorities set out by Government in A Programme for a Partnership Government.

The implementation of the measures proposed in the Plans is being delivered in two phases with 57 of these measures being advanced as part of the first phase.

The Government's investment to date and planned over the coming decade will protect 95% of those properties at risk within the 300 communities assessed to be at significant risk from flooding. **Figure 1-2** presents an example of flood protection works along the Dodder River in Dublin City.

Figure 1-2: Dodder Flood Protection Scheme (Courtesy of Dublin City Council)



In 2009, the OPW launched the Minor Flood Mitigation Works & Coastal Protection Scheme whereby the OPW may allocate to a Local Authority up to €750k to implement local solutions for local flood problems. This Scheme has proven to be very successful with approval given to €46m of funding for over 700 Minor Works projects by the end of 2018, providing benefits to almost 7,000 properties.

The need for further schemes, or the adaptation of existing, ongoing or planned schemes, as a result of increasing flood risk due to climate change will be triggered through the 6-yearly review cycle of flood risk, as required under the EU 'Floods' Directive. These regular reviews will be informed by observations of sea level rise and changes in rainfall patterns and flow regimes through the hydrometric monitoring programme and the climate projections current at that time. The trigger points can be identified in a timely manner to allow for the analysis, design and construction processes.

The OPW is currently engaging with other stakeholders and supporting pilot and research projects to explore softer forms of achieving flood protection, such as through natural water retention measures and an integrated approach to flood risk management.

Drainage Districts and Arterial Drainage Schemes

Drainage Districts are areas where drainage schemes were constructed under the Arterial Drainage Acts from 1842 up to 1943 to improve land for agricultural purposes. The statutory duty for

maintaining these schemes, that include 4,600km of river channel, rests with the Local Authorities, and is funded by the Minister for Housing, Planning and Local Government.

Following the passing of the Arterial Drainage Act, 1945, the OPW began the implementation of the various Arterial Drainage Schemes and continued into the early-1990s when the last major schemes were completed. The OPW has a statutory duty to maintain the completed Schemes in proper repair and in an effective condition. The annual maintenance programme is prepared by the OPW, and typically involves some clearance of vegetation and removal of silt build-up on a five-yearly cycle.

The OPW's arterial drainage maintenance works programme protects 260,000 hectares (650,000 acres) of agricultural lands and comprises 11,500km (7,150 miles) of river channel and approximately 800km (500 miles) of embankments. The OPW's national arterial drainage maintenance operations use best practice for drainage and environmental protection.

Urban Storm Water Drainage and Water-Bearing Infrastructure

The local authorities maintain the road and urban storm-water drainage infrastructure within their areas to help ensure that urban runoff can drain into drainage networks for storage and/or removal from potential risk areas. Irish Water is responsible for combined sewerage systems (carrying foul and storm water), and for maintaining the existing capacity of these systems, which can drain urban areas, and for managing new connections and inflows.

Water-bearing infrastructure, including piped networks and water retention structures, can potentially cause flooding in the event of failure or blockage. Piped networks might include water supply pipes or sewerage systems, while water-retention structures might include dams and embanked reservoirs and raised canals. The owners and operators of the infrastructure are responsible for managing the risk of flooding from that infrastructure. This involves asset inspection and monitoring, maintenance and renewal, and is undertaken in accordance with strict procedures for assets that constitute a potentially significant risk such as major dams.

Statutory Instrument SI No. 122 of 2010, requires that relevant infrastructure owners must assess the flood risk related to their assets and, where significant, identify measures to manage the risk in line with the requirements of the EU 'Floods' Directive, with a review of the risk to be carried out every six years.

1.4.3 Preparedness

Flood risk preparedness, response and resilience is an area of work that was identified for development by the National Flood Risk Policy Review, as it is not always possible to reduce the likelihood or severity of flooding to a community at risk through protection measures, but actions and measures can be taken to reduce the risk to people and damage to property and assets in the event of a flood.

This approach involves what are often referred to as 'non-structural' measures and includes:

- Increasing public awareness and preparedness prior to, during and after flood events to reduce potential damages caused by floods.
- Providing flood warning so that the public and response authorities can prepare for and respond effectively to flood events.
- Ensuring effective flood event response planning by the emergency response authorities, so that the response is effective and timely to reduce impacts on people and property.

The Interdepartmental Flood Policy Coordination Group, that is led by the OPW, was established to consider the extent that non-structural solutions could inform the implementation strategy of the Flood Risk Management Plans and to ensure that policies that can benefit communities and individuals directly – to be prepared for and respond to or live with flood risk – are carefully considered. A range of measures have been implemented and are under consideration or development under the oversight of the Group that will continue its work and build partnerships, greatly informed by the wealth of knowledge and output from the CFRAM Programme.

1.4.4 Data Collection and Flood Risk Assessment

Hydrometric Monitoring

The OPW and the EPA (jointly with local authorities) are the two main public bodies involved with surface water monitoring in Ireland, and between them maintain a network of approximately 640 surface water hydrometric monitoring stations. Other major bodies involved in monitoring include Waterways Ireland, the Marine Institute, Geological Survey Ireland, Irish Water and the ESB.

Hydrometric monitoring has an important role to play in flood risk management. Long-term records of flows, particularly high and flood-flows, are essential in the determination of design flood flows. Records of flood levels are also important to permit observation of flood events for calibration of flood models. Long-term hydrometric records can also assist in the detection of changes in flow regimes or mean sea level, such as might be due to climate change.

Most monitoring stations are now equipped with telemetry such that near real-time and real-time water level data can be captured centrally and/or published directly to websites for public use (www.waterlevel.ie). **Figure 1-3** presents an example of a typical monitoring station.

Figure 1-3: River Gauge with telemetry



Flood Risk Assessment

The OPW has completed the PFRA and the CFRAM Programme to deliver on key recommendations of the Report of the National Policy Review Group, and as part of the implementation of the EU 'Floods' Directive.

Work is ongoing to review and enhance the assessments, including the development of national, fluvial indicative flood maps, reviewing the ICPSS national coastal flood maps and the development of predictive flood mapping for flooding from Turloughs, which together will inform assessments of the rural risk in areas outside of the 300 communities covered by the CFRAM Programme. The detailed flood maps produced through the CFRAM Programme will also be reviewed and updated as necessary on an ongoing basis.

The FRMPs published in May 2018 will be reviewed in 2021. The flood mapping outlined above and the review of the FMRPs will continue to take the potential impacts of climate change and the need for adaptation into account. The review of the FRMPs, including the assessment of appropriate measures, will be informed by the priority impacts related to flooding and the adaptation actions that can impact on flood risk and flood risk management that are set out in the sectoral plans and local strategies.

1.5 Scope of Sectoral Adaptation Plan

The scope of the Climate Change Sectoral Adaptation Plan for Flood Risk Management builds on the work undertaken through the CFRAM Programme and includes:

- An overview of current and planned measures to manage Ireland's flood risk management,
- An outline of the potential impacts of climate change on flooding and flood risk not addressed by the Flood Risk Management Plans, based on existing science and analysis;
- Objectives and actions for climate change adaptation to be pursued and applied in the development of flood risk management strategies and measures.

This Sectoral Adaptation Plan is at a high-level and sets out goals and objectives, a framework for progressing measures along with further actions for research and assessment, and does not specify particular physical interventions at this time. The Plan can inform the identification of detailed adaptation approaches and potential measures for individual communities at a local level taking account of the local social, economic and environmental context.

This Plan provides information on the potential climate-related changes in flood hazard and risk that is valuable information for the public and for communities to further understand the flood risk to their assets and/or areas of interest.

The Plan does not specify how other sectors should provide for potential climate-related changes in flood hazard and risk as it is relevant to their assets and/or areas of interest. The Lead Department for each Sector is best placed, in consultation across all sectors to optimise benefits and to avoid unintended harmful consequences (referred to as 'maladaptation'), to determine how changes in flood risk might be addressed in the most appropriate manner for their Sector.

1.6 Structure of the Plan

This Climate Change Adaptation Plan for Flood Risk Management is structured in line with the Sectoral Planning Guidelines for Climate Change Adaptation published, in 2018, by the

Department of Communications, Climate Action and Environment, taking account of the advice and recommendations of the Advisory Council's Annual Review, 2019 as presented in **Figure 1-4**. The methodology adopted also provides a framework for this Plan to be reviewed and improved as experience and understanding increase, including through further research.

Under the National Climate Change Adaptation Framework (NCCAF), 2012, the OPW, as lead agency for flood risk management in Ireland, prepared the first Sectoral Adaptation Plan for Flood Risk Management, which was approved in December 2015 (OPW, 2015). This Plan updates the 2015 Plan, taking into account new information available on climate change and its potential impacts and developments in flood risk management since 2015, including progress made on the actions set out in the non-statutory adaptation, particularly in the areas of research, assessment (such as the extensive information generated through the National CFRAM Programme) and the planning, design and implementation of flood relief schemes.

- 1 - Governance, Coordination and Engagement
- 2 - Preliminary Flood Risk Assessment (PFRA)
- 3 - CFRAM Programme Flood Risk Assessment
- 4 - Flood Risk Management Plans (FRMPs)
- 5 - Cyclical Review

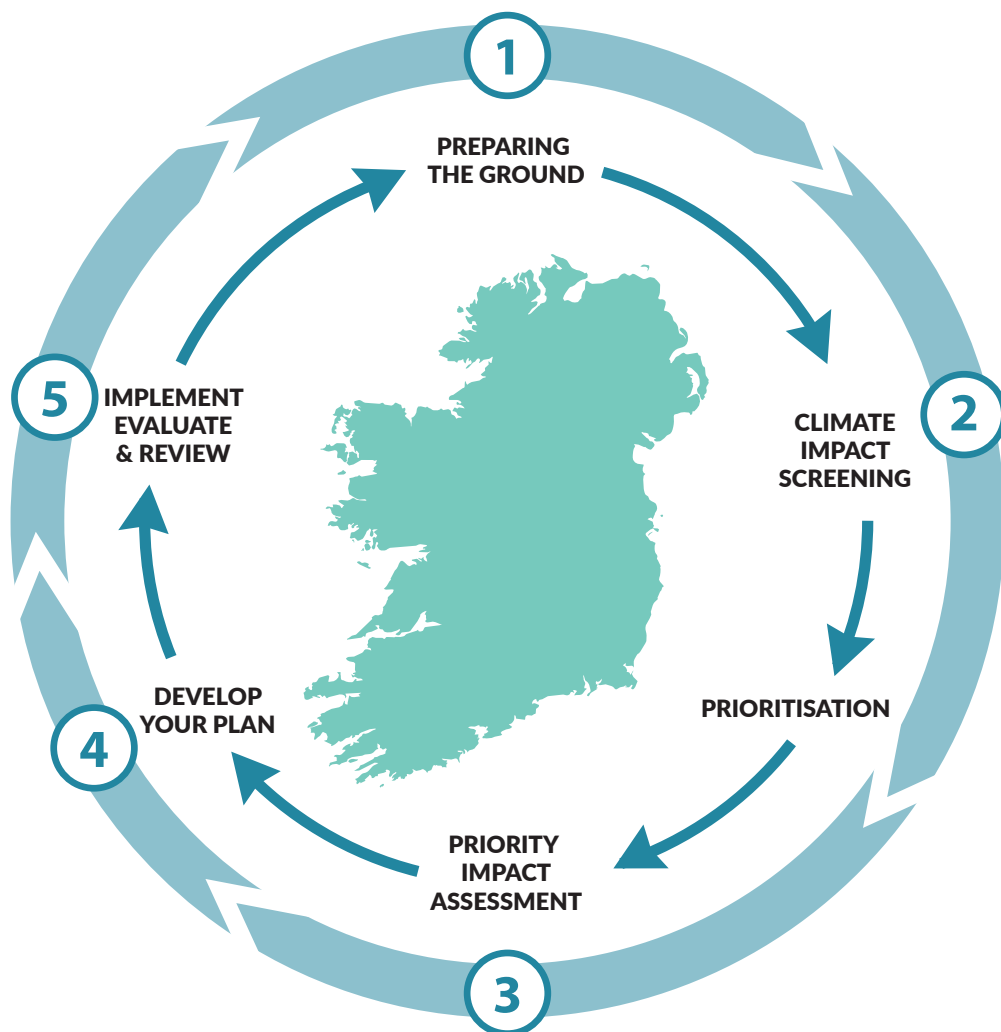


Figure 1-4: Flood Risk Management Planning and the Adaptation Planning Process

PART 2

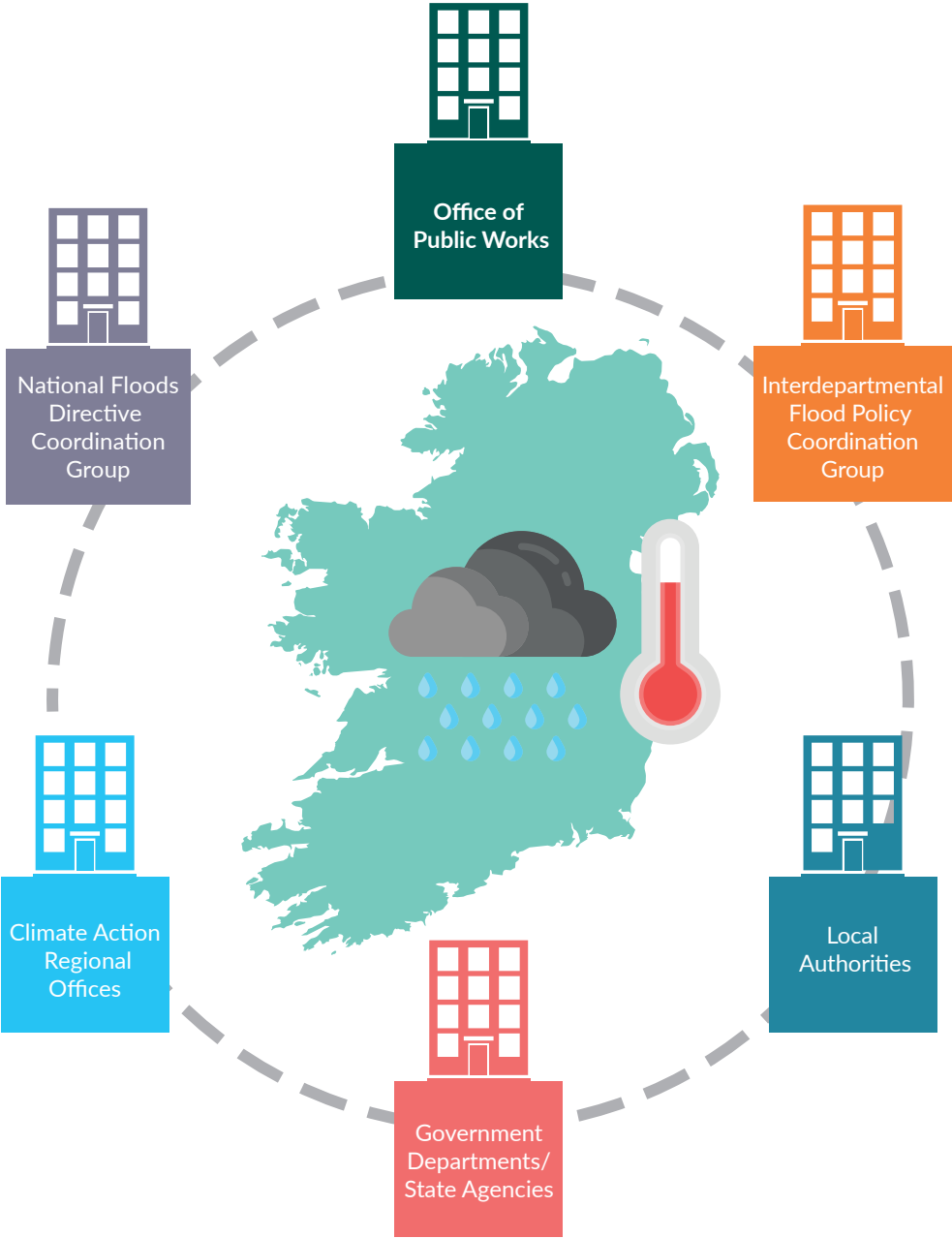
Preparing the Ground

KEY MESSAGES

- Long-standing coordination groups have been in place for many years to coordinate flood risk management across sectors and with the local authorities.
- Topics of discussion for the groups have included climate change and the Sectoral Adaptation Plan, promoting a cross-sectoral understanding and approach to climate change and adaptation in flood risk management.
- A cross-sectoral coordination workshop held by the OPW in 2018 provided a specific forum for the discussion of cross-sectoral issues for flooding and flood risk management, which has informed this Plan.
- The flood risk management coordination groups and workshops have informed the identification of cross-sectoral issues and the preparation of this Plan.
- It is recognised that coordinated adaptation planning will evolve and develop over time.

Since the Government Decision in September 2004 for the OPW to coordinate Government policy on flood risk, the OPW has established a number of cross sectoral groups, to share an understanding of flooding and flood risk and to coordinate the development and implementation of flood risk management policies and measures. These structures informed the development of this Climate Change Sectoral Adaptation Plan. **Figure 2-1** presents the relevant bodies involved.

Figure 2-1: - Climate Change Adaptation - Flood Risk Management bodies



2.1 Interdepartmental Flood Policy Coordination Group

The initial role of the Interdepartmental Flood Policy Coordination Group, chaired by the OPW, was to coordinate and inform the progress with implementing the recommendations of the Government's 2004 Report of the Flood Policy Review Group. In 2009, the Group also set the direction for the development of the CFRAM Programme.

The Interdepartmental Flood Policy Coordination Group was reconvened by Government in July 2015 to:

- explore the impact on individuals and communities of the FRMPs,
- recommend to Government policies and measures that would reduce the impact of flood risks on individuals and communities,
- recommend to Government policies and measures that would support individuals and communities to be prepared and respond effectively to flood risks,
- identify the lead Department and/or agency for each recommended policy measure, and,
- estimate the financial and resource implications of their recommendations.

The Group considers that a whole of Government approach is necessary to support flood risk management, so that Government Departments and State Agencies are each taking the lead to provide effective supports and policy measures for their areas of responsibility and to promote and address community and individual responses.

The Group is chaired by the Minister of State with special responsibility for the Office of Public Works and Flood Relief and membership includes representatives from across Government and the local authorities, as set out in **Appendix C**.

The Sectoral Adaptation Plan for Flood Risk Management was discussed with this Committee at its biannual meeting in May 2019.

2.2 National Floods Directive Coordination Group

The CFRAM Steering Group was established in 2009. It was established to provide for the engagement of key Government Departments and other State stakeholders in guiding the direction and the process of the implementation of the EU 'Floods' Directive, including the CFRAM Programme. The CFRAM Steering Group reported, through the OPW, to the Interdepartmental Flood Policy Coordination Group.

At the end of 2018, following the launch of the Flood Risk Management Plans, the Group was dissolved and reformed as the National Floods Directive Coordination Group. The terms of reference for this Group were amended to support the technical aspects for the delivery and review of the twenty nine Flood Risk Management Plans. The Group now supports consideration of the six-year cyclical review of flood risk management, required by the EU 'Floods' Directive, that necessitates climate change considerations to be included in the assessment and planning for flood risk management.

Climate change and the Sectoral Adaptation Plan for Flood Risk Management was discussed with this Committee at its biannual meetings in November 2018 and May 2019.

The membership of the Group is set out in **Appendix C**.

2.3 Shannon Flood Risk State Agency Coordination Working Group

The Shannon Flood Risk State Agency Coordination Working Group was established by the Government in January 2016. It has published and consulted on its Work Programme and it is a solutions-focussed Group that added value to the Shannon CFRAM Study by ensuring the best possible level of coordination between all statutory bodies involved in flood risk management of the Shannon River Basin. The membership of the Group is set out in **Appendix C**.

2.4 Cross-Sectoral Coordination Workshop

To inform the preparation and development of this Plan, the OPW held a consultation workshop on the 13th June 2018. The workshop was attended by representatives from stakeholder organisations, including Local Authorities, Government Departments, Academia, and operators of critical infrastructure. The two key topics for the workshop were:

- impacts of Flooding and Flood Risk Management Measures on Sectoral and Local Authority Objectives, and,
- impacts of other Sectors on Flood and Flood Risk Management.

The findings of this workshop have informed the preparation of this Plan. The organisations invited to attend this Workshop are set out in **Appendix C**.

Other sectors and agencies in the preparation of their adaptation plans have held workshops and knowledge sharing events at which the OPW has participated. These include Agriculture Forestry and Seafood, Critical Infrastructure, Water Quality and Services, Biodiversity, Built and Archaeological Heritage and Health.

The OPW held a meeting with representatives from each of the Climate Action Regional Offices (CAROs) during the preparation of the Plan to discuss coordination issues between the flood risk management sector and the local authority adaptation strategies.

2.5 OPW's Core and Planning Team

The OPW internally established a Core and Planning Team that was responsible for overseeing, coordinating and advocating climate change adaptation planning. The team had a broad spectrum of relevant knowledge and technical expertise necessary for the development of this adaptation plan, with individual representatives from across a range of sections within the OPW, and set out in **Appendix C**.

2.6 Cross-Sectoral Coordination in Adaptation Planning

The cross-sectoral impacts of flooding and flood risk management for other sectors, and of other sectors on flooding and flood risk management are discussed in Section 6.3.

Through its lead role for flood risk management in Ireland, the OPW manages the flood risk from the primary source of flooding, the rivers and seas; and coordinates for Government the management by all sectors of their respective flood risk.

To support other sectors with their assessment and management of flood risk for their sectors, the OPW provides technical advice. That advice has supported the adaptation plans by other sectors under the National Adaptation Framework.

The adaptation plans across all sectors and the local adaptation strategies are in their first iteration for public consultation. The development of the adaptation plans across the 12 sectors and by the local authorities will assist in the engagement of the multi-lateral issues arising from climate change. The coordination in adaptation planning will evolve and develop over time when a more thorough analysis of the connectivity across sectors will be possible.



PART 3

Climate Impact Screening

KEY MESSAGES

- Ireland has suffered from some severe flood events over recent decades, including the winter of 2015-16 when many thousands of properties were flooded, cut-off or at risk from flooding.
- Human activities are estimated to have already caused approximately 1.0°C of global warming above pre-industrial levels, and global mean sea level has risen about 20 cm since the beginning of the 20th century, and is rising at approximately 3.5 cm per decade at present.
- The Intergovernmental Panel on Climate Change (IPCC) has reported that for a 1.5°C rise in temperature, the global mean sea level could rise by up to approximately 1m by 2100, and projections of more intense Atlantic storms could potentially increase surge events and wave heights.
- Met Éireann has predicted that in Ireland the autumns and winters may become wetter, with a possible increase in heavy precipitation events of approximately 20%.
- The Preliminary Flood Risk Assessment (PFRA) screened for flood risk under current conditions at a national level.
- The CFRAM Programme included detailed assessments of flooding and impacts for potential future climate change scenarios, as well as under current conditions.

Ireland's climate is changing and analysis of the potential impacts and consequences of future climate change is essential to planning for, as well as monitoring and reviewing the effectiveness of approved evidence based measures. Extensive research has previously been undertaken by the OPW to assess the level of flood risk in Ireland that forms a basis for understanding the potential future impacts of climate change and the preparation of this Plan, as outlined below.

3.1 Existing Flood Risk in Ireland

Ireland is affected by a range of types of flooding. The most significant types of flooding nationally in terms of both hazard and risk are rivers (fluvial) and coastal flooding. Groundwater flooding is a significant source of flood hazard in the west of the country, where prolonged flooding can occur from turloughs. Pluvial flooding, from intense rainfall, has also occurred and caused substantial damage in some areas in recent years. Minor flooding has also occurred from other sources.

The most recent National Risk Assessment, completed by the Office of Emergency Planning (OEP, 2017), considered a range of natural and man-made risks and their significance for Ireland, including flooding. This assessment identified flooding as the most significant risk facing Ireland today, with both likelihood and impact being given a rating of 4 out of 5 ('likely' and 'high impact'). Many other Member States of the EU have undertaken similar national risk assessments and flooding has consistently featured as a major risk, with 17 of the 18 risk assessments identifying flooding as a national risk. An EU summary of these assessments (COM, 2014) notes that half of the national assessments "*underline floods as a particularly high level risk hazard*".

3.1.1 Past Flood Events

In October 2006, the OPW launched the National Historic Flood Event Database, which is publicly available on the OPW flood portal; www.floodinfo.ie. The database now contains information from almost 15,000 flood event reports relating to almost 5,500 locations around the country, dating back as far as 1763 (a flood in Kilkenny from the River Nore), and provides access to supplementary information on the floods such as photographs and reports, where available.

Some of the most notable or damaging floods to have affected Ireland in the last 40 years are outlined in **Table 3.1**.

The recent floods of the Winter of 2015/16 would in many ways have been the most exceptional on record; both in scale and extent. The flood event was on a national scale, with many rivers across the country reaching record levels, including the River Shannon that significantly exceeded the highest levels previously recorded over a period of more than 100 years.

Water levels recorded at many hydrometric monitoring stations in the winter of 2015/16 were among the three highest recorded at those stations over their period of record, which for many gauges extend for more than 50 years (see **Figure 3-1**).

Assessments of flood hazard and risk can make use of information on past floods, such as extents and impacts, but the quality of such assessments is dependent on how well data on those flood events has been captured and recorded.

3.1.2 The PFRA

This Adaptation Plan is focused on one particular climate impact; namely flooding and the potential for increased flooding and flood risk as a result of climate change.

As outlined in Section 1.3.3, the PFRA was a national screening assessment to identify the areas of potentially significant flood risk. This assessment included the components of the Climate Impact Chain as set out in the Guidelines for Climate Change Adaptation (DCCAE, 2018) covering a number of considerations as outline below.

Climate Stimuli: Rainfall, Sea Level, Storm Surge, Wave Environment

Impacts: Flooding

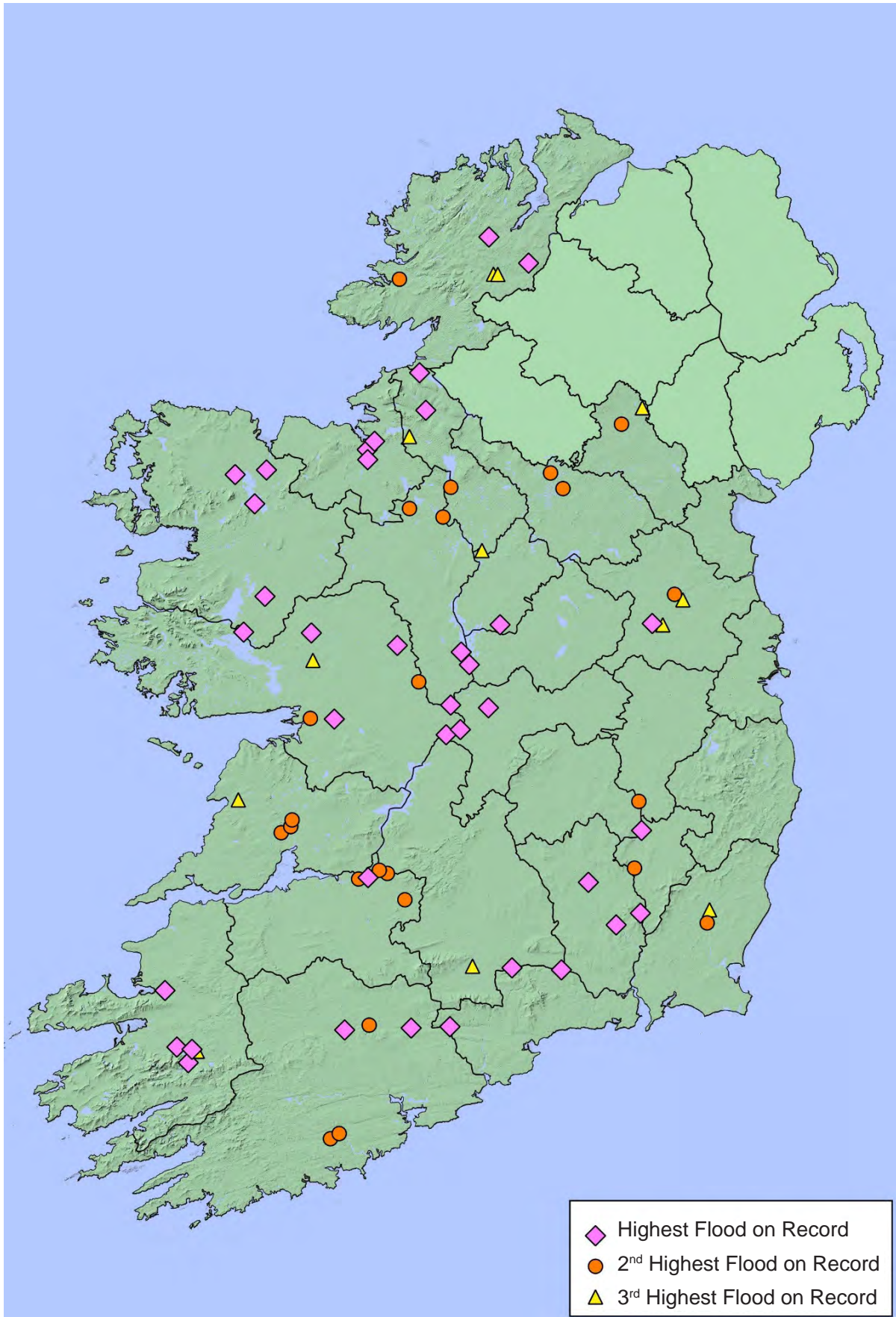
- **Sensitivity:** 'Vulnerability' classification assigned to different types of property, feature or asset that could be impacted by flooding (e.g., homes, businesses, transport or energy infrastructure, heritage and cultural properties and sites, etc.) that indicates the potential degree of impact in the event of a flood.
- **Exposure:** The location of each property, feature or asset that could be impacted by flooding was mapped against the projected flood extents.
- **Adaptive Capacity:** For the national screening assessment, flood protection measures were not taken into account as it had been decided that areas benefitting from flood defences should be defined as areas of potentially significant flood risk.

Sectoral Consequences: Increased flood risk to people, properties, infrastructure with associated sectoral impacts.

Table 3-1: Notable or Significant Past Floods in Ireland since 1980

Date	Location	Type	Impacts
Nov 1980	South West	Fluvial	Flooding in Mallow, Fermoy and Kanturk (178 properties flooded)
Aug 1986	National	Fluvial	'Hurricane Charlie' - Extreme events in South Dublin (over 450 properties flooded) and Wicklow (e.g., Dodder & Dargle Rivers)
Jan 1995	Kilkenny	Fluvial	70 properties flooded
Jan 1996	Clonmel	Fluvial	250 properties flooded
Winter 1995	West	Groundwater	Extensive flooding over prolonged periods. Affected South Galway in particular
Nov 2000	National	Fluvial	Extensive flooding in South East (over 500 properties flooded in Carrick-on-Suir, Carlow, Clonmel and Tullow) and around Dublin (over 250 properties flooded)
Feb 2002	East Coast	Coastal	€60m damage & at least 1250 properties flooded in Dublin - Flooding up to first floor level in Ringsend - 30 properties flooded in Mornington
Nov 2002	River Tolka	Fluvial	Repeat event after Nov 2000 along the Tolka, but more severe
Nov 2009	National	Fluvial, Groundwater	More than 1,600 properties flooded nationally, with over 700 in Cork City - Approx. €250m insured losses - Many rivers hit record levels - Extensive groundwater flooding in West
Oct 2011	Dublin area	Fluvial, Pluvial	2 fatalities - Nearly 1,700 properties flooded - Appx. €130m insured damages
June 2012	South-West	Fluvial, Pluvial	Intense storm events - Over 170 properties flooded in Clonakilty
Jan 2014	National Coast-line	Coastal	Storm surge and high tides - More than 300 properties flooded, c160 in Drogheda
Feb 2014	South & West Coast	Coastal (Incl. Wave Action)	Flooding of properties in Limerick and Cork City Centre - Extensive coastal storm damage around South and West Coasts
Winter 2015/16	National	Fluvial, Groundwater	Approximately 1000 properties flooded and thousands more at risk or cut-off nationally, with record flood levels in many parts of the country. Extensive and prolonged groundwater flooding in the West.
August 2017	Inishowen Peninsula, Donegal	Fluvial (Flash Flood)	Flash flood due to short period of very intense rain. Extensive land/mud slides.
November 2017	Mountmellick	Fluvial (Flash Flood)	Flash flood due to short period of very intense rain.

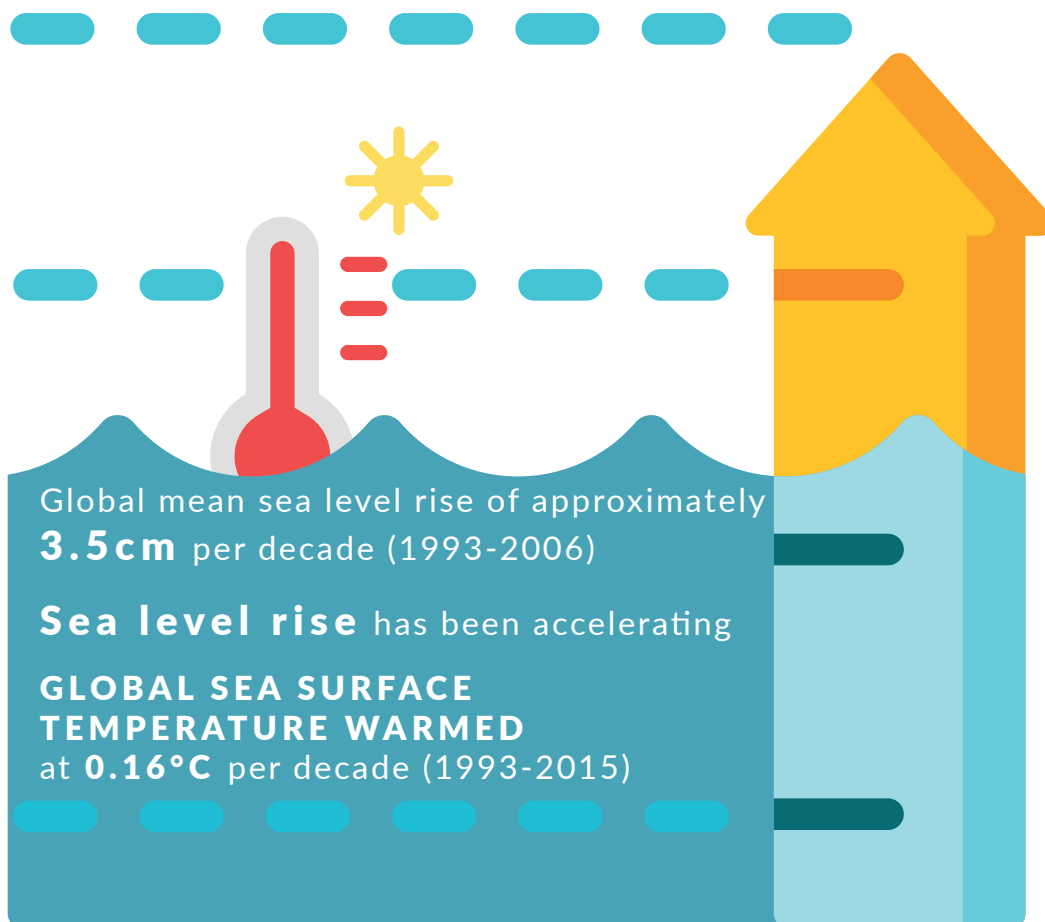
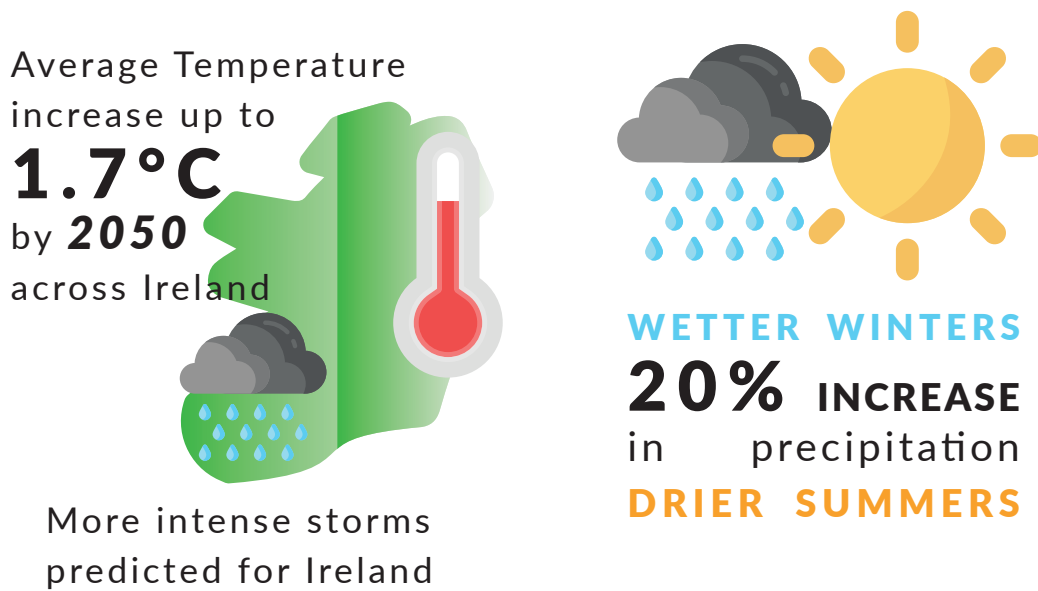
Figure 3-1: Ranking of the Flood Event of the Winter of 2015/16 at Hydrometric Gauges



3.2 Projected changes in Climate and Flood Risk

Some of the climate change projections based on the findings of international and national research, set out in **Appendix D** and their possible influences on flood risk are presented in **Figure 3-2** below and further detail is given overleaf.

Figure 3-2: Current and future flood change risks



- The IPCC has stated that human activities are estimated to have already caused approximately 1.0°C of global warming above pre-industrial levels, with a likely range of 0.8°C to 1.2°C (IPCC, 2018). National projections for mid-century indicate an increase in average temperatures across all seasons between 0.9-1.7°C, with the largest increase in the east of the country.
- Global sea surface temperature warmed over the period 1993-2015 at a rate of 0.16°C per decade.
- The Paris Agreement (COP 21) of 12 December 2015 (UNFCCC, 2015) committed 195 countries to the mitigation goal of limiting the increase in global temperature to well below 2°C above pre-industrial levels. However, global emissions would need to peak soon and then decline rapidly for the Paris Agreement goals to be feasible. Even in this scenario, uncertainty about the sensitivity of the climate to Greenhouse gases means there would remain at least a small chance of 4°C or more of warming by 2100.
- Met Éireann has predicted that in Ireland the autumns and winters may become wetter, with a possible increase in heavy precipitation events of approximately 20%, and that summers may become drier. However, the change in precipitation patterns in Ireland, particularly at a local level and for shorter (sub-seasonal) durations, remains uncertain and is the subject of ongoing research.
- Since the early 1990s, a rise in mean sea level of approximately 3.5 cm per decade has been observed. Various studies have shown that during the 20th century, sea level rise has been accelerating. Global mean sea level in 2016 was the highest yearly average since measurements started in the late 19th century; it was about 20 cm higher than at the beginning of the 20th century.
- The IPCC has reported that for a 1.5°C rise in temperature, the global mean sea level is likely to rise 0.26 to 0.77m by 2100, and by 0.1m more with a temperature rise of 2°C, although the model ensembles predict rises of up to 0.99m and 1.17m (at the 90%ile) respectively.
- The number of very intense storms is projected to increase over the North Atlantic Region, and that the winter track of these storms may extend further south and over Ireland more often.
- An increase in the number of intense storms over the North Atlantic could have a direct impact on storm surges, although there is still uncertainty around impact on storm surges.
- Coastal erosion can give rise to flood risk, and erosion rates will be increased in the future as sea levels rise.
- In the southwest of Ireland, significant wave heights have increased by 0.8 m per decade, although there is still uncertainty around the impacts of climate change on wave heights in the longer term.
- Climate change is not only reflected in terms of the average temperature, precipitation, etc., but also in the frequency and intensity of extreme weather conditions. The consensus among different modelling approaches is that extreme rainfall events are likely to increase in frequency in autumn and winter, although uncertainty remains in these projections and further research is required.
- The EU overall welfare loss under a high emissions scenario (Representative Concentration Pathway, or 'RCP' 8.5) is estimated to be around 1.9% of GDP (€240bn) per year at the end of the century, but it should be noted that the list of considered impacts is incomplete because key climate impacts cannot be quantified.

Please refer to **Appendix D** for further detail and references of the items outlined above.

Climate projections are based on computer models attempting to simulate an extremely complex and dynamic natural system, and different models make different projections. Further, a key factor in making climate projections are the future emissions of greenhouse gases (GHGs), and there is great uncertainty as to how emissions of GHGs will increase or decrease in the future.

The uncertainties are greater for some climatic parameters, such as projections of changes in rainfall patterns, and in particular short time-step (e.g., daily) rainfall. For other parameters, the uncertainty is less, such as the rise in mean sea level where a rise is already being observed and is accelerating.

Notwithstanding these uncertainties, there is a clear risk that flooding, arising from the projected change in climatic parameters, may become more frequent and severe in the future. It is prudent therefore to plan for the potential for change and with flexible strategies, adaptation decisions can and need to be considered today, and uncertainty should not be used to justify inaction.

Detailed assessments of the potential impacts of climate change on flood risk are undertaken through the CFRAM Programme for the priority areas as identified through the PFRA screening assessment, and are detailed in Section 5 of the Plan (Priority Impact Assessment).

3.3 Potential Impact of Climate Change on Flood Risk Management

3.3.1 Prevention

The Guidelines for the Planning System and Flood Risk Management (DECLG, & OPW, 2009), provide a clear, transparent framework for forward planning and development management with due consideration of flood risk.

The guidance on zoning for appropriate land use is based on existing risk, but with a recommendation that a precautionary approach be taken to potential future risk including the potential impacts of climate change, stating that *“A Precautionary approach should be applied, where necessary, to reflect uncertainties in flooding datasets ... and the ability to predict the future climate ... ”*, and that *“Development should be designed with careful consideration to possible future changes in flood risk, including the effects of climate change ... so that future occupants are not subject to unacceptable risks”*.

The potential impacts of climate change are provided for within the Guidelines, and the robust implementation of the Guidelines should reduce the potential impacts of climate change on properties developed in the future, although the application of the precautionary approach may have implications for the development potential in some areas.

3.3.2 Protection

Flood Relief Schemes

The evidence in the Flood Risk Management Plans highlights that 95% of properties at risk within the communities assessed to be at significant risk from flooding can be protected by flood relief schemes; completed, at design and construction or planned. **Figure 3-3** shows flooding of the River Shannon at Athlone, at which flood relief works are currently ongoing.

The design and construction of flood relief schemes in the current ten year investment programme will include assessment and investment for adaptation to the potential impacts of climate change needs as part of the scheme identification, development, design and implementation (see **Appendix B**). It will also require the carbon footprint to be estimated for each option and considered as part of the option assessment for future flood relief scheme.

The inclusion of climate change adaptation measures in the design and construction of flood relief schemes is relatively new. Therefore the standard of protection offered by some flood relief schemes completed to date may reduce over time as sea levels continue to rise, and if river flood flows and levels rise as a result of the impacts of climate change.

Figure 3-3: Flooding of the River Shannon at Athlone



Drainage Districts and Arterial Drainage Schemes

Increased land saturation and water-logging of lands benefitting from drainage schemes may occur during winter months if winter rainfall increases. There is, however, currently no evidence of the degree of increase in saturation or water-logging that may arise in potential futures, and the detrimental impact this could have on agricultural production is uncertain. The reduced water table from the drier hotter summers may mitigate some of the potential for increased saturation or water logging from the increased winter rainfall.

The most intense period of land use and agricultural production in the areas benefitting from the Drainage Schemes are however the summer months. As future summers are expected to be warmer and drier, it could be expected that climate change will be beneficial in terms of reducing saturation or water-logging of agricultural lands through both the reduction in rainfall and increased evaporation due to higher temperatures. However, management activities outside of the summer months can influence the annual productivity of the land, and increased rainfall, and resulting water-logging and flooding, during these periods could impact on agricultural production.

Future climate changes may have other, less direct, impacts on the drainage schemes, such as increased vegetation growth in-channel and along the banks affecting performance and maintenance demands.

Arterial Drainage Schemes based on embankments are primarily in estuarine areas to protect against tidal inundation and to a lesser extent fluvial flooding of rural areas and agricultural lands. These embankments would be faced with increasing pressure and, without adaptation, reducing standards of protection and increased likelihood of failure with rising sea levels and potentially increasing fluvial flood flows and levels.

Urban Storm Water Drainage and Water-Bearing Infrastructure

Urban storm-water drainage systems have been implemented over time to a range of design standards to permit rainfall over the urbanised area to drain away and prevent flooding. As a warmer column of air holds more water vapour, it can be expected that with rising temperatures and more energy in the atmosphere that more frequent, intense rainfall events may occur, such as those witnessed in Dublin in October 2011 and over the Inishowen Peninsula in August 2017. Such a change would result in an increase in the frequency and severity of pluvial flooding, effectively reducing the design-standard of the existing urban storm-water drainage systems.

Artificial water-bearing infrastructure that is fed from natural inputs, such as direct rainfall or flows into reservoirs from streams and rivers are likely to see changes in their inflows arising from the projected wetter winters and drier summers. Higher temperatures would also result in greater evaporation from open reservoirs. These changes to the inflows and losses may impact on the required operational management of the systems if they are to continue to meet their functional objective, with reductions in performance possible where the options for change are limited or exceeded by the degree of change in inflow and loss.

Water-bearing infrastructure that is fed artificially, e.g., pressurised, closed water supply networks and wastewater treatment networks and plants, may not be affected, other than by changes in input or demand arising as a secondary impact from other factors (e.g., greater water demand due to higher temperatures). Joint systems, such as combined sewer systems, may well however be affected in the same manner as naturally-fed systems and infrastructure.

3.3.3 Preparedness

The CFRAM Programme identified that 95% of properties at risk within the communities assessed to be at significant risk from flooding can be protected by flood relief schemes. For the balance of these properties, and for other properties at risk outside of these communities, other structural and non-structural measures are in place. The OPW's Minor Flood Mitigation Works and Coastal Protection Scheme remains to be a valuable measure to address localised flood risk.

Flood risk preparedness, response and resilience are, as non-structural measures, inherently adaptable, although some areas of this activity may be affected by the impacts of climate change, due to increased frequency and/or severity of flood events. The potential impacts that may be expected with regards to non-structural measures might include an increase in demand for resources to plan for, respond to and recover from more frequent and potentially more severe flood events. This might include increased number of trained personnel, availability of equipment such as sand bags or demountable barriers to provide protection to greater areas.

The establishment of the Flood Forecasting Service is an important resource to further improve emergency response and community resilience.

3.3.4 Data Collection and Flood Risk Assessment

Hydrometric Monitoring

Research on climate change impact and long term weather effects require knowledge of long-term hydrological trends that is gained only through the analysis of long-term data sets. The nationwide network of hydrometric gauging stations ensures appropriate hydrometric data are available for use in assessing the current pressing issues of climate change. The reference hydrometric network is essential for use in detecting, monitoring, and assessment of climate change, such as the increased frequency of flood events of a given magnitude.

The increased frequency and severity of extreme weather events could impact the breadth and depth of hydrometric data need, with demands for finer spatial and temporal resolution or increased quality, quantity and coverage of data growing with the complexity of climate change analysis. With the climate changing, continuous consistent and reliable real-time hydrometric data will be required by flood forecasting schemes and dam, reservoir and canal operations.

Climate change could also impact hydrometric stations directly whereby the stations themselves could become drowned out more frequently, and accessing the gauging sites during high flows could become more difficult.

Climate change may require a change in focus for the gauging authorities towards drought or increased flooding (e.g. the Foras Forbartha, now local authority / EPA network was set up primarily due to the droughts in the mid-70's), which in turn may have implications with regards to how the network is designed and operated.

Flood Risk Assessments

This measure relates to analysis (i.e., modelling and mapping the potential flood risk under future climate scenarios) rather than any physical intervention, and so is inherently adaptable. The assessment and planning needs to take account of the potential increases in flood risk, including the uncertainty associated with the potential change. Further analysis beyond that taken under the CFRAM Programme may be required as ongoing and future research revises the projections of climate change, which could place a demand on resources to review and update the hazard and risk assessments.



PART 4

Prioritisation of Impacts

KEY MESSAGES

- The range of potential impacts of climate change on flood risk management will vary in terms of the increased risk and/or cost of adapting to or reducing such risks and the timing of adaptation actions necessary to cater for the potential impacts.
- The area of flood risk management activity that require priority consideration are:
 - Flood Protection (Flood Relief Schemes)
 - Flood Risk Prevention (Impacts on Planning and Development Management)

This section assesses the degree of potential impact of climate change on flood risk and the different areas of flood risk management activity, and hence the priority that the associated adaptation actions should receive.

The purpose of this prioritisation is to:

- identify the scale and magnitude of potential impact on flood risk and across the various areas of flood risk management,
- inform a review of current planning and investment for climate change adaptation, and
- help identify and timing for delivery of current and further adaptation measures and approaches to manage the impact from climate change.

4.1 Impacts on Flood Risk

Detailed assessments of the potential impacts of climate change on flood risk were undertaken through the CFRAM Programme for the priority areas as identified through the PFRA screening assessment, and are detailed in Section 5 of the Plan (Priority Impact Assessment).

In terms of prioritising particular locations for adaptation action based on the future scale of risk, it should be noted that the change in risk will not be uniform over time across all locations, but will generally reflect the projected scale of increases in risk for the different communities. The ongoing monitoring of climate impacts through the hydrometric observations in conjunction with projections of future impacts will inform when the need arises to commence planning for action.

4.2 Prioritisation Process

There is a wide range of impacts that climate change might, or is expected to, have on flooding and flood risk management. The magnitude or degree of these impacts will vary substantially, where some may be very significant in terms of the increased risk and/or cost of adapting to or reducing such risks while others might be less significant requiring a modest response. The timing of adaptation actions necessary to cater for the potential impacts will also vary in terms of urgency.

4.2.1 Assessment of Urgency

While the impacts of climate change will evolve over the coming decades, the efficiency and/or effectiveness of the mitigation of some potential impacts will require early action. The urgency with respect to each impact reflects the timing as to when adaptation actions would be most effective and efficient to address the impact. For example, some actions will be evolving over time in parallel with the gradual increase in risk (e.g., increasing resources for 'Preparedness' measures), while others are required in anticipation of the projected changes (e.g., provisions for potential increases in flooding at the time of design and construction of structural protection works).

4.2.2 Assessment of Impact Significance

An indicative assessment of the impacts by area of flood risk management activity has been undertaken to identify those impacts that are more significant and might require a more substantial response. The assessment has been based on the perceived likelihood of occurrence of the impact and degree of the estimated impact, where the degree of impact is based on the impact not being mitigated at the appropriate time. The impact significance is then determined from a combination of these factors.

To guide the assessment of impact significance, indicative descriptions of the degree of impact have been used for the different categories of impact, including the number of properties potentially affected, the spatial extent of the impact, and the potential cost of the impact, as shown in **Table 4-1**. The impact score has generally been determined based on the most relevant or appropriate type of impact (e.g., number of properties or spatial extent), rather than all three, and so it should not be assumed that, for example, the indicative cost for an impact category applies to all impacts assigned to that category.

Table 4-1: Indicative Descriptions of Impact Categories

Impact				
Degree of Impact	No. Properties Affected	Spatial Extent of Impact	Indicative Cost of Impact	Score
Low	0	N/A	<€1m	1
Low to Medium	<1,000	Local	€1m - €10m	2
Medium	1,000 to 10,000	Catchment	€10m - €100m	3
Medium to High	10,000 - 100,000	Regional	€100m - €1bn	4
High	>100,000	National	>€1bn	5

Within the process applied in evaluating impact significance, it is worth noting that:

- No account is being taken of the approved flood risk management measures both underway and planned. In this way the impact of climate change across flood risk and flood risk management can be considered consistently and equally. This approach to prioritisation therefore highlights those changes, impacts and vulnerabilities that require specific and urgent action.
- The assessment is indicative only, as reliable, quantitative data are not available for most impacts, and where they are available the data will generally not be available with national coverage. The data and indicators would also be variable for different impacts and areas of activity, and so any inter-comparison would be somewhat subjective.

The likelihood scores have been assigned on a range of 1 to 5 according to whether the likelihood is 'Very Unlikely', 'Unlikely', 'Possible', 'Likely' or 'Nearly Certain', taking into account the uncertainty of the relevant climate parameter (e.g., mean sea level rise or increases in short-duration rainfall) and of the resultant impact.

4.2.3 Impacts on Flood Risk Management

Prevention

Flood risk prevention through sustainable planning can reduce future risk for built development that would be expected to have a useful life of many decades, with billions of Euro of development being built annually. It is therefore necessary and urgent to consider potential change in flood risk due to climate change at the spatial planning and development design stage, as adaptation after construction of the developments would be significantly more costly with the range of options considerably constrained.

Protection

Flood Relief Schemes

As flood relief schemes are based on structural works, it is more efficient to plan for adaptation at the design stage, rather than to attempt to retrofit adaptation once the scheme has been built. The strategic assessments and hydrometric observations of the onset of change will inform the timing of future adaptation interventions for the schemes.

For existing flood relief schemes, the standard of protection of the scheme may reduce over time in parallel with the onset of climate change. It is necessary to assess what adaptation might be required, but the implementation of future adaptation interventions will be required over the coming decades with the timing informed by the strategic assessments and hydrometric analysis.

The timing for implementing the adaption measures, identified in this Sectoral Plan will further inform the Government's investment in flood risk management over the coming decades and will feed into the €1bn investment already committed by Government.

Drainage Districts and Arterial Drainage Schemes

The impacts of climate change on the drainage districts and arterial drainage schemes will evolve over time, and there is some uncertainty as to the nature and scale of impact, related to the uncertainty over projected changes in precipitation. The impacts may be wide-spread but would primarily affect agricultural land and environmental habitats.

Urban Storm Water Drainage and Water-Bearing Infrastructure

In the same way as for the drainage schemes, the impacts of climate change for urban storm water drainage and other infrastructure will evolve over time, but is uncertain.

For the same reasons related to flood relief schemes, it is necessary and urgent to plan for adaptation at the design stage for such infrastructure, although the scale of expected impact, or benefit of adaptation, would be of a reduced scale relative to the flood relief schemes.

Preparedness

Flood risk preparedness, response and resilience are, as non-structural measures, inherently adaptable, and adaptation actions will be required over time in parallel with the onset of climate change impacts.

Data Collection and Flood Risk Assessment

Hydrometric Monitoring

The collection of hydrometric data informs research on climate projections and tracking of the onset of climate change impacts. This will need to be undertaken on an ongoing basis, although ensuring that the appropriate network of gauges is in place should be undertaken at an early stage.

Flood Risk Assessment

The assessment of the potential impacts of climate change for flood risk, including the preparation and review of flood maps, will need to be undertaken on an ongoing basis to ensure that the assessment of vulnerabilities and projections of impacts reflect the most up-to-date science and research to inform appropriate adaptation.

4.3 Conclusions

The outcomes of the assessment of urgency and impact significance are set out in **Table 4-2**. The prioritisation assessment has concluded, based on the likely significance of impact and the urgency of action, that the most substantial and/or urgent impacts by area of flood risk management activity that require more urgent consideration are:

Very High Priority:

- Flood Protection (Flood Relief Schemes)
- Flood Risk Prevention (Impacts on Planning and Development Management)

High Priority:

- Flood risk Preparedness, Response and Resilience (Forecasting and Warning)
- Urban Storm Water Management and Water-Bearing Infrastructure

The requirement for potential future flood relief schemes for areas of currently low risk that may become prone to significant risk in the future is an impact of very high significance, but does not require urgent action now, with the need for such interventions to be considered through ongoing observation and review of projections and risk.

Table 4-2: Prioritisation of Impacts

Potential Impacts of / Response to Climate Change on Flood Risk Management	Comment	Urgency	Likelihood		Impact		Significance		
			Desc	Score	Desc	Score	Desc	Score	
Flood Risk Prevention									
1	Impacts of increasing flood risk on new developments / development potential	Increased flood risk to lands that may not have previously flooded could impact on new developments and the suitability of lands for development. Failure to address urgently could lead to large numbers of new properties / developments being exposed to increased risk in the future.	Urgent	Nearly Certain (Coastal)	5	High	5	Very High	25
Flood Protection									
2	Adaptation measures required for old schemes in response to increased flows and water levels	Assessment required of adaptation actions that may be necessary for completed flood relief schemes to avoid reductions in the standard of protection and increasing damages – Requirements for the implementation of the identified actions will evolve over time.	Urgent	Nearly Certain (Coastal)	5	Medium to High	4	Very High	20
3	Planning for adaptation in the design and implementation of new flood relief schemes	Adaptation planning for new flood relief schemes is required at design and implementation stage to avoid significantly increased costs of retrofitting adaptation after completion and/or increased flood damages due to falling standards of protection.	Urgent	Nearly Certain (Coastal)	5	High	5	Very High	25
4	Provision for climate change in Local (Minor Works) Schemes	Adaptation should be incorporated into the design and implementation of the Minor Works Schemes that are implemented by the local authorities, where this is possible and proportionate in terms of analysis required and the nature of the work.	Ongoing	Likely	4	Medium	3	Medium	12
5	Assessment of potential of Green Infrastructure as a flood risk management approach	Green Infrastructure can offer multiple sectoral benefits, as well as potential mitigation co-benefits, but needs assessment in terms of effectiveness in reducing flood flows and as an adaptation approach.	Ongoing	Possible	3	Low to Medium	2	Low	6
6	Requirement for potential future flood relief schemes in areas currently at low risk	Flood relief schemes may be required in areas that are currently at low risk to protect communities against increased flood flows or levels.	Evolving	Nearly Certain (Coastal)	5	High	5	Very High	25

Potential Impacts of / Response to Climate Change on Flood Risk Management		Comment	Urgency	Likelihood		Impact		Significance	
				Desc	Score	Desc	Score	Desc	Score
7	Economic viability of adaptation may require amendments to Cost Benefit Analyses practice	Taking account of the potential increased damages due to climate change in the economic appraisal of schemes will reflect the damages avoided by providing for climate change in scheme design and will support early adaptation.	Ongoing	N e a r l y Certain (Coastal)	5	Medium	3	High	15
8	Reduced efficiency of drainage schemes in winter	Likely wetter winters may reduce the performance of the drainage schemes.	Evolving	Likely	4	Low to Medium	2	Me-dium	8
9	Impact of warmer / drier summers	Warmer, drier summers may lead to increased vegetation and siltation, which in turn could increase maintenance requirements.	Evolving	Possible	3	Low to Medium	2	Low	6
10	Increased risk of over-topping / failure of scheme embankment	Assessment required of the risk of failure or over-topping of arterial drainage scheme embankment with increasing flood levels. Impacts are regional and rural, however some properties may be impacted.	Ongoing	N e a r l y Certain	5	Low to Medium	2	Me-dium	10
11	Increased flooding or risk due to increased rainfall intensities or inflows to water storage / processing infrastructure	Increases in rainfall intensities will increase the frequency of flooding related to urban storm water drainage, and may require adaptation to the operating procedures for other water-bearing infrastructure.	Evolving	N e a r l y Certain	5	Medium	3	High	15
12	Increased rainfall intensities may increase urban (pluvial) flooding	The implementation of Sustainable Drainage Systems (SUDS) may offset the impacts of climate change.	Ongoing	N e a r l y Certain	5	Medium	3	High	15
Flood Risk Preparedness, Response and Resilience									
13	More frequent flooding of properties and communities, requiring greater resilience to minimise impacts	Resilience can reduce the damage caused by floods, and improve recovery after an event.	Evolving	N e a r l y Certain	5	Low to Medium	2	Me-dium	10

Potential Impacts of / Response to Climate Change on Flood Risk Management		Comment	Urgency	Likelihood Desc Score		Impact Desc Score		Significance Desc Score	
14	Need for awareness of flood risk to facilitate building resilience	Collation and publication of data on past floods provides evidence of flood risk. Continuing updating of the flood event database; www.floodinfo.ie .	Ongoing	N e a r l y Certain	5	Low	1	Low	5
15	More frequent flood warnings required	With increasing flood risk, the value of a flood warning service increases, along with the frequency of the need to forecast events and issue warnings.	Ongoing	N e a r l y Certain	5	Medium	3	High	15
16	More frequent flood emergency response events	The activation of emergency response is likely to become more frequent and resource-intensive under future scenarios	Evolving	N e a r l y Certain	5	Low to Medium	2	Me- dium	10
Data Collection and Flood Risk Assessment									
17	Need for more data to monitor climate change and inform research and assessments	More observation data on water levels and flows is required to monitor the evolution and effects of climate change. No direct impacts to flood risk, but very important for research and assessment and for monitoring change.	Ongoing	N e a r l y Certain	5	Low to Medium	2	Me- dium	10
18	To address the uncertainty of climate change, ongoing research, with assessments of impacts on flood risk, will be required	Ongoing research is required in relation to climate projections, including research specific to impacts on flooding and flood risk. This will inform ongoing assessments of potential future vulnerabilities and impacts.	Ongoing	N e a r l y Certain	5	Low to Medium	2	Me- dium	10

PART 5

Priority Impact Assessment

KEY MESSAGES

- Through the CFRAM Programme, the OPW has assessed the risk in detail for 300 communities across Ireland that are home to more than 3 million people and have produced flood maps for these areas – see www.floodinfo.ie.
- The CFRAM Programme has identified measures that, in combination with the measures already completed or that were previously at construction or under design, will provide protection to 95% of the properties at risk within the 300 areas.
- The CFRAM assessments indicate potentially very significant increases in the number of properties that could become at risk and in the degree of impacts under the future scenarios. The impact of climate change on both hazard and risk is however site specific and varies significantly from community to community.
- Flood relief schemes that are currently in construction or under design, or that are planned as set out in the FRMPs will protect many of the properties that would otherwise become prone to flooding in future scenarios, or the schemes have, or will be, designed taking account of climate change and the need for adaptation.
- Climate change will impact on different aspects of the national flood risk management programme to different degrees, with the highest priority impacts being on flood protection and on spatial planning and development management.
- Non-structural flood risk management measures (e.g., preparedness measures) tend to be more inherently adaptable to changes in flood frequency and severity.

This section outlines the potential impacts of climate change on flooding and flood risk as determined through assessments previously undertaken as part of the CFRAM Programme.

To inform effective and efficient adaptation in the flood risk management sector, it is necessary to understand how the potential changes in climatic parameters can affect the frequency and severity of flooding into the future, and how the resulting flood risk and potential damages could be affected. This understanding is also of great importance for other sectors, such as agriculture, transport, forestry, energy, etc., to understand how the potential changes in flood regime could impact each sector such that this can be taken into account in developing appropriate adaptation strategies.

5.1 Potential Future Scenarios

There is a wide range of projections of future changes in the climatic drivers of flooding due to a number of factors, including:

- emission scenario projections into the future,
- different models used to simulate how the emissions projections will impact the future climate, and,
- different parameter sets used in each of the models.

While there is a very high level of confidence that the mean sea level is rising and that the rate of rise has accelerated over recent decades, and that mean sea levels will continue to rise over the coming decades and probably centuries, it is not known at what rate this ongoing rise will occur over this period. There is also considerable uncertainty over the potential changes into the future in local, short-duration extreme rainfall patterns, which are most relevant to the fluvial and pluvial flooding.

Given this uncertainty, it is clearly not possible to state with confidence exactly what the future will look like in terms of the frequency or severity of flood events. To decide on selecting one single scenario, i.e., a specific degree of sea level rise and a defined increase in peak flood flows and rainfall intensities, and to design flood defences for this specific scenario could well give rise to 'maladaptation'. This is where excess funds are invested to cater for a worse future than actually occurs, or where works are undertaken that prove to be inadequate, due to a worse than expected future, and which cannot be amended to cater for the worse-than-foreseen future. It is not feasible to assess the potential impacts and implications of all of the future climate projections on flooding in Ireland.

For the purposes of the CFRAM Programme, the OPW adopted two indicative potential futures for flood risk assessment; the Mid-Range Future Scenario (MRFS) and the High-End Future Scenario (HEFS). These were selected to reflect, based on information available at the time, a future in the latter part of the century that would be:

- a. typical or near to the general average of the future climate projections (MRFS), and,
- b. a more extreme future based on the upper end of the range of projections of future climatic conditions and the impacts such changes would have on the drivers of flood risk (HEFS).

The changes in flood-related parameters under each scenario are set out in **Table 5-1**. The allowances set out in **Table 5-1** were not derived from a specific set of projections from the IPCC reports. They were, rather, based on a range of sources available at the time, including research outputs from down-scaling climate impact projections by Sweeney and Fealy (2006), the EPA Report on climate change impacts (2003), and the guidance at that time from the UK, the Flood and Coastal Defence Project Appraisal Guidance (FCDPAG3) (DEFRA, 2006).

It is important to reiterate, however, that the MRFS and HEFS are not intended to represent specific projections and model outcomes, but rather provide potential, or 'representative' futures; an approach based on the theory of representative futures (Whetton et al., 2012). This approach is based on the use of indicative or possible futures developed from an overview of the ensemble of future projections that are used to assess the vulnerability of a community to potential future changes that in turn informs the adaptive approach within the design process, rather than assuming and designing to one specific projection of change. As such, they are not specifically time-bound, but could be taken, where a time-line is required, to represent possible futures for 2100.

The MRFS and HEFS provide potential futures that permit flood hazard and risk assessments to be undertaken to identify possible impacts of climate change on flooding, which, in turn, enables an assessment of the vulnerability of different communities and areas around the country to such possible changes. This will inform how flood risk in these communities should be managed now and into the future.

It can be seen that the allowances for the MRFS and HEFS for mean sea level rise would be close to the average and the top end of the projections from the IPCC 5th Report respectively. The scenarios also lie mid-range and at the upper end of the projections of sea level rise in the IPCC 1.5°C report (IPCC, 2018). Research on the application of the scenario-neutral approach for flood risk management (Broderick et al., 2017) indicates that allowances for change in peak flood flows also cover the significant majority of projected changes (based on the Coupled Model Inter-comparison Project 5, or 'CMIP5' ensemble) for the catchments tested and across the four Representative Concentration Pathways (RCP) (emissions scenarios).

Table 5-1: Allowances in Flood Parameters for the Mid-Range and High-End Future Scenarios

Parameter	MRFS	HEFS
Extreme Rainfall Depths	+ 20%	+ 30%
Peak Flood Flows	+ 20%	+ 30%
Mean Sea Level Rise	+ 500 mm	+ 1000 mm
Land Movement	- 0.5 mm / year ¹	- 0.5 mm / year ¹
Urbanisation	<i>No General Allowance – Review on Case-by-Case Basis</i>	<i>No General Allowance – Review on Case-by-Case Basis</i>
Forestation	- 1/6 Tp ²	- 1/3 Tp ² + 10% SPR ³

Note 1: Applicable to the southern part of the country only (Dublin – Galway and south of this)

Note 2: Reduction in the time to peak (Tp) to allow for potential accelerated runoff that may arise as a result of drainage of afforested land

Note 3: Add 10% to the Standard Percentage Runoff (SPR) rate: This allows for temporary increased runoff rates that may arise following felling of forestry.

The comparability of the two future scenarios adopted for the CFRAM Programme against current international projections gives confidence that they are acceptable as plausible futures for use in assessing potential requirements for adaptation.

Ongoing and future research may provide revised projections of potential impacts, which in turn may necessitate revised hazard and risk assessments. In this instance, use will be made in so far as possible of work done to date based on the MRFS and HEFS, e.g., through interpolation, although consideration may need to be given to undertaking assessments for more extreme change, i.e., for projections of changes beyond the HEFS.

5.2 Future Scenario Flood Hazard and Flood Risk Assessments

The CFRAM Programme assessed flood hazard and flood risk, including the production of flood maps, for the MRFS and HEFS as well as for the current conditions for 300 communities that are home to over 3 million people, and for reaches in between these communities and down to the open sea. The Programme has hence generated a substantial quantity of data on the potential future increases in hazard and risk data nationally. The future scenario flood maps are available from the OPW flood portal: www.floodinfo.ie.

In order to carry out a risk assessment from these hazards it was necessary to identify the numbers and types of properties at risk for the scenarios, and the damages that would occur for specific events. This data is included in Appendix E of the Flood Risk Management Plans (FRMPs) for each of the AFAs. The FRMPs are also available from the OPW flood portal: www.floodinfo.ie.

An analysis of this data has been undertaken for the communities assessed under the CFRAM Programme (see footnote 1 below) to determine the potential impact the MRFS and HEFS would have relative to the Current Scenario.

The potential increase in flood extents and the increases in impacts for properties and infrastructure are demonstrated in Case Studies examining impact arising from fluvial flood risk and coastal flood risk in both the urban and rural areas.

It is clear from this national summary that, without the ongoing and future investment in flood protection works, the impact of the MRFS and HEFS on flooding and flood risk in terms of increased damage for a given event frequency would be very significant.

- For flood events that would occur relatively frequently (those with a 10%, or 1 in 10, chance of occurring or being exceeded in any given year), the number of properties that would potentially become at risk increase very significantly in percentage terms, with a commensurate rise in potential damages. It should be noted however that:
 - The number of properties currently at risk from these relatively frequent events is quite low, and so the increase in the absolute number of additional properties that would be at risk is less than for more severe / less frequent events, and,
 - the majority of these properties are to be protected against such events by flood relief schemes that are currently in construction or under design, or that are planned as set out in the FRMPs.
1. Data from some AFAs, such as those from the pilot CFRAM studies (e.g. Lee CFRAM and Fingal East Meath FRAM Studies) was not available in a comparable format and could not be aggregated into the main CFRAM data set for review. In a small number of other cases (approximately 5%) the AFA risk data is not disaggregated into Coastal and Fluvial flooding, and so engineering judgement was used to determine the appropriate split. As these issues only represent a small proportion of the overall data set, it is not expected that they would materially affect the analysis as a whole.

- For rare flood events (those with a 1%, or 1 in a 100, chance in any given year), the number of properties at risk increase significantly, but less so than for the more frequent floods. For example, the number of properties that could become at risk in the MRFS approximately doubles for fluvial (river) flooding and approximately quadruples for coastal flooding. However, climate change is taken into account in the design and implementation of the flood relief schemes currently in construction or under design, or that are planned as set out in the FRMPs, and so many of these additional properties will also be protected.
- For both scenarios and across the range of frequency, or severity, of flood event, the potential impacts of future increases in coastal flooding are greater than for fluvial flooding.

The assessments under the CFRAM Programme have identified that impact of climate change on both hazard and risk is site specific and varies significantly from community to community, with no clear national geographical trends.

The intensification of development within urban areas and the increasing value of properties and their contents can further increase potential future damages beyond those potentially arising from changes in flood frequency and/or severity due to climate change.

Case Study 1: Fluvial Flood Risk – Climate Impact Assessment for Ballinasloe, Co. Galway

A climate impact assessment for fluvial flood risk has been carried out for Ballinasloe. This is based on the Shannon CFRAM Study using the Present Day Scenario in comparison to the MRFS and HEFS. The following two figures present flood extent maps showing the Present Day Scenario and High End Future Scenario for the 1% Annual Exceedance Probability (AEP) event (commonly known as the 100-year event).

Both figures present flood extents for the 100-year event, and the second figure includes a 30% increase in peak flood flow under the climate change scenario.

Figure 5-1: Fluvial Flood Extents–Present Day Scenario (1% AEP Event)

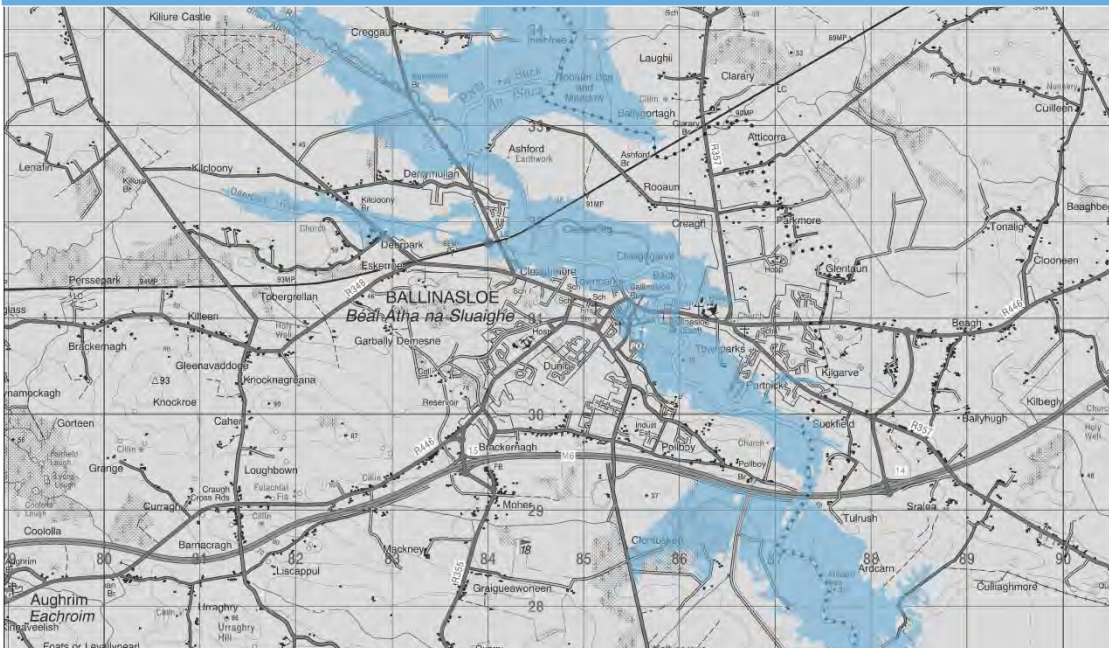
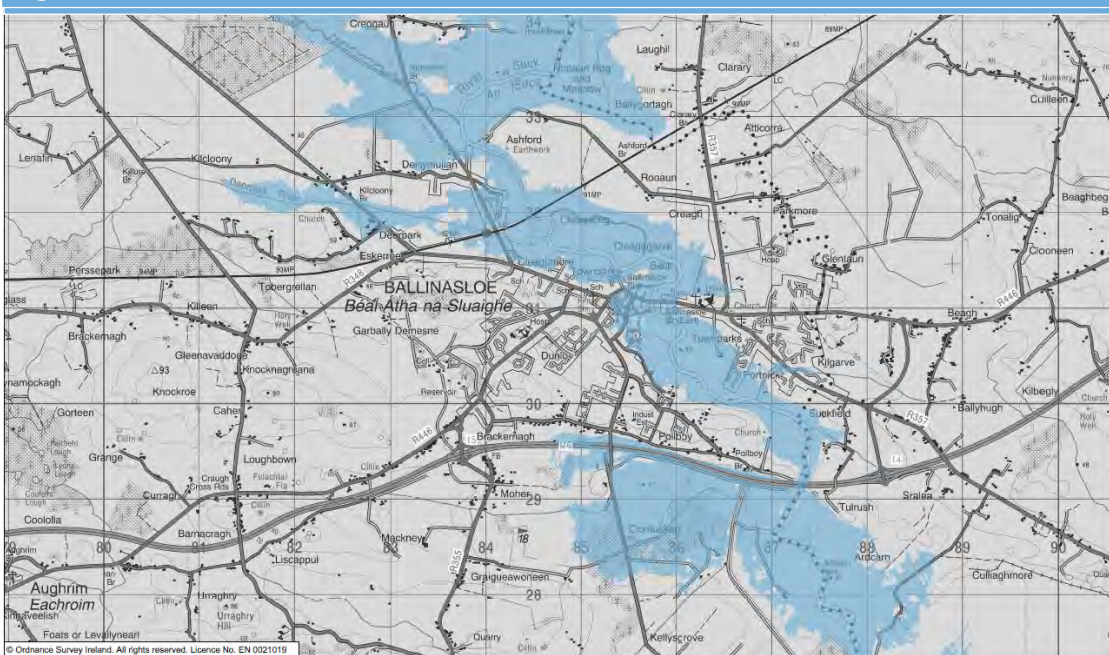


Figure 5-2: Fluvial Flood Extents– High End Future Scenario (1% AEP Event)



The tables below provides details on the number and type of risk receptors, as well as the estimated event damage cost for the Present Day Scenario and High End Future Scenario.

This shows that there is an estimated 49 residential properties currently at risk from flooding during the 1% AEP event. Under climate change condition, which is estimated as a flow increase of 30% under the HEFS, the number of residential properties is predicted to increase to 65 in comparison to the current condition. The cost of flood damage at Ballinasloe is currently estimated at over €10 Million for the 1%AEP event and this is predicted to almost double under climate change condition.

Type of Risk	10% AEP	1% AEP	0.1% AEP
Event Damage (€)	425,527	10,244,554	22,417,232
No. Residential Properties at Risk	4	49	70
No. Business Properties at Risk	0	2	3
No. Utilities at Risk ¹	5	6	11
No. Major Transport Assets at Risk ²	0	0	1
No. Highly Vulnerable Properties at Risk ³	0	2	4
No. of Social Infrastructure Assets at Risk ⁴	2	2	2
No. Environmental Assets at Risk ⁵	0	0	0
No. Potential Pollution Sources at Risk ⁶	7	63	152

Type of Risk	10% AEP	1% AEP	0.1% AEP
Event Damage (€)	7,257,824	19,262,669	54,312,176
No. Residential Properties at Risk	43	65	87
No. Business Properties at Risk	1	3	3
No. Utilities at Risk ¹	6	8	11
No. Major Transport Assets at Risk ²	0	1	1
No. Highly Vulnerable Properties at Risk ³	1	4	4
No. of Social Infrastructure Assets at Risk ⁴	3	3	3
No. Environmental Assets at Risk ⁵	0	0	0
No. Potential Pollution Sources at Risk ⁶	53	127	277

Note 1,2,3,4,5 and 6 provide examples of Types of Risk under each category:

- 1) Power Stations, Water Treatment Plans, Waste Water Treatment Plans, Gas Assets and Telecommunication Exchanges
- 2) Motorway, National, Regional and Local Roads, Ports, Airports
- 3) Hospitals, Schools, Nursing / Residential Homes, Prisons, Camping / Caravan / Halting Sites
- 4) Schools, Libraries, Community Centres, Local and Central Government Offices (incl. Post Office), Emergency Services (Fire, Garda, Civil Defence, RNLI and Coast guard Stations), Health Centres, Churches, Parks and Public Gardens, Sports Facilities, Playgrounds, Local Cultural Heritage Sites
- 5) Natura 2000 sites (SACs, SPAs), Ramsar Sites, Annex IV (Habitats Directive) species of flora and fauna, and their key habitats, Natural Heritage Areas, Nature Reserves, Wildfowl Sanctuary, OSPAR, National Parks
- 6) Plants licensed under Directives 96/61/EC and 91/271/EC, septic tanks greater than 500 PE, significant slurry storage facilities, establishments defined under Directive 2012/18/EU

For further information on details and type of risk receptors, please refer to **Appendix E** of The Flood Risk Management Plan for Ballinasloe available at www.floodinfo.ie under Publications.

Case Study 2: Coastal Flood Risk – Climate Impact Assessment for Limerick City

A climate impact assessment for coastal flood risk has been carried out for Limerick City and Environs. This is based on the Shannon CFRAM Study using the Present Day Scenario in comparison to the MRFS and High End Future Scenario (HEFS). The following two figures present flood extent maps showing the Present Day Scenario and HEFS for the 0.5% Annual Exceedance Probability (AEP) event (also commonly known as 200-year event). Both figures present flood extents for the 200-year event, and the second figure includes 1m of sea level rise under the climate change scenario.

Figure 5-3: Coastal Flood Extents – Present Day Scenario (0.5% AEP Event)

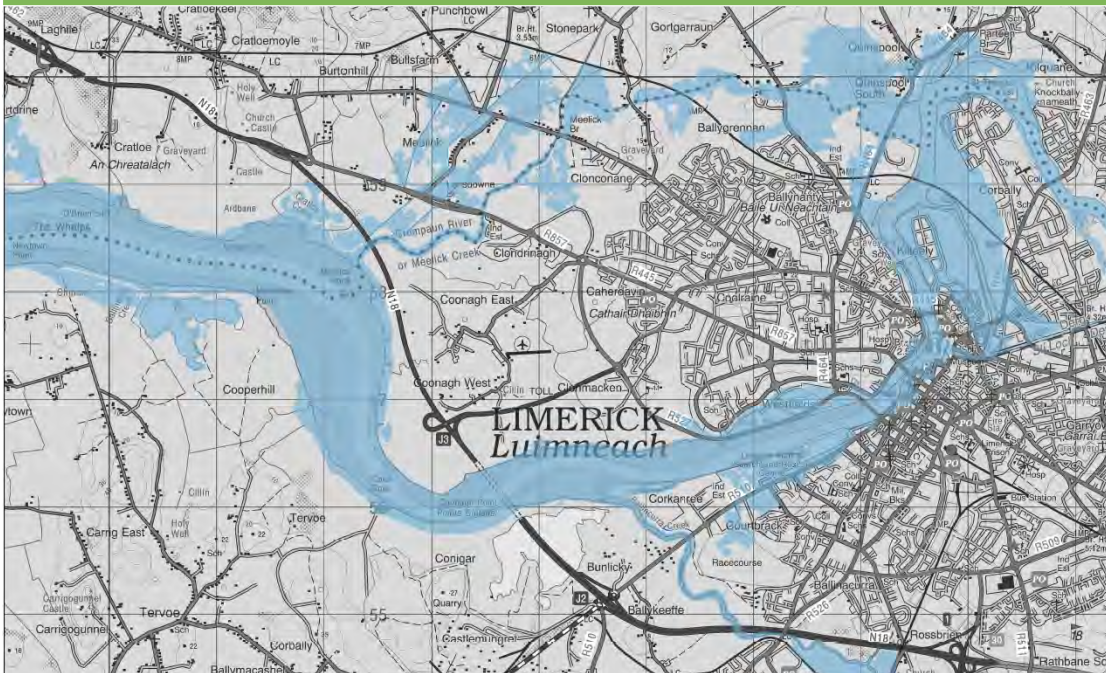
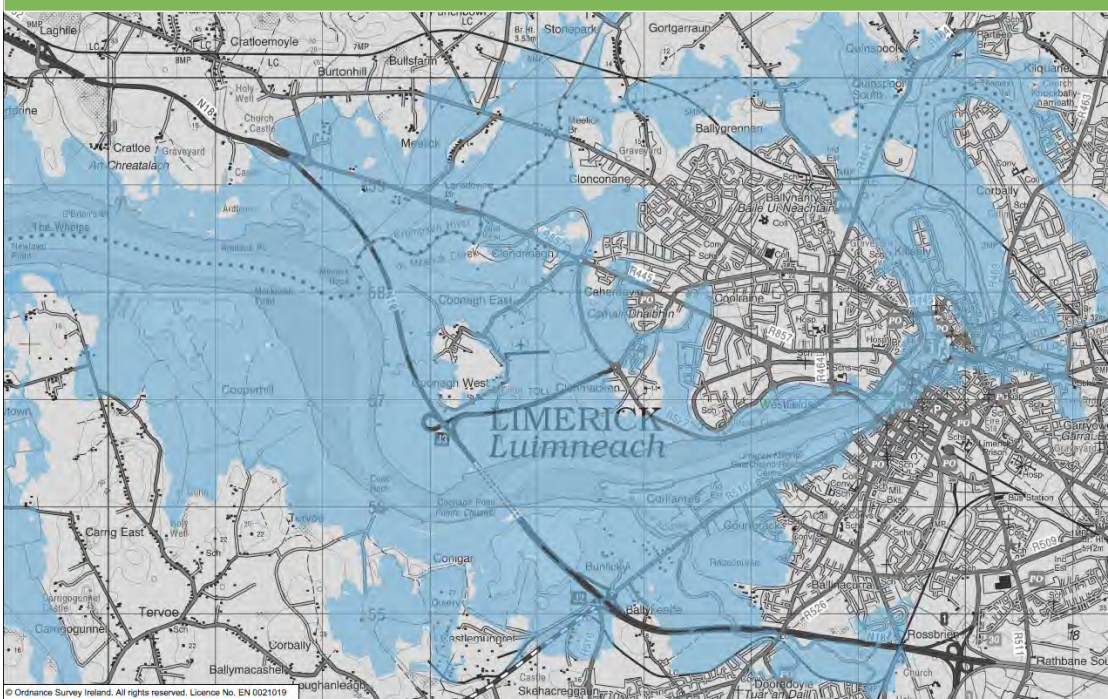


Figure 5-4: Coastal Flood Extents – High End Future Scenario (0.5% AEP Event)



The tables below present details on the number and type of risk receptors, as well as the estimated event damage cost for the Present Day Scenario and High End Future Scenario.

This shows that there is an estimated 1,122 residential properties and 248 business properties currently at risk from flooding during the 0.5% AEP event. Under climate change condition, which is estimated as sea level rise by 1m under the HEFS, the number of residential and business properties at risk is predicted to increase by more than double in comparison to the current condition. The cost of flood damage at Limerick City and Environs is currently estimated at over €83 Million for the 0.5%AEP event and this is predicted to rise to over €1 Billion under climate change condition. This corresponds to an increase of 12.5 times in comparison to the current condition.

Type of Risk	10% AEP	0.5% AEP	0.1% AEP
Event Damage (€)	3,776,223	83,149,253	497,504,513
No. Residential Properties at Risk	89	1,122	1,856
No. Business Properties at Risk	6	248	485
No. Utilities at Risk ¹	0	0	2
No. Major Transport Assets at Risk ²	27	49	85
No. Highly Vulnerable Properties at Risk ³	0	4	6
No. of Social Infrastructure Assets at Risk ⁴	2	6	14
No. Environmental Assets at Risk ⁵	4	4	6
No. Potential Pollution Sources at Risk ⁶	0	0	0

Type of Risk	10% AEP	0.5% AEP	0.1% AEP
Event Damage (€)	358,259,000	1,035,710,958	1,752,867,802
No. Residential Properties at Risk	1,757	2,636	5,047
No. Business Properties at Risk	239	510	766
No. Utilities at Risk ¹	0	2	2
No. Major Transport Assets at Risk ²	40	69	85
No. Highly Vulnerable Properties at Risk ³	1	6	6
No. of Social Infrastructure Assets at Risk ⁴	3	12	14
No. Environmental Assets at Risk ⁵	5	6	6
No. Potential Pollution Sources at Risk ⁶	1	1	4

Note 1,2,3,4,5 and 6 provide examples of Types of Risk under each category:

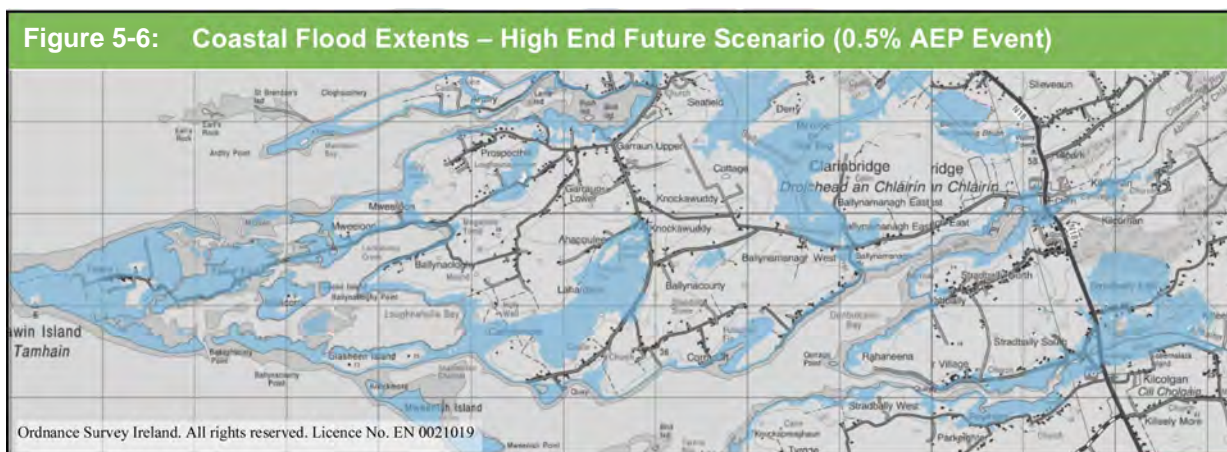
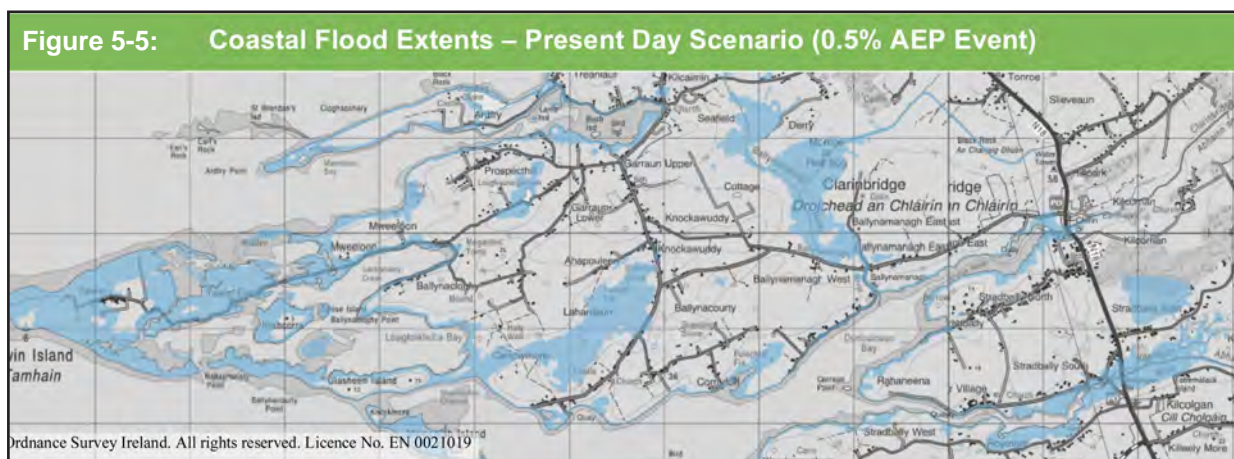
- 1) Power Stations, Water Treatment Plans, Waste Water Treatment Plans, Gas Assets and Telecommunication Exchanges
- 2) Motorway, National, Regional and Local Roads, Ports, Airports
- 3) Hospitals, Schools, Nursing / Residential Homes, Prisons, Camping / Caravan / Halting Sites
- 4) Schools, Libraries, Community Centres, Local and Central Government Offices (incl. Post Office), Emergency Services (Fire, Garda, Civil Defence, RNLI and Coast guard Stations), Health Centres, Churches, Parks and Public Gardens, Sports Facilities, Playgrounds, Local Cultural Heritage Sites.
- 5) Natura 2000 sites (SACs, SPAs), Ramsar Sites, Annex IV (Habitats Directive) species of flora and fauna, and their key habitats, Natural Heritage Areas, Nature Reserves, Wildfowl Sanctuary, OSPAR, National Parks
- 6) Plants licensed under Directives 96/61/EC and 91/271/EC, septic tanks greater than 500 PE, significant slurry storage facilities, establishments defined under Directive 2012/18/EU

For further information on details and type of risk receptors, please refer to **Appendix E** of the Flood Risk Management Plan for Limerick City & Environs available at www.floodinfo.ie under Publications.

Case Study 3 – Coastal Flood Risk – Climate Impact Assessment for Ardfry to Kilcolgan, County Galway

A climate impact assessment for coastal flood risk has been carried out for the study area from Ardfry to Kilcolgan. The assessment is based on the Irish Coastal Protection Strategy Study (ICPSS) flood extent maps using the Present Day Scenario in comparison to the High End Future Scenario (HEFS).

The ICPSS flood extent maps showing the Present Day Scenario and HEFS for the 0.5% AEP event (commonly known as the 200-year event), are presented in the following two figures. Both figures present flood extents for the 200 year event and the second figure includes 1m of sea level rise under the climate change condition.



There are a number of historical flood events, from both fluvial and coastal sources, recorded within the study area, including coastal flood events in January 2014 and January 2018 which represent the highest tidal water levels recorded on nearby OPW gauges. The January 2014 event caused considerable damage on Tawin Island affecting approximately 1.2km of existing coastal defences. The January 2018 event resulted in flooding to a number of properties in Clarinbridge with flooding also reported in Kilcolgan, although no properties were reported to have been impacted.

The table below presents details of the number and type of risk receptors for the Present Day Scenario and HEFS. The table shows that there is an estimated 21 residential properties and 7 business properties currently at risk of coastal flooding during the 0.5% AEP event.

Under the HEFS, more than 4 times the number of residential (96 no.) and three times the number of business properties (21 no.) are predicted to be at risk in comparison to the current condition.

There are a number of environmental assets located within the study area including the Galway Bay Complex Special Area of Conservation (SAC), proposed Natural Heritage Area (pNHA) and OSPAR Marine Protected Area (MPA), and the inner Galway Bay Special Protection Area (SPA) and Ramsar Site which may be negatively impacted under the HEFS. For example, coastal habitats in the intertidal zone will be at risk from rising sea levels and may be permanently under water in the future resulting in many coastal habitats being lost or irreversibly altered.

In addition to the increased number of properties and assets at risk in the future climate change scenario, rising sea levels will likely increase the risk of properties being isolated or “cut off” during extreme coastal storm events.

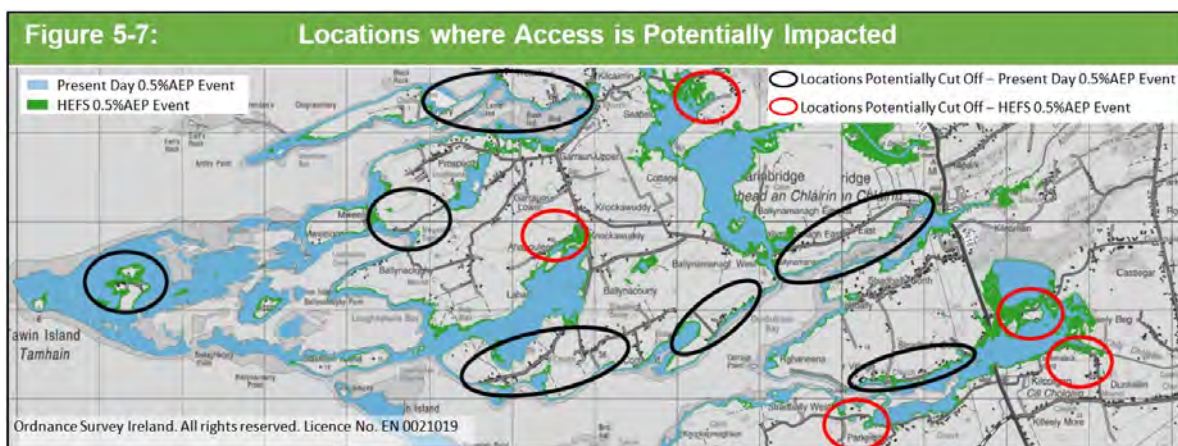
Table 5-6: Present Day Scenario		
Type of Risk	0.5% AEP	0.1% AEP
No. Residential Properties at Risk	21	30
No. Business Properties at Risk	7	10
No. Utilities at Risk ¹	0	0
No. Major Transport Assets at Risk ²	21	21
No. Highly Vulnerable Properties at Risk ³	0	0
No. of Social Infrastructure Assets at Risk ⁴	41	43
No. Environmental Assets at Risk ⁵	5	5
No. Potential Pollution Sources at Risk ⁶	0	0

Table 5-7: High End Future Scenario		
Type of Risk	0.5% AEP	0.1% AEP
No. Residential Properties at Risk	96	123
No. Business Properties at Risk	21	29
No. Utilities at Risk ¹	0	0
No. Major Transport Assets at Risk ²	26	26
No. Highly Vulnerable Properties at Risk ³	0	0
No. of Social Infrastructure Assets at Risk ⁴	56	59
No. Environmental Assets at Risk ⁵	5	5
No. Potential Pollution Sources at Risk ⁶	0	0

Note 1,2,3,4,5 and 6 provide examples of Types of Risk under each category:

- 1) Power Stations, Water Treatment Plans, Waste Water Treatment Plans, Gas Assets and Telecommunication Exchanges
- 2) Motorway, National, Regional and Local Roads, Ports, Airports
- 3) Hospitals, Schools, Nursing / Residential Homes, Prisons
- 4) Libraries, Community Centres, Local and Central Government Offices (incl. Post Office), Emergency Services (Fire, Garda, Civil Defence, RNLI and Coast Guard Stations), Health Centres, Churches, Parks and Public Gardens, Sports Facilities, Playgrounds, Local Cultural Heritage Sites
- 5) Natura 2000 sites (SACs, SPAs), Ramsar Sites, Annex IV (Habitats Directive) species of flora and fauna, and their key habitats, Natural Heritage Areas, Nature Reserves, Wildfowl Sanctuary, OSPAR, National Parks
- 6) Plants licensed under Directives 96/61/EC and 91/271/EC, septic tanks greater than 500 PE, establishments defined under Directive 2012/18/EU

The figure below illustrates the locations where access may be impacted during Present Day and HEFS 0.5% AEP events. Sea level rise will also result in access to properties and communities being impacted more often as extreme water levels, such as those predicted for the Present Day Scenario 0.5% AEP flood event, will occur more regularly in the future due to climate change.



While Flood Risk Management Plans have now been prepared under the CFRAM Programme for those communities considered most at risk, there may be other coastal communities (outside of the existing coastal AFAs), such as those between Ardfry and Kilcolgan, which are vulnerable to the impacts of climate change and in particular sea level rise.

The following are a number of possible actions, which

could be implemented to assist in the further quantification and mitigation of the risk of damage or loss due to coastal flooding in the area:

- Capture of more detailed and more frequent baseline survey information to assist with the assessment of flood risk, e.g. more detailed coastal topographical data.
- Updating of extreme coastal water level estimates to incorporate the latest observed tide gauge and storm event data.
- Development of new, or enhanced capability for existing, coastal flood early warning systems.
- Restriction of future development in areas that are highly susceptible to the impacts of climate change, e.g. in areas likely to be cut off due to rising sea levels.

The potential impacts of climate change can also be considered in terms of changing frequency for a given magnitude or severity of event, i.e., what will be the frequency of an event that has a likelihood of occurring in any given year under current conditions of 1%, or 1 in a 100, for example.

Table 5-8 shows the approximate expected future frequency of extreme flood levels for recent coastal floods in Dublin, Cork and Limerick under both the MRFS (500mm rise in mean sea levels) and the HEFS (1000mm of mean sea level rise).

Table 5-8: Potential Future Frequency of Recent Coastal Flood Events under the Current Scenario, the MRFS and the HEFS

Event	Indicative Frequency of Event Occurrence (% chance of occurrence in any given year)		
	Current Scenario	MRFS	HEFS
Dublin - Feb 2002	1 - 2%	50%	Very Frequent
Limerick - Feb 2014	1 - 2%	5 - 10%	50%
Cork - Feb 2014	1 - 2%	50%	Very Frequent

Such increases in flood frequency would lead to very significant increases in damages without adaptation. However, flood relief schemes have been built or are planned for these cities and many other communities at risk from coastal flooding.

5.3 Conclusions on Potential Future Flood Hazards and Risks

There is a clear indication that sea levels are rising, that the rate of rise is currently accelerating and that, notwithstanding the uncertainties associated with climate change projections, flooding is expected to become more frequent and severe in the future.

Through the CFRAM Programme flood maps for two future scenarios, the MRFS and HEFS, have been prepared for 300 communities around Ireland, and for other river reaches, and has determined that the increase in damages and numbers of properties that would be potentially affected by the MRFS and HEFS is very significant. Flood maps for the future scenarios, and community-level assessments of the impacts are available from the OPW flood portal: www.floodinfo.ie.

It should be noted however that flood relief schemes that are currently in construction or under design, or that are planned as set out in the FRMPs will protect many of the properties that would otherwise become prone to flooding in future scenarios, or the schemes have, or will be, designed taking account of climate change and the need for adaptation.

The increases in flood risk in other areas where the risk is currently low, will need to be monitored and kept under review on an ongoing basis, such as through the cyclical flood risk assessments required under the EU 'Floods' Directive (see **Appendix B.4**). Future flood risk management measures, such as flood relief schemes, may be necessary in these other communities (see **Appendix B.2**).



PART 6

Sectoral Adaptation Plan for Flood Risk Management

KEY MESSAGES

- The overall, long-term goal adopted by the OPW on climate adaptation for flooding and flood risk management is:
Promoting sustainable communities and supporting our environment through the effective management of the potential impacts of climate change on flooding and flood risk.
- To deliver on this goal, the OPW has identified the following adaptation objectives:
 - **Objective 1:** Enhancing our knowledge and understanding of the potential impacts of climate change for flooding and flood risk management through research and assessment
 - **Objective 2:** Adapting flood risk management practice to effectively manage the potential impact of climate change on future flood risk
 - **Objective 3:** Aligning adaptation to the impact of climate change on flood risk and flood risk management across sectors and wider Government policy
- A number of actions have been identified under each adaptation objective across the areas of activity in flood risk prevention, protection and preparedness and resilience, as well as in further research and capacity building.
- Flooding is a cross-sectoral issue that needs to be considered by all sectors and local authorities in considering future development and adaptation to future climatic changes.
- Other sectors can, through their actions impact positively or detrimentally on flooding, flood risk and flood risk management.
- Close cooperation between many sectors is critical towards ensuring a coherent and whole of government approach to climate resilience in relation to flooding and flood risk management.

The actions required to adapt flood risk management practice to effectively and efficiently manage flood risk into the future are developed within the scope of an overall, long-term goal and a set of objectives. The goal and objectives presented here are commensurate with the five-year term of this plan but also outline a long-term strategic vision. A monitoring and review process will allow for adjustments over time based on improvements in understanding, advances in science and experience of implementation.

The goal and objectives are based on:

- an understanding of the potential impact climate change may have on flood risk and flood risk management,
- prioritisation of climate change impacts,
- consultation with key stakeholders and consideration of other sectoral plans, and,
- capacity within the economy to deliver flood risk management infrastructural and other projects

6.1 Goal for Adaptation in Flood Risk Management

The OPW recognises:

- The strong body of evidence that climate change is occurring and likely to continue to occur for the next century and beyond, and the impacts such change may have in terms of flood hazards, and hence flood risks;
- That there is a considerable degree of spatial, temporal and quantitative uncertainty in relation to the projected impacts of climate change, but that action is required now to understand and prepare for the potential impacts of climate change;
- That effective adaptation requires an integrated approach among all relevant parties;
- That Government has adopted the twenty-nine Flood Risk Management Plans, and allocated €1bn investment to 2028 that includes adaptation measures in flood relief schemes, to address potential impact from climate change in the future.

Goal for Flood Risk Management

Promoting sustainable communities and supporting our environment through the effective management of the potential impacts of climate change on flooding and flood risk.

In this context, the OPW will lead to ensure that the possible impacts of climate change, and the associated uncertainty, shall continue to be embedded and considered at all stages of the development and implementation of flood risk management programmes and plans.

6.2 Adaptation Objectives

To deliver upon the overall, long-term goal for adaptation in flood risk management, actions are required towards meeting a number of Adaptation Objectives, as described below.

Objective 1: Enhancing our knowledge and understanding of the potential impacts of climate change for flooding and flood risk management through research and assessment

Having as robust a knowledge and understanding as possible of the full range of potential impacts of climate change for flooding, including the potential increases in flood frequency and severity, and in

the consequential impacts that could arise, will increase the capacity of the flood risk management sector to adapt successfully to future changes and to avoid maladaptation.

Actions to promote further research into potential future changes on the drivers of flooding, and assessment of changes in flood hazard and risk that could arise, will help provide this knowledge and understanding.

Effective adaptation to the potential impacts of climate change on flooding and flood risk management will require adequate capacity within the OPW and other public bodies with responsibility for flood risk management. This will require capacity building actions in terms of knowledge and expertise and embedding adaptation into policies, strategies and work practices. Equally, other sectors, stakeholders and the public who are or may be impacted by the potential future increased risks from flooding need to have the understanding of these potential risks, and knowledge of what can or should be done to help manage this risk. This can be developed through effective communication actions.

This Objective is aligned to the objectives in the OPW Statement of Strategy 2017-2020 to:

- Spearhead the national delivery of strategic flood risk assessment and management
- Enhance public understanding of flood risk and its management

Objective 2: Adapting flood risk management practice to effectively manage the potential impact of climate change on future flood risk

Climate change is very likely to impact on how flood risk is managed and the resources required to achieve effective flood risk management. Actions are therefore required to adapt flood risk management practice to help ensure that the management of flood risks remains effective into the future.

This Objective is aligned to the objective in the OPW Statement of Strategy 2017-2020 to:

- Protect communities from river and coastal flood events

Objective 3: Aligning adaptation to the impact of climate change on flood risk and flood risk management across sectors and wider Government policy

Effective flood risk management requires a 'whole-of-Government' approach and coordinated action between different sectors. Under the oversight of the Interdepartmental Flood Policy Coordination Group, a range of stakeholders have roles in delivering elements of the overall national flood risk management strategy.

This Objective is aligned to the objectives in the OPW Statement of Strategy 2017-2020 to:

- Coordinate an integrated, 'whole-of-Government' approach to flood risk management
- Support sustainable planning and development

6.3 Cross-Sectoral Adaptation for Flood Risk

Flooding is a cross-sectoral issue that can affect all aspects of life, and that can also be impacted, beneficially or detrimentally, by human actions under other sectors or at a local level. As such,

flooding is a cross-sectoral issue that needs to be considered by all sectors and local authorities in considering future development and adaptation to future climatic changes.

Flood risk management activities are aimed at reducing the exposure to floods or the impacts floods can have, and hence will generally have a positive impact on other sectors. Physical interventions, such as structural flood protection, can however impact negatively on certain sectors, such as the environment and cultural heritage, which needs to be considered and the impacts avoided, eliminated, reduced or mitigated in so far as possible.

Other sectors can, through their actions, impact on flooding, flood risk and flood risk management. These impacts can be:

- positive, by reducing runoff, attenuating floods or reducing impacts and damages such as through land management and farming practice and the application of sustainable urban drainage systems (SUDS);
- negative, by increasing runoff, restricting flow paths or by creating new potential risks or escalating vulnerability to damage, such as through new development or infrastructure located in flood-prone areas, or,
- positive or negative, by impacting on the processes of flood risk management through physical interventions, legislative / regulatory requirements, etc.

The range of potential impacts of flooding on other sectors, and of other sectors on flooding and flood risk management, are set out in **Appendix F**.

It is important to note that flood risk management should not be considered only after development decisions are made. It is preferable, and is generally less expensive, to avoid or prevent new flood risks than it is to mitigate and protect after the creation of a risk.

Close cooperation between many sectors is critical towards ensuring a coherent and whole of government approach to climate resilience. It is important that the actions proposed in all of the sectoral adaptation plans and strategies are aligned to avoid conflict and realise possible synergies. The OPW has and will continue to cooperate with relevant sectors in the implementation of flood risk management policy, programmes and projects to ensure effective and sustainable flood risk management for both the current and possible future climate change impacts.

The OPW has published the outputs from the CFRAM Programme on www.floodinfo.ie. The contents of this website include flood maps for both current and climate change scenarios (HEFS and MRFS). This website is a useful resource for both the public and sectors to assess the possible impact of both current and future flood risk. The OPW has issued these datasets in GIS format to Local Authorities and Government bodies.

6.4 Adaptation Actions for Flood Risk Management Activities

The adaptation actions required to meet the overall, long-term goal and adaptation objectives, to address and manage the potential impacts of climate change on flooding and flood risk management are set out in **Table 6-1**. The basis and reasoning for these actions is set out in **Appendix E**.

Table 6-1: Adaptation Objectives and Actions for the Flood Risk Management Sector

Ref.	OBJECTIVE / ACTION	RESPONSIBLE	WHEN
<i>OBJECTIVE 1: Enhancing our knowledge and understanding of the potential impacts of climate change for flooding and flood risk management through research and assessment</i>			
1.A	Engage with findings and recommendations arising from climate change research initiatives such as the Global Climate Observation System National Committee reports (expected in the next two years) and where possible, align hydrometric monitoring objectives and resources with climate change objectives.	OPW, EPA , Local Authorities	2021 and Ongoing
1.B	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.	OPW	2024 and Ongoing
1.C	Review the flood risk, including potential impacts of climate change, for areas designated as being at potentially significant flood risk.	OPW	2020 and Ongoing
1.D	Through reviews of the Preliminary Flood Risk Assessment, informed by the most up-to-date research and projections of climate change, assess the potential risk of flooding from urban storm-water drainages systems and from water-bearing infrastructure.	Local Authorities, Waterways Ireland, ESB and Irish Water	2024 and Ongoing
1.E	The OPW will ensure that its six-yearly review of the Flood Risk Management Plans will be informed by the most up-to-date research and projections of climate change on flooding and flood risk, and will include other sector led adaptation measures being implemented under the National Adaptation Framework.	OPW, Local Authorities , Waterways Ireland, ESB and Irish Water	2021 and Ongoing
1.F	Improve, through research, the understanding of the potential impacts of climate change on the climatic parameters that can influence flooding and flood risk management.	EPA, Met Éireann, Irish Water, GSI and OPW	Ongoing
1.G	Publication of the PFRA, as reviewed and updated, and of the most up-to-date flood maps for current and potential future scenarios.	OPW	2019 and Ongoing
1.H	The OPW will continue to strengthen its adaptive capacity and further embed adaptation within work processes and decision-making.	OPW	Ongoing

Ref.	OBJECTIVE / ACTION	RESPONSIBLE	WHEN
1.I	The OPW will continue to support Local Authorities, including through their network of Climate Action Regional Offices, and other Sectors to help further build awareness and capacity in relation to the impacts of climate change on flood risk and possible adaptation opportunities led by other sectors.	OPW, CARO's	Ongoing
OBJECTIVE 2: Adapting flood risk management practice to effectively manage the potential impact of climate change on future flood risk			
2.A	Assessment of appropriate adaptation measures for those existing flood relief schemes, where climate change may in time impact the current standard of protection.	OPW	2027
2.B	The Brief for the detailed development of flood relief schemes to include a requirement for a Scheme Adaptation Plan that will set out how climate change has been taken into account during the design and construction, and what adaptation measures might be needed and when into the future.	OPW	2019 and Ongoing
2.C	Proposals submitted under the Minor Works Programme should take account of the potential impacts of climate change to ensure, where possible, that any measures proposed are adaptable to possible future changes.	Local Authorities	Ongoing
2.D	The inclusion of potential increases in flood damages as part of the economic cost-benefit analysis for future flood relief schemes will be reviewed.	OPW, DPER	2021
2.E	Progress a review of the current and future effectiveness of the protection provided by existing Arterial Drainage Scheme embankments to urban developments.	OPW	Ongoing
2.F	Maintain and update on an ongoing basis the National Flood Event Database (www.floodinfo.ie).	OPW, Local Authorities	Ongoing
OBJECTIVE 3: Aligning adaptation to the impact of climate change on flood risk and flood risk management across sectors and wider Government policy			
3.A	Ensure that potential future flood information is obtained and/or generated through a Flood Risk Assessment (FRA) that is then used to inform suitable adaptation requirements within the planning and development management processes in line with the Guidelines on the Planning System and Flood Risk Management (DHPLG & OPW, 2009).	DHPLG, OPW, Planning Authorities & Developers	Ongoing

Ref.	OBJECTIVE / ACTION	RESPONSIBLE	WHEN
3.B	The OPW, in coordination with other relevant stakeholders, will continue to enhance its knowledge and capacity with regards to Natural Water Retention Measures (NWRMs) and will assess the potential for NWRMs as part of the development of the future flood relief schemes.	OPW & Other Stakeholders in Catchment Management	Ongoing
3.C	The planning and design of future assets should take into account, and be adaptable to, the potential future impacts of climate change.	Local Authorities, Waterways Ireland, ESB and Irish Water	Ongoing
3.D	The requirements for urban storm water drainage systems for new development should take into account the potential future impacts of climate change, including consideration of the use of sustainable drainage systems.	DHPLG, Local Authorities, Irish Water	Ongoing
3.E	Progress the establishment of the national flood forecasting and flood warning service	Met Éireann, OPW, DHPLG, Local Authorities	Ongoing
3.F	Progress research on how community resilience may be advanced within the overall field of emergency management and further develop this aspect as part of the overall review of the Framework of Major Emergency Management.	DHPLG, D/Defence, Authorities DRCD, Local	Ongoing



PART 7

Implementation, Review and Evaluation

KEY MESSAGES

- To ensure progress and continual improvement in adaptation, the implementation of this Plan will be monitored and reviewed through current structures. This will be informed by indicators to enable critical assessment and to measure progress.
- An annual review of progress will be undertaken to inform the Annual Sectoral Adaptation transition Statement for Flood Risk Management.

This Plan is to be implemented in parallel to the delivery of the twenty nine FRMPs, approved by Government and announced on 3rd May 2018.

The current structures to manage Ireland's flood risk management will be responsible for implementing, reviewing and evaluating this Plan. These structures will ensure that all stakeholders in flood risk and flood risk management are:

- kept updated of progress,
- co-operating and working to ensure that synergies and cross-benefits between plans are fully realised, and,
- helping to ensure this Plan can be updated in a timely and informed manner.

7.1 Implementation

The actions set out in this Plan have identified the responsible agencies and timeline for completion. Some of the actions identified are not planned for implementation during this Plan, but it is important to identify those measures that at this time need to be implemented in the longer term. These actions will be kept under review including as the evidence grows.

The actions set out are subject to the availability of resources to each relevant organisation within their future budgetary provisions.

7.2 Review and Evaluation

The actions set out in this Plan will be reviewed by the:

- Interdepartmental Flood Policy Coordination Group, that monitor and routinely report to Government on the progress with the implementation of all flood risk management policies and measures across Government,
- National EU 'Floods' Directive Coordination Group, and,
- The OPW.

The review will be informed by the OPW based on regular management and governance processes and a review against progress made on each action to inform the Annual Sectoral Adaptation Transition Statement.

Tracking and measuring progress towards the adaptation objectives of the Plan will provide:

- information about the efficacy of the actions taken;
- a way to share information and lessons learned with others; and
- ensure transparency to stakeholders.

The review and evaluation will need to be informed by indicators to enable critical assessment and to measure progress. The National Adaptation Framework notes that a priority for Ireland will be a project to develop a range of adaptation indicators to enable progress in preparing for the long-term effects of climate change to be monitored. A research project considering 'selecting and using indicators of climate resilience' has commenced under the EPA's climate research programme. Pending the completion of this project and/or the adoption of a national set of adaptation indicators, consideration has been given to the use of an interim set of indicators specific to flooding and flood risk management.

It is preferable to measure outcomes rather than outputs, but outcomes in relation to climate change adaptation will often take many years or decades to realise and may be difficult to quantify. Process-based indicators, that seek to monitor key stages that lead to choices about end points or outcomes can hence be used to ensure that defined actions are being implemented to promote a culture of, and capacity for, adaptation, and that adaptation is embedded in flood risk management processes.

The reporting of progress, as set out below, will track the implementation of each of the actions set out in the Plan, and so only a limited number of indicators are defined to measure progress in key areas where quantitative measurement is possible and meaningful. The adaptation indicators to be measured are:

- i. The length and percentage of coastline for which flood mapping has been prepared and published for two or more future scenarios (Actions 1.B and 1.G),
- ii. The length and percentage of river reach (with a catchment area greater than 5km²) for which flood mapping has been prepared and published for two or more future scenarios (Actions 1.B and 1.G),
- iii. The number and percentage of completed flood relief schemes for which appropriate adaptation options have been assessed and/or for which Scheme Adaptation Plans have been prepared (Actions 2.A and 2.B),
- iv. The number and percentage of flood relief schemes under construction for which appropriate adaptation options have been assessed and/or for which Scheme Adaptation Plans have been prepared (Action 2.B), and
- v. The number of properties (residential and commercial) benefitting from a flood relief scheme for which appropriate adaptation options have been assessed and/or for which Scheme Adaptation Plans have been prepared (Outcome Indicator).

7.3 Reporting of Progress

As well as reporting through the Interdepartmental Flood Policy Coordination Group, Ireland has certain reporting requirements to the UNFCCC and the EU with respect to climate change adaptation, and the flood risk management sector has and will continue to contribute to such reporting requirements.

The Minister of State with responsibility for the Office of Public Works and Flood Relief is required under the Climate Action and Low Carbon Development Act (2015) to present to each House of the Oireachtas an “Annual Sectoral Adaptation Transition Statement” (Section 14). The Statement is required to include:

- (i) A record of the adaptation policy measures adopted by the Minister of the Government presenting the annual sectoral adaptation statement concerned, and
- (ii) An assessment of effectiveness of these adaptation policy measures in the achievement of their purpose.

The Statement provides a mechanism for the annual review and evaluation of the Sectoral Adaptation Plan.

REFERENCES

BASE, 2013. Challenges to planning climate adaptation strategies in Europe

Bosello, F., Boteler, B., Campos, I., Capriolo, A., Hilden, M., Jeuken, A., and Penha-Lopes, G. 2013. Challenges to Planning Climate Adaptation Strategies in Europe. Edited by Andrew Reid. BASE Policy Brief, Issue no. 1. Available at: <https://base-adaptation.eu/> [Accessed 22/01/2019].

Broderick, C., Murphy, C., 2013. 'Catchment hydrology under future climate scenarios'. In: Marine Institute (eds.) *RESCALE: Review and Simulate Climate and Catchment Responses at Burrishoole, Technical Report*. Marine Research Sub Programme 2007-2013., Marine Institute: Ireland.

Broderick, C. Murphy, C., Wilby, R. and Matthews, T., 2019. *Using a scenario-neutral framework to avoid potential maladaptation to future flood risk, Water Resources Research.*

Church J.A., and White N., 2006. A 20th century acceleration in global sea-level rise *Geophysical Research Letters*, Vol. 33, L01602.

Church J.A., and White N., 2011. Sea-Level Rise from the Late 19th to the Early 21st Century. *Surv Geophys* Vol 32, pp585–602.

COM, 2014. Overview of Natural and Man-made Disaster Risk in the EU {SWD(2014) 134 final}

COM, 2013. An EU Strategy on adaptation to climate change. {SWD(2013) 216 final}.

COM, 2009. Adapting to Climate Change: Towards a European Framework for Action. {SWD(2009) 147 final}.

COM, 2007. Green paper from the commission to the council, the European parliament, the European Economic and Social Committee and the committee of the regions adapting to climate change in Europe options for EU action {SWD(2007) 354 final}.

DCCAE, 2017. National Mitigation Plan.

DCCAE, 2018. National Adaptation Framework.

DCCAE, 2018. Sectoral Planning Guidelines for Climate Change Adaptation.

DHPLG/OPW, 2009. Guidelines on the Planning System and Flood Risk Management

DECLG, 2012. National Climate Change Adaptation Framework.

DECLG, 2014: Ireland's Sixth National Communication under the United Nations Framework Convention on Climate Change.

DeConto, R. M. and Pollard, D., 2016. Contribution of Antarctica to Past and Future Sea-Level Rise. *Nature* 531 (7596), 591-597.

DEFRA, 2006. FCDPAG3, Flood and Coastal Defence Project Appraisal Guidance: Economic Appraisal.

Deser, C., A. Phillips, V. Bourdette, and H. Y. Teng, 2012: Uncertainty in climate change projections: The role of internal variability. *Climate Dynamics*, 38(3-4), 527–546.

Desmond, M., O'Brien, P., and McGovern, F. 2009. A Summary of the State of Knowledge on Climate Change in Ireland.

Desmond, M., O'Brien, P. and McGovern, F. 2017. A Summary of the State of Knowledge on Climate Change Impacts for Ireland. Report 11 (2010-2016), EPA Research Report (2014-CCRP-FS.19). Wexford: Environmental Protection Agency. Available at: www.epa.ie/pubs/reports/research/climate/research223.html [Accessed 10/01/2019]

Devoy, R.J.N., 2008. Coastal vulnerability and the implications of sea-level rise for Ireland. *Journal of Coastal Research*, 24(2),

De Winter, R.C., Sterl, A., de Vries J., Weber, S.L., and Ruessink, G., 2012. The effect of climate change on extreme waves in front of the Dutch coast. *Ocean Dynamics*, DOI 10.1007/s10236-012-0551-7.

Dunne, S., Hanafin, J., Lynch, P., McGrath, R., Nishimura, E., Nolan, P., Ratnam, J.V., Semmler, T., Sweeney, C. and Wang, S. 2008. Ireland in a Warmer World, Scientific Predictions of the Irish Climate in the Twenty-First Century. (R. McGrath and P. Lynch, eds.), Community Climate Change Consortium for Ireland.

Dunne, S., Hanafin, J., Lynch, P., McGrath, R., Nishimura, E., Nolan, P., Ratnam, J.V., Semmler, T., Sweeney, C. and Wang, S. 2009. Ireland in a Warmer World, Scientific Predictions of the Irish Climate in the Twenty-First Century. (R. McGrath and P. Lynch, eds.), Community Climate Change Consortium for Ireland.

Dwyer, N., and Devoy, R., 2012. 'Sea Level' In: Dwyer, N. ed. *The Status of Ireland's Climate*, 2012.

Dwyer, N., 2008. Climate Change – Implementation of the Global Climate Observing System in Ireland, Environmental Research Centre Report no. 8, Environmental Protection Agency, Johnstown Castle, Wexford.

EPA, 2003. Sweeney et al., ERTDI Report Series No. 15, Climate Change Scenarios and Impacts for Ireland. Environmental Protection Agency, Johnstown Castle, Wexford.

EPA, 2013a. Coastal Climate Adaptation in Ireland: Assessing current conditions and enhancing the capacity for climate resilience in local coastal management (2008-CCRP 3.6) Environmental Protection Agency, Johnstown Castle, Wexford.

EPA, 2013b. Coordination, Communication and Adaptation for Climate Change in Ireland: an Integrated Approach (COCOADAPT) (2007-CCRP-2.2.6a) Environmental Protection Agency, Johnstown Castle, Wexford.

EPA, 2018. The Development of an Irish Climate Information Platform (ICIP) – Phase 3 (2015–2017), EPA Research Report No. 258, Environmental Protection Agency, Johnstown Castle, Co. Wexford.

EPA, 2013c. Murphy et al, Hydrodetect (2010-CCRP-DS-2.2) Environmental Protection Agency, Johnstown Castle, Wexford.

European Communities, 2009. Implementation strategy for the water framework directive (2000/60/ec) technical report - 2009 - 040 guidance document no. 24 river basin management in a changing climate.

European Environment Agency, 2017. Climate change, impacts and vulnerability in Europe 2016. An indicator-based report. EEA Report No. 1/2017, 410 pp.

European Environment Agency, 2017. *Indicator Assessment - Mean Precipitation.* Denmark: European Environment Agency.

EU, 2007. Directive 2007/60/EC on the Assessment and Management of Flood Risk. Official Journal of the European Communities L288 of 6th November 2007, p.27.

Fisher, E.M. and R. Knutti, 2016. Observed heavy precipitation increase confirms theory and early models. *Nature Climate Change* 6: 986-991.

Flood, S and Sweeney, J. 2012. Quantifying impacts of potential sea-level rise scenarios on Irish coastal cities. In: Otto- Zimmermann, K (ed) *Resilient Cities 2011.* Springer, London.

Gallagher, S., Tiron, R., and Dias, F., 2013. 'Predicting the future wave climate of Ireland: 2031-2060.' In Gleeson, E., McGrath, R., and Treanor, M., 2013. *Ireland's Climate the Road Ahead.* Met Eireann.

Government of Ireland. Arterial Drainage Act, 1945 Dublin: Stationary Office.

Government of Ireland. Arterial Drainage Act, 1995 Dublin: Stationary Office.

Government of Ireland. S.I. 122 of 2010 European Communities (Assessment and Management of Flood Risks) Regulations 2010. Dublin: Stationary Office.

Government of Ireland. S.I. 495 of 2015 European Communities (Assessment and Management of Flood Risks) (Amendment) Regulations.

Hall, J., Murphy C., and Sweeney J, 2012. Robust Adaptation to Climate Change in the Water Sector in Ireland. EPA, CCRP report no.16.

HR Wallingford, 2006. Tsunamis - Assessing the Hazard for the UK and Irish Coasts.

IPCC, 2018: Summary for Policymakers. In: Global warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty [V. Masson-Delmotte, P. Zhai, H. O. Pörtner, D. Roberts, J. Skea, P. R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J. B. R. Matthews, Y. Chen, X. Zhou, M. I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, and T. Waterfield (eds.)]. World Meteorological Organization, Geneva, Switzerland, 32 pp.

IPCC, 2014: Summary for policymakers. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

IPCC, 2013: Summary for Policymakers. In: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

IPCC, 2012: Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation. Summary for Policymakers. Cambridge University Press, Cambridge.

J.C. Ciscar et al., 2018. *Climate impacts in Europe: Final report of the JRC PESETA III project*, EUR 29427 EN, Publications Office of the European Union, Luxembourg.

Jevrejeva, S., Moore, J.C., Grinsted, A., and Woodworth P.L., 2008. Recent global sea level acceleration started over 200 years ago? *Geophysical Research Letters*, Vol. 35, L08715.

Jevrejeva, S., Grinsted, A., and Moore, J.C., 2014. Upper limit for sea level projections by 2100, *Environmental Research Letters*, 9 104008

Joint Research Centre (JRC), 2014. Climate Impacts in Europe The JRC PESETA II Project. Luxembourg: Publications Office of the European Union. <http://base-adaptation.eu/>

Kahan, D.M., Peters, E., Wittlin, M., Slovic, P., Larrimore Ouellette, L., Braman D and Mandel, G., 2012 The polarizing impact of science literacy and numeracy on perceived climate change risks *Nature Climate Change* doi:10.1038/nclimate1547

Kundzewicz, Z.W., et al., 2013. Flood risk and climate change: global and regional perspectives. *Hydrological Sciences Journal*, 59 (1), 1–28

Łupikasza, E.B., 2017. Seasonal patterns and consistency of extreme precipitation trends in Europe, December 1950 to February 2008. *Climate Research* 72: 217-237.

Menéndez M., and Woodworth P.L., 2010. Changes in extreme high water levels based on a quasi-global tide-gauge data set. *Journal Of Geophysical Research*, Vol. 115.

Mott McDonald Ltd, 2011. Preliminary Flood Risk Assessment, The Predictive Assessment of Potentially Significant Flood Risk.

Murphy, C. 2013. Climate change and catchment hydrology. In Gleeson et al, 2013. Irelands Climate the Road Ahead. Met Eireann.

Murphy, C. and Charlton, R. 2008 'Climate Change and Water Resources in Ireland'. In: Sweeney, J. (eds.) *Climate Change: Refining the Impacts*, Environmental Protection Agency: Ireland

Nolan G, Gillooly M, and Whelan K. (eds). 2009. Irish Ocean Climate and Ecosystem Status Report 2009. *Marine Institute*, Galway, Ireland.

Nolan, P., 2015, Ensemble of regional climate model projections for Ireland, EPA Research Report No. 159, Environmental Protection Agency, Johnstown Castle, Co. Wexford.

Norwegian Meteorological Institute, 2013. Extreme Weather Events in Europe:preparing for climate change adaptation.

O'Dwyer, B. and Alexander P. J. [Compiled by]. (n.d.) *Climate Ireland – Essential Climate Information*. Available at:

www.climateireland.ie/web_resource/pdf/localAuthority/essentialClimateInformation.pdf [Accessed 10/01/2019]

O'Dwyer, B., Hashemi, M., and Gault, J., 2018. The Development of an Irish Climate Information Platform (ICIP) – Phase 3 (2015–2017), EPA Research Report No. 258, Environmental Protection Agency, Johnstown Castle, Co. Wexford.

OEP, 2012. A National Risk Assessment for Ireland.

OEP/Department of Defence, 2017. A National Risk Assessment for Ireland.

Olbert, A.I., Dabrowski, T., Nash, S., and Hartnett, M., 2012. Regional modelling of the 21st century climate changes in the Irish Sea. *Continental Shelf Research*, 41, pp 48-60.

OPW, 2004. Report of the Flood Policy Review Group.

OPW, 2011. Main Overview Report - Preliminary Flood Risk Assessment.

OPW, 2015. Climate Change Sectoral Adaptation Plan for Flood Risk Management.

Palmer, M., Howard, T., Tinker, J., Lowe, J., Bricheno, L., Calvert, D., Edwards, T., Gregory, J., Harris, G., Krijnen, J., Pickering, M., Roberts, C. and Wolf, J, 2018. United Kingdom Climate Projections 2018 Marine Report.

PWC, 1999. Arterial Drainage Maintenance Programme – Report on Measurement of Return of Investment, Price Waterhouse Coopers & Ferguson McIlveen, Ireland.

Stainforth, D., Allen, M., Tredger, E., and Smith, L. (2007). Confidence, uncertainty and decision-support relevance in climate predictions. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences* 365(1857), 2145-2161.

Sweeney and Fealy, 2006. ICARUS, Downscaling Global Climate Models for Ireland: Providing Future Climate Scenarios.

Steele-Dunne S., Lynch P, McGrath R, Semmler T., Wang S., Hanafin J, Nolan P., 2008. The impacts of climate change on hydrology in Ireland *Journal of Hydrology* 356, pp 28– 45.

UNFCCC, 2015. COP 21, Report of the Conference of the Parties on its twenty-first session, Paris, 30 November to 13 December 2015.

UN, 2015a. Envision2030: 17 goals to transform the world for persons with disabilities. <https://www.un.org/development/desa/disabilities/envision2030.html> [Accessed 11/03/2019]

UN, 2015b. The Sendai Framework for Disaster Risk Reduction. Third UN World Conference on Disaster Risk Reduction.

von Schuckmann, K., Le Traon, P., Smith, N., Pascual, A., Brasseur, P., Fennel, K. and Djavidnia, S., 2018. Copernicus Marine Service Ocean State Report, *Journal of Operational Oceanography*, 11:sup1, S1-S142, DOI: 10.1080/1755876X.2018.1489208.

Walsh, S., and Dwyer, N., 2012. 'Rainfall' In: Dwyer, N. ed. *The Status of Irelands Climate*, 2012.

Whetton. P, Hennessy. K., Clarke, J., McInnes, K., and Kent, D., 2012. Use of Representative Climate Futures in Impact and Adaptation Assessment, *Climatic Change* (2012).

Woodworth, P. L., Gregory, J. M. and Nicholls, R. J. 2005. Long term sea level changes and their impacts. *The global coastal ocean: multiscale interdisciplinary processes*, Robinson A. R. and Brink K. H., eds.

Woodworth P.L., and Blackman D.L., 2004. Evidence for Systematic Changes in Extreme High Waters since the Mid-1970s. *American Meteorological Society Journal of Climate* Vol 17.



APPENDICES



APPENDIX A

FLOODING AND FLOOD RISK

A flood is defined in the EU 'Floods' Directive (EC, 2007) as a “temporary covering by water of land not normally covered by water”, i.e., the temporary inundation of land that is normally dry. Flooding is a natural process that can happen at any time in a wide variety of locations.

Flood hazard is the potential threat posed by flooding to people, property, the environment and our cultural heritage. The degree of hazard is dependent on a variety of factors that can vary from location to location and from one flood event to another. These factors include the extent and depth of flooding, the speed of the flow over the floodplains, the rate of onset and the duration of the flood.

A.1 Types and Causes of Flooding

Flooding can occur from a range of sources, individually or in combination.

Coastal Flooding

Coastal flooding occurs when sea levels along the coast or in estuaries exceed neighbouring land levels, or overcome coastal defences where these exist, or when waves overtop over the coast. The primary drivers of coastal flooding that might be affected by climate change are:

- Increases in mean sea level, and astronomical tidal variations in level,
- Storm frequency and intensity, which can create surge and extreme wave events that can further raise sea levels, and
- Wind speed and direction, which can create or exacerbate surge events, force water into estuaries and harbours, and create extreme wave conditions.

A number of coastal flood events occurred during the winter of 2013-14, including in January 2014, when large numbers of properties were flooded in Drogheda and along the East coast, and then again in February 2014, when Limerick and Cork cities were badly affected along with a number of other towns along the south and west coasts.

Fluvial Flooding

Fluvial flooding occurs when rivers and streams break their banks and water flows out onto the adjacent low-lying areas (the natural floodplains). This can arise where the runoff from heavy rain exceeds the natural capacity of the river channel, and can be exacerbated where a channel is blocked or constrained or, in estuarine areas, where high tide levels impede the flow of the river out into the sea.

Different rivers will respond differently to rainfall events, depending on a range of factors such as the size and slope of the catchment, the permeability of the soil and underlying rock, the degree of urbanisation of the catchment and the degree to which flood waters can be stored and attenuated in lakes and along the river's floodplains. A storm of a given rainfall depth and duration may cause flooding in one river, but not in another, and some catchments may be more prone than others to prolonged rainfall or a series of rain events. River flooding can occur rapidly in short, steep rivers or after some time, and some distance from where the rain fell, in larger or more gently flowing rivers. Changes in rainfall patterns, such as might be caused by climate change, will have different impacts on flood magnitudes and frequency in different catchments.

There have been a large number of fluvial flood events in recent years in Ireland. Intense rainfall in June 2012 over the South West led to flash flooding in a number of towns, such as Clonakilty, Blackpool, Douglas and Glanmire. The winter of 2015-16 saw record flood levels in many areas of the country, including along the river Shannon, and many hundreds of properties severely affected. Flash floods occurred over the Inishowen Peninsula and Mountmellick in August and November 2017 respectively, leading to the rapid flooding of many properties.

Pluvial Flooding

Pluvial flooding occurs when the amount of rainfall exceeds the capacity of urban storm water drainage systems or the infiltration capacity of the ground to absorb it. This excess water flows overland, ponding in natural or man-made hollows and low-lying areas or behind obstructions. This occurs as a rapid response to intense rainfall before the flood waters eventually enter a piped or natural drainage system. This type of flooding is driven in particular by short, intense rain storms, such as that which occurred over the Dublin area in October 2011.

Groundwater Flooding

Groundwater flooding occurs when the level of water stored in the ground rises as a result of prolonged rainfall, to meet the ground surface and flows out over it, i.e. when the capacity of this underground reservoir is exceeded. Groundwater flooding tends to be very local and results from the interaction of site-specific factors such as local geology and tidal variations. While water level may rise slowly, it may cause flooding that remains in place for extended periods of time. Hence, such flooding may often result in significant damage to property or disruption to transport.

In Ireland, groundwater flooding is most commonly related to turloughs in the karstic limestone areas prevalent in particular in the west of Ireland. Extensive groundwater flooding due to extended periods of heavy rain has occurred around South Galway and areas of Mayo, Roscommon and neighbouring counties on a number of occasions in recent decades, including in 1995, 2009 and during the winter of 2015/16, when some areas were affected for many months.

Other Causes of Flooding

The above causes of flooding are all natural; caused by either extreme sea levels or heavy or intense rainfall. Floods can also be caused by the failure or exceedance of capacity of built or man-made infrastructure, such as bridge collapses, from blocked or under-sized drainage systems or other piped networks, the failure or over-topping of reservoirs or other water-retaining embankments (such as raised canals), structural failure or exceedance of design flows for flood relief schemes.

A.2 Impacts of Flooding

Impacts on people and communities

Flooding can cause physical injury, illness and loss of life. Deep, fast flowing or rapidly rising flood waters can be particularly dangerous. For example, even shallow water flowing at 2 metres per second can knock children and many adults off their feet, and vehicles can be moved by flowing water of only 300mm depth. The risks increase if the floodwater is carrying debris. Some of these impacts may be immediate, the most significant being drowning or physical injury due to being swept away by floods.

Floodwater contaminated by sewage or other pollutants (e.g. chemicals stored in garages or commercial properties) is also likely to cause illnesses, either directly as a result of contact with the polluted floodwater or indirectly, as a result of sediments left behind.

As well as the immediate dangers, the impact on people and communities as a result of the stress and trauma of being flooded, having access to their property cut-off by floodwaters, or even of being under the threat of flooding, can be immense. Long-term impacts can arise due to chronic illnesses and the stress associated with being flooded and the lengthy recovery process.

The ability of people to respond and recover from a flood can vary. Floods will typically pose a greater challenge to vulnerable people in society such as the elderly and people with a disability or a long-term illness. Some people may also have difficulty in replacing household items damaged in a flood and may lack the financial means to recover after a flood.

Floods can also cause impacts on communities, as well as individuals through the temporary, but sometimes prolonged, loss of community services or infrastructure, such as schools, health services, community centres or amenity assets.

Impacts on property

Flooding can cause severe damage to properties, including homes and businesses. Floodwater is likely to damage internal finishes, contents and electrical and other services and possibly cause structural damage. The physical effects can have severe long-term impacts, with re-occupation sometimes not being possible for prolonged lengths of time.

The damage costs of flooding are increasing, partly due to increasing amounts of electrical and other equipment within developments. The degree of damage generally increases with the depth of flooding, and sea-water flooding may cause additional damage due to corrosion.

Flooding can also be detrimental to agricultural lands, primarily through causing water-logging which damages crops, prevents crops from being planted / harvested and restricts use for grazing.

Impacts on Infrastructure and the Economy

The damage flooding can cause to infrastructure, such as transport or utilities like electricity, gas, water supply and water treatment, can have significant detrimental impacts on individuals and businesses and also local and regional economies.

Flooding of primary roads or railways can deny access to large areas beyond those directly affected by the flooding for the duration of the flood event, as well as causing damage to the road or railway itself. Flooding of water distribution infrastructure such as pumping stations or of electricity sub-stations can result in loss of water or power supply over large areas. Direct flooding of waste water treatment facilities and pumping stations can have significant detrimental effects to the environment, knocking them offline so that untreated effluent discharges directly to watercourses and the sea, or in the case of combined surface water and foul water systems, drastically increased flows would lead to flows in excess of the plant capacity going untreated to their outfall.

The impact of floods on infrastructure can therefore magnify the impact of flooding well beyond the immediate area flooded. The long-term closure of businesses, for example, can lead to job losses and other economic impacts.

Impacts on the Environment

In addition to the impact on waste water infrastructure, detrimental environmental effects of flooding can include soil and bank erosion, bed erosion or siltation, land-slides and damage to vegetation as well as the impacts on water quality, habitats and flora and fauna caused by pollutants carried by flood water (such as untreated waste water effluent, chemicals, sediment, etc.). Flooding can however play a beneficial role in natural habitats. Many wetland habitats are dependent on annual flooding for their sustainability and can contribute to the storage of flood waters to reduce flood risk elsewhere.

Impacts on our Cultural Heritage

In the same way as flooding can damage properties, flood events can damage or destroy assets or sites of cultural heritage value. Particularly vulnerable are monuments, structures or assets (including building contents) made of wood or other soft materials, such as works of art and old paper-based items such as archive records, manuscripts or books. More substantial structures are also at risk, particularly from direct contact with flowing water or exposure and undermining of foundations through soil erosion. Soil erosion during flood events could also destroy buried heritage and archaeological sites.

A.3 Assessing Flood Hazard

A flood hazard assessment is the identification and quantification of the potential hazards due to flooding for a given location or area. It seeks to identify the potential extents of flooding and areas subject to particular hazards, such as deep or fast-flowing water, for given flood event magnitudes, and to assess the likelihood of such flood events occurring both now and in the future.

Flood hazard assessments can be undertaken at a range of scales, including national, regional, local and site-specific. They can also be undertaken to varying degrees of detail, from highly-detailed assessments that will typically involve survey work and modelling, to indicative assessments based on anecdotal, surrogate or historic information or simple analysis. The scale and level of detail of assessment will depend on the objective of the assessment, and what scope and degree of confidence is required in the outputs.

For a detailed flood hazard assessment, a computer-based model is typically developed that attempts to replicate and simulate how the natural river or coastline and its floodplains will behave and convey water during high flows or extreme sea levels. For river systems, this requires a hydrological analysis to determine what flood flows might be expected to occur for a given probability or frequency of occurrence.

The probability or frequency can be expressed as, for example, a flood that has a 1 in a 100 or 1% chance of being equalled or exceeded in any given year (referred to as the 1% Annual Exceedance Probability (AEP) flood), or, expressed in another way, a flood that might occur, on average and over a long period of time, once every hundred years (the 100-year flood). Such models, although complex, are still only representations of very complex natural systems, and all flood estimates and hazard assessments carry a degree of inherent uncertainty. This uncertainty can be reduced where the models can be calibrated against real, past flood events.

Indicative methods can provide quick, low-cost assessments of flood hazard. They are generally however, by their very nature, much less reliable, or more uncertain, than detailed, model-based assessments.

The outputs of a flood hazard assessment will generally include flood maps. These can show a range of the factors that contribute to flood hazard but most commonly indicate flood extents and flood depth for past flood events (historic flood maps) or for events of a given probability of occurrence (predictive flood maps).

A.4 Assessing Flood Risk

Flood risk is a function of the degree of flood hazard (taking account of probability and magnitude) and the vulnerability of properties, communities, infrastructure and our environment to damage or loss in the event of a flood.

The degree of flood hazard is assessed through a flood hazard assessment as outlined above. The risk can then be assessed by examining what could be affected by the flood, and what damage could arise were a flood to occur.

As per a flood hazard assessment, a flood risk assessment can be undertaken at a range of scales from national down to site-specific, and in a detailed or indicative way. The outputs of a flood risk assessment will be information explaining the potential losses or consequences that could arise due to flooding.



APPENDIX B

FLOOD RISK MANAGEMENT IN IRELAND

B.1 Flood Risk Prevention

The National Flood Policy Review of 2004 identified flood risk prevention (i.e., the avoidance of creating new flood risks) as an area needing further development in Ireland. At the core of 'prevention' as a flood risk management strategy is sustainable development.

Shortly after the adoption of the Policy Review, the OPW and the Department of Environment, Heritage and Local Government (DEHLG) began developing guidelines to assist planners in taking flooding into consideration in planning and development management. The guidelines were published for consultation in 2008, and then adopted and published under Section 28 of the Planning Act in November 2009 (DEHLG/OPW, 2009).

These Guidelines provide a clear framework for sustainable planning taking a risk-based approach whereby flood-sensitive development should avoid flood-prone areas, based on classifications of land-use vulnerability and flood zones. On an exceptional basis, town centre development in flood prone areas may be appropriate (subject to a justification test), providing the risk is managed. The Guidelines apply to developers, as well as the planning authorities, and so public bodies, semi-state companies and private developers, should apply the principles and approach set out, including avoiding development in areas prone to flooding where possible.

The Guidelines have been in effect, at the time of publication, for over ten years, and have achieved wide-spread application. The successful and effective implementation of the guidelines is critical for the sustainable management of flood risk in Ireland in the long-term.

B.2 Flood Protection

Flood Relief Schemes

The Arterial Drainage (Amendment) Act, 1995, provided the OPW with the powers to implement flood relief schemes to provide flood protection to local communities, as opposed to catchment-wide schemes aimed at improving agricultural production. Flood relief schemes can provide protection by a range of means, such as:

- Storing floodwater upstream;
- Preventing high coastal or river levels from spilling into the community using walls or embankments;
- Allowing more water to pass through a community by increasing the capacity of the river channel; and
- Diverting flood flows around or away from a community.

Since 1995, 43 major schemes have been completed by the end of 2018, with a further 35 from the existing capital programme (i.e., prior to the publication of the FRMPs) currently at various stages of design, planning or construction. The completed major schemes have cost a total of €350m, provide protection to over 9,500 properties and provide an overall benefit of approximately €1.7bn. A list of the major schemes completed by the end of 2018 is provided in **Table B-1**, while those that were under construction or in design/planning by the end of 2018 are listed in **Table B-2**.

The schemes once completed are monitored by inspection, and maintained according to the nature of the scheme, e.g., regular maintenance of mechanical components such as pumps, maintenance of vegetative cover of embankments, channel maintenance of channels, etc.

Table B-1: Major Flood Relief Schemes Completed by End of 2018

Schemes	Properties Protected
Gort Town, Co. Galway	21
Sixmilebridge, Co. Clare	16
Morrell, Co. Kildare	10
Lacken/Ardrahan, Co. Galway	5
Dromcollogher, Co. Limerick	10
Maam Valley, Co. Galway	2
Clancy Strand, Limerick City	100
Harry's Mall, Limerick City	134
Duleek, Co. Meath	88
Ballymakeogh, Co. Tipperary	53
Cappamore, Co. Limerick	70
Dunmanway, Co. Cork	35
Hazelhatch, Co. Kildare	26
Carrick-on-Suir, Co. Tipperary	110
Kilkenny City	200
River Tolka - Dublin City	1,346
River Tolka - Meath	332
River Tolka, Fingal	18
Leixlip, Co. Kildare	50
Newcastlewest, Co. Limerick	150
New Ross, Co. Wexford	65
Spencer Dock, Dublin City	1,200
Mallow North, Co. Cork	136
Mallow South & West, Co. Cork	94
Ennis Upper, Co. Clare	450
Waterford City - Phase 1	198
Waterford City - Phases 2,3,4	417
Carlow Town, Phase A	61
Carlow Town, Phase B	124
Fermoy North, Co. Cork	77

Schemes	Properties Protected
Fermoy South, Co. Cork	187
Clonmel North, Co. Tipperary	142
Clonmel North & East, Co. Tipperary	358
Mornington, Co. Meath	162
Johnstown, Co. Kildare	25
Tullamore, Co. Offaly	100
River Dodder (Tidal), Dublin City	1,000
Clanmoyle, Dublin City	51
Bray, Co. Wicklow	660
Foynes, Co. Limerick	188
South Campshires, Dublin City	737
Northlands, Co. Meath	27
Bellurgan, Co. Louth	35

Table B-2: Major Flood Relief Schemes under Construction or in Design /Planning at End of 2018

Schemes at Construction	Properties to be Protected
Ashbourne, Co. Meath	47
Athlone, Co. Westmeath	550
Bandon, Co. Cork	392
Claregalway, Co. Galway	77
Clonakilty, Co. Cork	296
Dodder River, Dublin City	938
Dunkellin, Co. Galway	23
Ennis Lower, Co. Clare	700
Ennis South, Co. Clare	127
Skibbereen, Co. Cork	312
Templemore, Co. Tipperary	110
Schemes at Design/Planning	Properties to be Protected
Arklow, Co. Wicklow	707
Ballinhassig, Co. Cork	8
Ballymakeera, Co. Cork	80
Blackpool, Cork City	285
Camac River, Dublin City	562
Carrigaline, Co. Cork	129
Clontarf, Dublin City	400
Crossmolina, Co. Mayo	116
Douglas/Togher, Co. Cork	231
Enniscorthy, Co. Wexford	232
Glashaboy, Co. Cork	106
Gort Lowlands, Co. Galway	25
King's Island, Limerick City	473
Lower Lee (Cork City)	2,100
Lower Morell, Co. Kildare	36
Macroom, Co. Cork	12
Malahide, Co. Dublin	37
Midleton, Co. Cork	215
Poddle River, Dublin City and Co. Dublin	840
Portmarnock, Co. Dublin	18

Schemes at Design/Planning	Properties to be Protected
Raphoe, Co. Donegal	212
Sandymount, Dublin City	1,141
Skerries, Co. Dublin	61
Whitechurch Stream, Co. Dublin	165

Many of the completed schemes have been tested by flood events and have prevented properties from flooding, such as in Mallow in November 2009, January 2010 and again in the winter of 2015/16, in Dublin in January 2014 and in Clonmel in February 2014. As with the Arterial Drainage Schemes, the OPW has a statutory duty to maintain these flood relief schemes.

The FRMPs, produced through the CFRAM Programme, identify a further 118 schemes that are being progressed. The progression of these schemes is supported by the Government's NDP 2018 – 2027, which includes a total funding allocation of €940m over the lifetime of the Plan to underpin the delivery of the existing flood relief capital works programme and the additional prioritised flood relief schemes recommended in the Flood Risk Management Plans. The NDP allocation taken with the funding allocations already made in 2016 and 2017 under the capital investment plan Building on Recovery: Infrastructure and Capital Investment 2016 – 2021 represents total investment of some €1 billion in flood defence schemes. The annual allocation for flood defence measures will increase to €100m by 2021 demonstrating the priority placed by the Government on addressing Ireland's flood risk and reflecting also the flooding policy priorities set out by Government in A Programme for a Partnership Government. To achieve greatest benefit Government investment to implement the structural measures proposed in the Plans is being prioritised, and 57 of these schemes are being advanced as part of the first phase of delivery of the future capital programme as listed in **Table B-3**. Each Scheme requires an assessment of existing and newly constructed flood defence assets that can compliment the OPW flood defence asset database.

Some major flood relief schemes have been implemented under Local Authority powers, including the River Tolka Scheme and the River Dodder works. This route is taken where the Local Authority powers are deemed to be more suitable, but funding and/or technical advice is generally provided by the OPW in the preparation and implementation of such schemes.

In 2009, the OPW launched the Minor Flood Mitigation Works & Coastal Protection Scheme whereby the OPW may allocate to a Local Authority up to €750,000 to implement local solutions for local flood problems. This Scheme has proven to be very successful with approval given to €46m of funding for over 700 Minor Works projects by the end of 2018, providing benefits to almost 7,000 properties.

The OPW is currently engaging with other stakeholders and supporting pilot and research projects to explore softer forms of achieving flood protection, such as through natural water retention measures and an integrated approach to flood risk management.

Drainage Districts and Arterial Drainage Schemes

Drainage Districts are areas where drainage schemes to improve land for agricultural purposes were constructed under various Arterial Drainage Acts from 1842 up to 1943. When a subsequent scheme covered the same ground as one of the earlier schemes, the previous District was abolished.

Of the 293 schemes carried out, 170 remain covering 4,600km of channel. The location and extent of the Drainage Districts are shown in **Figure B-1**.

The statutory duty for maintaining these schemes rests with the Local Authorities concerned, and is funded by the Minister for Housing, Planning and Local Government. While the Local Authorities are required to report regularly on their maintenance to the OPW, the standard of this maintenance would appear to vary widely.

Table B-3: Flood Relief Schemes from the FRMPs being advanced in first phase

Schemes	Properties to be Protected
Abbeydorney, Co. Kerry	9
Aglish, Co. Waterford	5
Ardee, Co. Louth	7
Athea, Co. Limerick	15
Athy, Co. Kildare	99
Avoca, Co. Wicklow	15
Ballina, Co. Mayo	167
Ballinasloe, Co. Galway	221
Ballyduff, Co. Waterford	13
Ballyhale, Co. Kilkenny	25
Baltray, Co. Louth	44
Banna, Co. Kerry	19
Bantry, Co. Cork	198
Bunratty, Co. Clare	2
Burnfoot, Co. Donegal	36
Carlingford, Co. Louth	296
Carlow, Co. Carlow	35
Carrick-on-Shannon, Co. Leitrim	76
Carrowkeel, Co. Donegal	13
Castleconnell, Co. Limerick	42
Castlefin, Co. Donegal	35
Clifden, Co. Galway	24
Clonaslee, Co. Laois	45
Cois Abhainn Flood Cell in Westport, Co. Mayo	6
Cavan Town	110
Downies, Co. Donegal	4

Schemes	Properties to be Protected
Drogheda, Co. Louth	240
Dundalk, Co. Louth	1,737
Galway City	942
Glenties, Co. Donegal	8
Golden, Co. Tipperary	8
Graigenamanagh, Co. Kilkenny	64
Holycross, Co. Tipperary	1
Kenmare, Co. Kerry	235
Kilkee, Co. Clare	194
Killaloe, Co. Clare	4
Kilrush, Co. Clare	20
Knocklofty, Co. Tipperary	5
Leitrim, Co. Leitrim	58
Leixlip, Co. Kildare	63
Lifford, Co. Donegal	78
Limerick City	417
Longford, Co. Longford	17
Loughlinstown, Co. Dublin	256
Mohill, Co. Leitrim	7
Mornington, Co. Meath	50
Mountmellick, Co. Laois	46
Naas, Co. Kildare	485
Nenagh, Co. Tipperary	58
Portarlington, Co. Laois	144
Rahan, Co. Offaly	4
Rathbraghan, Co. Sligo	16
Rathkeale, Co. Limerick	3
Shannon, Co. Clare	143
Springfield/Clonlara, Co. Clare	18
Tralee, Co. Kerry	768
Wexford Town	179

Following the passing of the Arterial Drainage Act, 1945, the OPW began investigations to determine where Arterial Drainage Schemes would be expedient and economically viable. The implementation of the Schemes began in the late-1940s and continued into the early-1990s when the last major schemes were completed.

A total of 11,500km of river channel form part of the Arterial Drainages Schemes that also include 800km of embankments. The location and dates of the major Schemes undertaken throughout the country is provided in **Table B-4**, and the location and extent of the Schemes are shown in **Figure B-1**.

The purpose of the Arterial Drainage Schemes was primarily to provide outfall for the drainage of agricultural lands to enhance production. This typically involved lowering or widening river beds to facilitate the drainage and discharge of neighbouring lands and drainage channels. While not the primary purpose of the Schemes, they did also provide enhanced conveyance capacity where they passed through towns, villages and dispersed rural communities that in turn has reduced the flood risk to properties in these areas.

While new Arterial Drainage Schemes are no longer being undertaken, the OPW has a statutory duty to maintain the completed Schemes in proper repair and in an effective condition. The annual maintenance programme is prepared by the OPW, and typically involves some clearance of vegetation and removal of silt build-up on a five-yearly cycle.

To minimise potential ecological impacts, the OPW undertakes these statutory maintenance works in accordance with a set of procedures called “Environmental Guidance: Drainage Maintenance and Construction”, which is published on the OPW website. This guidance entails 34 procedures relating to the environmental planning and implementation of drainage maintenance activities. Included are environmental procedures relating to construction works, invasive species, protected animals, protected plants and habitats. The guidance forms the backbone of mitigating the main environmental impacts of drainage maintenance.

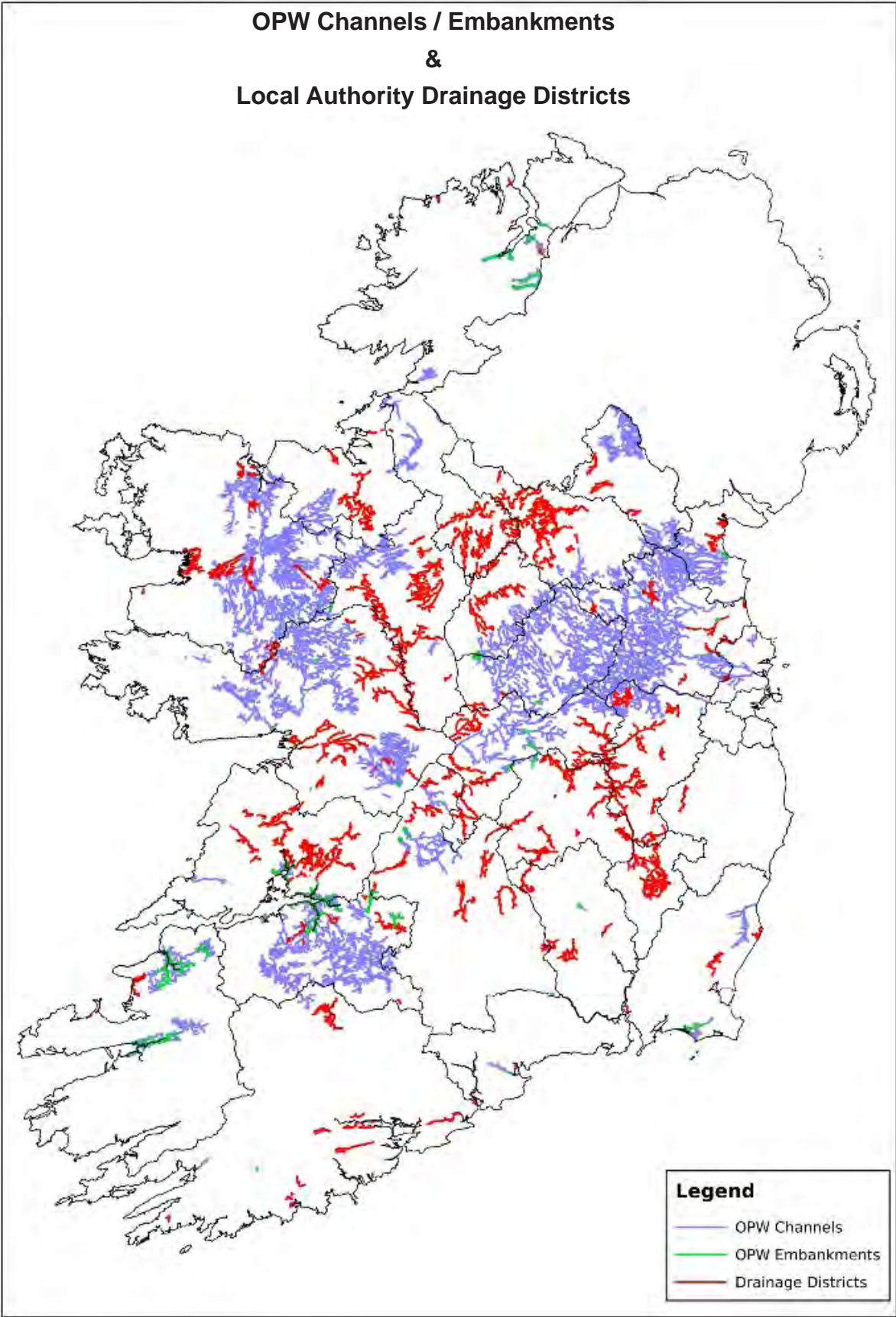
The OPW’s cooperation with Inland Fisheries Ireland (IFI) has continued, building on the significant environmental improvements achieved in the past. This relationship has been ongoing for 15 years. Through recent consultation on the new environmental guidance, IFI expertise has been influential in the development and improvement of several work practices and procedures. Newer procedures on tree and vegetation management incorporated into the guidance further supports an environmental approach to drainage maintenance.

Table B-4: Completed Major Arterial Drainage Schemes

Scheme	Counties	Duration of Works	Benefitting Area (Acres)
Brosna	Offaly, Westmeath, Laois	1948 - 55	86,200
Glyde & Dee	Louth, Meath, Monaghan, Cavan	1950 - 57	26,300
Feale	Kerry	1951 - 59	26,500
Corrib-Clare	Galway, Mayo, Roscommon	1954 - 64	74,900
Owenogarney ¹	Clare	1955 - 59	2,100
Nenagh	Tipperary, Offaly	1955 - 60	6,500
Deel & Swillyburn	Donegal	1957 - 61	3,500
Shannon ¹	Clare	1958 - 60	1,800
Ballyteigue / Kilmore	Wexford	1959 - 61	2,300
Maine	Kerry	1959 - 63	11,600
Fergus ¹	Clare	1959 - 63	5,400
Inny	Westmeath, Longford, Meath, Cavan	1960 - 68	50,000
Moy	Mayo, Sligo, Roscommon	1960 - 71	61,000
Broadmeadow & Ward	Meath, Dublin	1961 - 64	7,400
Swilly, etc. ¹	Donegal	1961 - 68	3,200
Killimor / Cappagh	Galway	1962 - 68	12,600
Deel	Limerick, Cork	1962 - 68	11,900
Shannon ¹	Limerick	1962 - 71	12,100
Duff	Leitrim, Sligo	1963 - 65	3,600
Corrib-Headford	Galway, Mayo	1967 - 73	19,400
Owenavarragh	Wexford	1968 - 70	2,600
Carrigahorrig	Tipperary, Offaly	1968 - 71	3,800
Boyne	Meath, Westmeath, Louth, Cavan, Kildare, Offaly	1969 - 86	119,000
Groody	Limerick	1970 - 73	3,000
Maigue	Limerick, Tipperary, Cork	1973 - 86	30,500
Corrib-Mask-Robe	Mayo, Galway	1979 - 86	24,000
Boyle	Roscommon, Sligo, Mayo	1982 - 92	26,800
Bonet	Leitrim, Sligo	1982 - 92	3,200
Monaghan Blackwater	Monaghan	1984 - 92	5,850
TOTAL			647,050

Note 1: Estuarine Embankment Scheme

Figure B-1: Arterial Drainage Schemes and Drainage Districts



The Environmental River Enhancement Programme (EREP) also continues as a key part of the new guidance. This programme enhances the ecological value of drained channels, maximising the river corridor ecological quality whilst retaining the flood relief and drainage capacity. This programme has evolved to greater use of appropriate physical measures that match the channels natural characteristics, using materials and potential more in keeping with the natural channel hydromorphology. The IFI also uses its expertise on fish passage to assist in identifying barriers to fish movement, and through a new procedure assist OPW in removing these barriers.

A review of the drainage maintenance programme (PWC, 1999) found that the programme provides very significant economic benefits relative to cost.

Urban Storm Water Drainage and Water-Bearing Infrastructure

Urban development can significantly increase flood risk in two primary ways:

1. Urbanisation can, without specific measures such as use of permeable paving, water storage for roof runoff and sustainable urban drainage systems, increase both the rate and volume of runoff from rainfall events; and
2. Urbanisation creates assets that can be potentially damaged by flooding.

Local Authorities, as part of their function in managing sustainable planning, levy developments to provide urban storm-water drainage systems to manage and reduce the risk from pluvial flood events, such as the extreme event that occurred in the Dublin area in October 2011. Local Authorities further maintain the road and urban storm-water drainage infrastructure within their areas to help ensure that urban runoff can drain into drainage networks for storage and/or removal from potential risk areas.

Irish Water is responsible for combined sewerage systems (carrying foul and storm water), and for maintaining the existing capacity of these systems, which can drain urban areas, and for managing new connections and inflows.

Historically urban storm-water drainage systems have typically been designed with a capacity of somewhere in the range of a 5-year to 20-year storm event. In the event of more extreme rainfall events, ponding in low-lying urban areas can occur causing property flooding. This can be tackled by enhancing the capacity of the drainage system, which can often be prohibitively expensive, or the hazard and risk from overland flow and ponding can be managed through measures such as retro-fitting sustainable urban drainage systems that can have benefits to water quality, ecology and amenity as well as for flood risk reduction.

Statutory Instrument (SI) No. 122 of 2010, that transposes the EU 'Floods' Directive, requires that relevant infrastructure owners must assess the flood risk related to urban storm water drainage systems and reservoirs and, where significant, identify measures to manage the risk in line with the requirements of the Directive, with a review of the risk to be carried out every six years.

The FRMPs, published in May 2018, which are now being implemented set out the measures that can benefit the management of flood risk nationally, including those related to urban storm water drainage systems. In accordance with the EU 'Floods' Directive, Local Authorities and Irish Water are now engaged in the first review of the risk associated with urban storm water drainage systems and from any reservoirs or other water-bearing infrastructure that are in their ownership.

Water-bearing infrastructure, including piped networks and water retention structures, can potentially cause flooding in the event of failure or blockage. Piped networks might include water supply pipes or sewerage systems, while water-retention structures might include dams and embanked reservoirs and raised canals.

The owners and operators of the infrastructure are responsible for managing the risk of flooding from that infrastructure. This involves asset inspection and monitoring, maintenance and renewal, and is undertaken in accordance with strict procedures for assets that constitute a potentially significant risk such as major dams.

SI No. 122 of 2010, requires that relevant infrastructure owners must assess the flood risk related to their assets and, where significant, identify measures to manage the risk in line with the requirements of the Directive, with a review of the risk to be carried out every six years. In accordance with the Directive, relevant owners are now engaged in the first review of the flood risk associated with their infrastructure.

B.3 Preparedness

Flood risk preparedness, response and resilience is an area of work that was identified for development by the National Flood Risk Policy Review. The Interdepartmental Flood Policy Coordination Group, that is led by the OPW, was established to consider the extent that non-structural solutions could inform the implementation strategy of the Flood Risk Management Plans and to ensure that policies that can benefit communities and individuals directly – to be prepared for and respond to or live with flood risk – are carefully considered.

It is not always possible to reduce the likelihood or severity of flooding to a community at risk. However, actions and measures can be taken to reduce the risk to people and damage to property and assets. Action can also be taken to make sure that people and communities are prepared for flood events. This can be achieved through increased awareness of and preparations for the risk of flooding. Knowing when floods are likely to occur and taking actions immediately before, during and after a flood can mitigate the impacts of flooding on individuals and communities.

This approach involves what are often referred to as ‘non-structural’ measures and include:

- Increasing public awareness and preparedness prior to, during and after flood events to reduce potential damages caused by floods,
- Providing flood warning so that the public and response authorities can prepare for and respond effectively to flood events,
- Ensuring effective flood event response planning by the emergency response authorities, so that the response is effective and timely to reduce impacts on people and property.

These types of measure enhance the resilience of communities to flood events such that they are better prepared for, and can recover more quickly from, floods. Much work has been done to enhance the application of this approach in Ireland, including:

- Provision of real-time data on water levels on www.waterlevel.ie and historical flood data on www.floodinfo.ie,
- Provision of a Forecasting Service which allows Local Authorities and other relevant stakeholders up to three days advance notification of impending coastal storm surge events,
- The ‘Plan, Prepare, Protect’ initiative booklet was prepared in 2014 that provides practical advice to the public on how to prepare for potential flooding,

- Launch of the annual 'Be Winter Ready' (www.winterready.ie) campaign which is designed to create awareness among people and communities by providing them with relevant information to support their plans to prepare for and deal with a period of severe weather,
- The provision of the national past flood event database (now available via www.floodinfo.ie) to promote awareness of flooding.
- The guidelines and templates for flood event emergency response plans prepared by the OPW and Department of Environment, Heritage and Local Government under the Framework for Major Emergency Management in 2008 have been revised.
- Ireland joined the European Flood Awareness System (EFAS) partner network in 2010. The OPW is the formal national point of contact for accessing the EFAS services and receiving flood notifications issued where a high probability for flooding is forecast.
- The Government decided in 2016 to establish a National Flood Forecasting and Warning Service. The service will deal with flood forecasting from river and coastal sources and when fully operational will involve the issuing of flood forecasts and general alerts at both national and catchment scales. The first stage of the services comprises a Flood Forecasting Service that will be a new operational unit within Met Éireann with guidance for standards and performance overseen by the OPW.
- The Government agreed on 8th November 2016 (S180/20/10/1272B) to introduce a targeted and prioritised once off Voluntary Homeowner Relocation Scheme for those primary residential homes that were flooded during the flooding event in winter 2015/2016. This is a once-off national scheme of humanitarian assistance, targeting aid at those residential homes worst affected by that flood event for which there are no alternative feasible measures.
- Supported communities' preparedness by working with the Irish National Flood Forum.
- The OPW has undertaken a study to look at the potential support by Government of Individual Property Protection.

The Interdepartmental Flood Policy Coordination Group will continue its work and build partnerships, greatly informed by the wealth of knowledge and output from the CFRAM Programme. The Group will bring forward further feasible proposals for Government's consideration to support and assist households and communities through non-structural flood risk management and mitigation measures.

B.4 Data Collection and Flood Risk Assessment

Hydrometric Monitoring

The two main public bodies involved with surface water monitoring in Ireland are:

- The EPA jointly with Local Authorities, which have responsibilities and a network of approximately 240 stations oriented towards measurement of medium and low flows for water quality and resource management purposes; and,
- The OPW, which captures data for flood risk management purposes. The OPW has collected hydrometric data (water levels and river flows) since the mid-nineteenth century for arterial drainage and flood relief works. Data collection began more systematically on a catchment-wide basis from 1939. There are currently approximately 400 surface water stations in the OPW hydrometric network.

Other major bodies involved in monitoring include Waterways Ireland, the Marine Institute, Geological Survey Ireland, Irish Water and the ESB. The National Hydrometric Working Group, co-chaired by the OPW and the EPA, was established in 2013 to improve the overall monitoring, processing, availability and use of good quality hydrometric data.

The overall aim is to provide a forum and foster greater cooperation among the various bodies responsible for, or directly involved in, hydrometric activities in Ireland.

Hydrometric monitoring has an important role to play in flood risk management. Long-term records of flows, particularly high and flood-flows, are essential in the determination of design flood flows (e.g., the flow that has a 1% probability of occurring or being exceeded in any given year, or, in other terminology, the 100-year flow) and to determine flows for past events. Records of flood levels are also important to permit observation of flood events for calibration of flood models. Long-term hydrometric records can also assist in the detection of changes in flow regimes or mean sea level, such as might be due to climate change.

Most monitoring stations are now equipped with telemetry such that near real-time and real-time water level data can be captured centrally and/or published directly to websites for public use (www.waterlevel.ie).

From 1975 to 2014, flood estimation in Ireland was generally undertaken using the methodologies and data provided in the Flood Studies Report (FSR), and from analysis based on the various national hydrometric databases. The Flood Studies Update, available from the FSU Web Portal (www.opw.ie/en/fsu/) and launched in late 2014, is a substantial update of the FSR based on a major research programme (initiated, managed and funded by the OPW) and the substantially greater hydrometric database than that available for the FSR. Ongoing hydrometric monitoring is critical for ensuring robust estimation of flood flows and for monitoring changes in the hydrological regime that might be caused by land use change, urbanisation and climate change.

Flood Risk Assessment

The OPW in conjunction with key stakeholders undertook the PFRA (Section 1.3.3) and the National 'CFRAM' Programme (Section 1.3.5) to deliver on key recommendations of the Report of the Flood Policy Review Group (OPW, 2004), and as part of the implementation of the EU 'Floods' Directive. While only a requirement of the second and subsequent cycles of the Directive, the OPW included assessments and consideration of the potential impacts of climate change in the first cycle implementation, including in the preparation of flood maps and risk assessments, making use of two potential future scenarios as described in Section 5.1.

The 'Floods' Directive is cyclical, requiring a review of the PFRA, the flood maps and the FRMPs on a six-yearly cycle. The OPW is currently leading the implementation of the second cycle of implementation of the Directive. This includes:

- Developing an improved set of national, fluvial indicative flood maps, including areas outside of those areas covered by the CFRAM Programme,
- Reviewing the national indicative coastal flood mapping, taking account of recorded data over the last 10 years,

- Improvement of the flood mapping for flooding from Turloughs through a project being led by the Geological Survey of Ireland,
- A review of the floods that have occurred since the first cycle PFRA and their impacts,
- The review and update of flood maps on an ongoing basis to reflect physical changes and/or to take account of new information.

The FRMPs published in May 2018 will be reviewed in 2021. The flood mapping outlined above and the review of the FMRPs will continue to take the potential impacts of climate change and the need for adaptation into account.



APPENDIX C

Structures that Support Development of the Climate Change Sectoral Adaptation Plan for Flood Risk Management

Interdepartmental Flood Policy Coordination Group

The Group is chaired by the Minister of State with special responsibility for the Office of Public Works and Flood Relief and membership includes:

- Office of Public Works
- County and City Management Association
- Department of Agriculture, Food and the Marine
- Department of Business, Enterprise and Innovation
- Department of Communications, Climate Action and Environment
- Department of Culture, Heritage and the Gaeltacht
- Department of Defence
- Department of Employment Affairs and Social Protection
- Department of Finance
- Department of Housing, Planning and Local Government
- Department of Public Expenditure and Reform
- Department of Transport, Tourism and Sport

Membership of the National Floods Directive Coordination Group

- Office of Public Works
- County and City Management Association
- Department of Agriculture, Food and the Marine
- Department of Culture, Heritage and the Gaeltacht
- Department of Housing, Planning and Local Government
- Department for Infrastructure (DfI), Rivers (formerly Rivers Agency Northern Ireland)
- Environmental Protection Agency
- Electricity Supply Board
- Geological Survey of Ireland (Department of Communications, Climate Action and Environment)
- Irish Water
- Met Éireann
- Office of Emergency Planning
- Waterways Ireland

Membership of the Shannon Flood Risk State Agency Coordination Working Group

- Office of Public Works
- Bord na Móna
- Department of Culture, Heritage and the Gaeltacht
- Electricity Supply Board
- Environmental Protection Agency
- Inland Fisheries Ireland
- Irish Water
- Local Authorities, represented by the County and City Managers Association
- Waterways Ireland

Workshop in June 2018 on Climate Change Sectoral Adaptation Plan

Organisations invited to this Workshop:

- Climate Action Regional Offices
- Department of Agriculture, Food and the Marine
- Department of Communications, Climate Action and Environment
- Department of Culture, Heritage and the Gaeltacht
- Department of Finance, Public Expenditure and Reform
- Department of Foreign Affairs
- Department of Health
- Department of Housing, Planning and Local Government
- Department of Transport, Tourism and Sport
- Environmental Protection Agency
- Health Service Executive
- Irish Water
- Local Authority Representatives
- Met Éireann
- National Standards Authority of Ireland
- OPW
- Transport Infrastructure Ireland & Transport Infrastructure Operators
- University Researchers

OPW's Core and Planning Team

- Flood Relief and Risk Management Division
- Hydrology and Coastal Section
- Environment Section
- Regional Divisions

APPENDIX D

POTENTIAL IMPACTS OF CLIMATE CHANGE ON CLIMATIC PARAMETERS RELEVANT TO FLOODING AND FLOOD RISK

This Appendix discusses the potential impacts on the climatic parameters that can influence flooding and flood risk resulting from climate change. It outlines the findings of international and national research on projections of future climate change under the following subject areas:

- Temperature
- Wind Speeds
- Storm Surges
- Sea Temperatures
- General Impacts of Climate Change
- Precipitation
- Sea Level Rise
- Wave Heights
- Weather Extremes

The Appendix concludes with some discussion on the uncertainty related to these projections.

D.1 Temperature

The Intergovernmental Panel on Climate Change (IPCC) has stated that human activities are estimated to have already caused approximately 1.0°C of global warming above pre-industrial levels, with a likely range of 0.8°C to 1.2°C (IPCC, 2018). Another IPCC report (IPCC, 2018) also states that each of the last three decades has been successively warmer at the Earth's surface than any preceding decade since 1850, noting that the period from 1983 to 2012 was likely the warmest 30-year period of the last 1400 years in the Northern Hemisphere.

A report by the Joint Research Centre into climate change impacts in Europe (JRC, 2014) predicted a temperature increase from the control period 1961-1990 until the 2080s of up to 2.4-3.9°C. The warming is highest in the Northern Europe region, and lowest in the UK & Ireland region, for all climate simulations. The recent JRC PESETA III study (Ciscar et al., 2018), under the high warming scenario, shows that at the end of the century, Europe is projected to face a warming of nearly 4°C (consistent with the IPCC AR5 projections). The increase in temperature shows large variation both spatially and seasonally. Winter and summer temperature is projected to increase, on average, by 2.7°C and 3.0°C respectively over Britain and Ireland (mean value of all bias adjusted Regional Climate Models) and, on a local basis, values may be even higher.

Changes in Ireland's climate are in line with and similar to relevant global trends. The annual average surface air temperature in Ireland has increased by approximately 0.8°C over the period 1900-2011, an average of 0.07°C per decade (Dwyer, 2012, cited in Desmond et al., 2017). In the period 1961 to 2010 there has been an increase in the number of warm days (those with temperatures over 20°C), and a decrease in the number of frost days (those with temperatures below 0°C), in line with observations across Western Europe.

National projections for mid-century indicate an increase in average temperatures across all seasons between 0.9-1.7°C, with the largest increase in the east of the country (Nolan, 2015, cited in Desmond et al., 2017). Another similar report indicated that warm days are expected to increase and heat waves to occur more frequently (Nolan 2015, cited in O'Dwyer et al., 2018).

The Paris Agreement (COP 21) of 12 December 2015 (UNFCCC, 2015) committed 195 countries to the mitigation goal of limiting the increase in global temperature to well below 2°C above pre-industrial levels. However, current commitments to reduce emissions, even if fully implemented, will lead to an estimated 2.7°C rise in average global temperatures by 2100 (Jeffery, L. et al., 2015). Global emissions would need to peak soon and then decline rapidly for the Paris Agreement goals to be feasible. Even in this scenario, uncertainty about the sensitivity of the climate to Greenhouse gases means there would remain at least a small chance of 4°C or more of warming by 2100.

D.2 Precipitation

The IPCC has stated that direct trends in precipitation are difficult to measure with the available record, however the contrast in precipitation between wet and dry regions and between wet and dry seasons will increase, although there may be regional exceptions.

Several studies (Fisher & Knutti 2016, EEA, 2017, and Łupikasza, 2017) agree that annual precipitation since 1960 shows an increasing trend of up to 70 mm per decade in north-eastern and north-western Europe, and a decrease of up to 90 mm per decade in some parts of southern Europe. Mean summer precipitation has significantly decreased by up to 20 mm per decade in most of southern Europe, while significant increases of up to 18 mm per decade have been recorded in parts of northern Europe (EEA, 2017). In Europe, the frequency of very wet days has increased over the last 50 years. In Ireland, there has been an increase in average annual rainfall of approximately 60 mm or 5% in the period 1981 to 2010, compared to the 30-year period 1961 to 1990. The largest increases were in the west of the country (Walsh and Dwyer, 2012).

Met Éireann has predicted that in Ireland the autumns and winters may become wetter, with a possible increase in heavy precipitation events of approximately 20%, and that summers may become drier, with a projected 12-40% increase in the number of extended dry periods (Nolan, 2015). However, the change in precipitation patterns in Ireland, particularly at a local level and for shorter (sub-seasonal) durations, remains uncertain and is the subject of ongoing research.

D.3 Wind Speeds

Climate projections indicate that mean wind speeds in Ireland are not expected to change significantly over the coming decades, with slight increases in winter wind speeds (1-2%) and decreases in summer (2-3%) for 2021-2060. According to an EPA report (EPA, 2018), the number of very intense storms is projected to increase over the North Atlantic Region. Projections indicate that the winter track of these storms may extend further south and over Ireland more often (Nolan 2015, cited in EPA 2018). National projection suggests an overall decrease in wind speed and an increase in extreme wind speeds associated with southerly shifting storms, particularly during winter (Nolan 2015, cited in O'Dwyer *et al.*, 2018).

It should be noted that the Irish observational records indicate that average annual wind speeds decreased in the 1990s, with this trend continuing in the early years of the 21st century. The latter is consistent with the predicted movement of storm tracks towards polar areas, whereby fewer storms would affect Ireland but the influence of rising sea surface temperatures is likely to lead to more extreme storms. This in turn would indicate that the frequency of very intense cyclones affecting Ireland is likely to increase, which in turn could cause more storm surge events.

D.4 Sea Level Rise

Sea level rise is mainly due to melting ice and thermal expansion (water expands when heated), a phenomena referred to as thermosteric rise. About 30% of contemporary sea level rise can be attributed to thermal expansion (von Schuckman et al., 2018).

The European Environment Agency website¹ states that global mean sea level in 2016 was the highest yearly average since measurements started in the late 19th century; it was about 20 cm higher than at the beginning of the 20th century.

The Fifth Assessment Report from the IPPC predicts, with medium confidence, that global mean sea level rise for 2081–2100, relative to 1986–2005, will likely be in the range of 0.26 to 0.82 m for the different possible future climate scenarios, but that under Representative Concentration Pathway (RCP) 8.5 the rise in sea level by 2100 will be in the range of 0.52 to 0.98m (IPCC, 2013). The more recent IPCC report on the effects of global warming of 1.5°C (IPCC, 2018) projects that for this rise in temperature the global mean sea level is likely to rise 0.26 to 0.77m by 2100, and by 0.1m more with a temperature rise of 2°C, although the model ensembles predict rises of up to 0.99m and 1.17m (at the 90%ile) respectively. However, a rise of up to 2m by 2100 is considered plausible (Jevrejeva et al., 2014, DeConto and Pollard, 2016). Sea level rise will continue beyond 2100 even if global warming is limited to 1.5°C in the 21st century (IPCC, 2018).

The UK Climate Projections (UKCP18) Marine Report (Palmer et al., 2018) includes sea level rise projections to 2100, relative to a 1981 – 2000 average. This report predicts mean sea level rise around the UK coastline will likely be in the range of 0.08 to 0.70m for RCP2.6, 0.15 to 0.83m for RCP4.5 and 0.30 to 1.15m for RCP8.5. The extent of predicted sea level rise varies substantially by geographic location with the largest increases expected in the south of the country, due to a number of factors that affect regional sea level change including glacial isostatic adjustment.

A 2013 study by the National University of Ireland, Galway, forecast an overall sea level rise of approximately 0.47m using a regional ocean model to downscale a 120 year period of the SRES A1B Scenario from AR4 (Olbert et al., 2012). Since the early 1990s (1993) a sea level rise of c. 3.5 cm per decade (currently c. 3.4 mm/year) has been observed. Earlier tide gauge records pre-1990 show sea level rise of 1–2 mm/year for Ireland's coasts (Devoy, 2008, cited in Desmond et al. 2017).

The rise in sea level varies spatially around the globe and measurement using satellite data has shown a global sea level rise of 3.3mm per year between 1993 and 2006. This data indicates that the sea level rise on the North West Shelf, which includes the sea around Ireland, has risen by 2.6mm over the same period (von Schuckman et al., 2018). These values are corroborated by tidal records from Newlyn in Cornwall which indicate a mean sea level rise of approximately 1.7mm per year since 1916 (Dwyer and Devoy 2013). Various studies have shown that during the 20th century, sea level rise has been accelerating (Church & White 2006, Church & White 2011, Jevrejeva et al., 2008, von Schuckman et al., 2018) and that there has been an increase in extreme sea levels and waves in recent decades (Woodworth & Blackman 2004, Menéndez & Woodworth 2010).

A rise in mean sea level may lead to an increase in the rates of beach and coastal erosion, which in turn may increase coastal flood risk. Coastal retreat rates along the Atlantic coast are currently 0.5 to 1.0m/year in those areas most affected by storms and will be increased in the future as sea levels rise (Nolan et al., 2009).

¹ <https://www.eea.europa.eu/data-and-maps/indicators/sea-level-rise-5/assessment>

D.5 Storm Surges

In a warming climate there are concerns that storm surges may increase in frequency and intensity due to a combination of rising sea level and an increase in the frequency of extreme weather, including storms (IPCC, 2014).

According to the IPCC report, there is likely to be an increase in the number of intense cyclones and associated strong winds, particularly in winter over the North Atlantic, however, there is low confidence in region-specific projections of frequency and intensity. This could have a direct impact on storm surges, which are primarily caused by low pressure and strong winds. Dunne *et al.* (2008) states that rising sea levels will enhance the impact of storm surges and station data analysis shows increases in the frequency of such occurrences at all sites in future simulations.

However, there is still uncertainty around impact on storm surges and the UKCP18 Marine Report suggests, based on storm surge modelling work, a best estimate of no significant additional increase in the statistics of extreme water levels associated with atmospheric storminess change only (Palmer *et al.*, 2018).

D.6 Wave Heights

Accelerated sea level rise has usually been considered as the major climate change impact on coastal systems. However, for many coasts, changes in wave and surge conditions are potentially more important. The potential change in the hydrodynamic boundary conditions may exacerbate the situation at defences that are already under attack during extreme sea states or may cause defences that are now considered to be safe to be deemed unsafe in the future (de Winter *et al.*, 2012).

In the southwest of Ireland, significant wave heights (the mean height of the highest 1/3 of waves) have increased by 0.8 m per decade (Nolan *et al.*, 2009). Gallagher *et al.* (2013) predicted an overall decrease in mean significant wave heights for the period 2031-2060, with respect to the period 1981-2009, with a maximum decrease in the winter mean of 20 cm.

The UKCP18 Marine Report projections suggest average wave height changes of the order of 10-20% and a general tendency towards lower wave heights in the 21st century. Changes in extreme waves are also of the order of 10-20%, but there is no agreement in relation to whether the change is an increase or decrease (sign of change) among the model projections (Palmer *et al.*, 2018).

Record-breaking wave heights were observed along the European coast at two monitoring stations in the northwest of Great Britain, particularly during the years 2009, 2013 and 2014. For example, in 2013, the buoy in the north of the British Isles showed the highest-ever significant wave height recorded by such an instrument, reaching 19 metres.

D.7 Sea Temperatures

Desmond *et al.* (2008) report an increase of 0.85°C in Irish coastal sea temperatures since 1950 with 2007 being the warmest year in Irish Coastal records. The Copernicus Marine Service Ocean State Report states that, between 1993 and 2016, sea surface temperatures at the North West Shelf have increased by 0.3°C per decade (von Schuckman *et al.*, 2018).

The trends are similar to what has been observed globally, with reports that ocean warming is largest near the surface, and the upper 75m warmed by 0.11°C per decade over the period 1971 to 2010 (IPCC, 2013) and are predicted to continue over the coming decades with possibly large impacts on marine ecology. The Copernicus Marine Service Ocean State Report states that global sea surface temperature warmed over the period 1993-2015 at a rate of 0.16°C per decade (von Schuckman *et al.*, 2018).

D.8 Weather Extremes

Climate change is not only reflected in terms of the average temperature, precipitation, etc., but also in the frequency and intensity of extreme weather conditions. According to Dunne *et al.* (2009), modelling the sensitivity of the climate system to Atlantic sea surface temperatures suggests that there will be an increase in the frequency of the very intense cyclones that have maximum wind speeds of more than 30 m/s; and increases in the extreme values of wind and precipitation associated with the cyclones. This will translate into an increased risk of storm damage and flooding. The consensus among different modelling approaches is that extreme rainfall events are likely to increase in frequency in autumn and winter. However, there is still considerable uncertainty in these projections and further research is required (Dunne *et al.*, 2009).

D.9 General Impacts of Climate Change

According to JRC PESETA III Report (Ciscar *et al.*, 2018), climate change due to global warming will induce a broad range of environmental and socio-economic impacts across Europe, without taking into account planned or public adaptation. Many impacts on society and the environment will be connected to changes in climate extremes due to their disproportionate rise compared to the corresponding change in climatological averages. River flood risk is projected to increase in many regions of Europe. Coastal floods, especially in the second half of this century with accelerating sea level rise, will show a dramatic increase along most European coastlines.

In several impact areas, there is a clear geographical north-south divide: countries in the south will be impacted more by global warming compared with the northern parts of Europe. From the economic perspective, the potential impact on welfare (expressed as consumption) due to six impact categories (residential energy demand, coastal floods, inland floods, labour productivity, agriculture and heat-related mortality) has been assessed. The EU overall welfare loss under a high emissions scenario (RCP 8.5) is estimated to be around 1.9% of GDP (€240 bn) per year at the end of the century, but it should be noted that the list of considered impacts is incomplete because key climate impacts cannot be quantified (Ciscar *et al.* 2018).

The JRC also studied the costs and benefits of adaptation, with the objective to maintain a 1 in 100-year level of flood protection across Europe into the future. The reduction in damages that could be achieved through effective adaptation is estimated at €53 billion/year by the 2080s, at a cost of €7.9 billion/year (JRC, 2014).

Damage from floods has increased, but evidence linking this to climate change is weak, because of a lack of data and the effect of past flood risk management. It seems that there has been a measure of adaptation but that exposure of assets at risk has increased (Norwegian Meteorological Institute, 2013).

As a result of the increases in the frequency and intensity of heavy rainfall predicted by climate models, it is likely that flood risk will increase over much of Europe (Norwegian Meteorological Institute, 2013).

The future magnitude and frequencies of floods are not clear, in part due to the uncertainty about the future evolution of the underlying causes but also because of other factors, including the effects of human intervention.

Climate change is likely to have significant impacts on freshwater hydrology (Broderick and Murphy, 2013). The interaction between the climate system and land-surface hydrology is complex and any changes in precipitation and evaporation will result in knock on effects for the rest of the hydrological cycle (Broderick and Murphy, 2013). Murphy (2013) conducted a review of recent Irish research into the hydrological impacts of climate change. While there is indication of wetter winters and drier summers from a number of different studies, he argues that *“it is difficult at this stage to attribute observed trends in observations of Irish river flows to anthropogenic climate change”*.

Steele-Dunne et al. (2008) studied nine Irish catchments to estimate the impact of climate change on hydrology in Ireland. Their research suggested that predicted increase in extreme precipitation events will lead to an elevated risk of flooding with this being particularly significant in the southwest of the country, and those catchments with fast response times.

The pattern of human settlement in Ireland has been concentrated on urban development along the rivers and coasts with more than 50% of Ireland’s population currently coastal in distribution, mainly in urban environments from small seaside towns to the main urban centres (Desmond et al., 2017), creating the potential for significant increases in the event of substantial rises in mean sea level.

It is important to note that flood damage simulations are subject to a high degree of uncertainty related to the lack of definitive projections of extreme precipitation. In the Irish context, a recent study has estimated that approximately 350 km² of land is vulnerable under a 1m sea level rise with potential economic costs relating to property insurance in the region of €1.1 billion per year (Flood and Sweeney, 2012).

The impacts of climate change specifically on flooding and flood risk are described in Section 5.2.

D.10 Uncertainty

According to EU BASE Policy Brief (Bosello *et al.* 2013), a key limitation to planning climate change adaptation strategies stems from uncertainties and insufficient knowledge on the spatial and temporal patterns of climate change and its impacts. Uncertainties over future climate change inherently exist in all projections of climate change and its impacts.

A number of methods including complex climate models have been employed to provide detailed information about future climate. An output of one or more climate models simulating one or more scenarios of future prediction, e.g. global warming, is simply an indicative, subject to many assumptions and suitable for certain purpose. Stainforth *et al.* (2007) suggests that the interpretation of climate models to inform policy and decision support must consider at least four distinct sources of uncertainty, namely: forcing uncertainty, initial condition uncertainty, model uncertainty, and model inadequacy.

Uncertainties arise in part from an incomplete knowledge of factors considered outside the climate system (forcing uncertainty), yet affecting it, such as future greenhouse gas emissions or land use change (Stainforth *et al.* 2007). Our imprecise knowledge of the current state of the climate system

(initial condition uncertainty) or imperfect characterisation of initial conditions introduces perdition errors within the computational models. Climate change models may yield different responses as a result of differences in physical and numerical formulations and external forces (model uncertainty). Downscaling of global models to smaller geographical scales can also increase uncertainty.

There is also uncertainty relating to the natural variability of the climate system that occurs in the absence of external factors and includes processes intrinsic to the atmosphere, the ocean, and the coupled ocean-atmosphere system (Deser *et al.* 2012). Other sources of uncertainty include changes in social, economic, environmental and technical systems as well as potential changes in the regulatory system.

When investigating how best to adapt to climate change, these uncertainties can introduce further inaccuracy into assessments of current and future vulnerabilities to the impacts of climate change and evaluating adaptation measures. Incorrect projection now could lead to either higher investment or to exposing communities to greater risks. However, with flexible strategies, adaptation decisions can and need to be made today, and uncertainty should not be used to justify inaction.

In relation to flood risk management, an incomplete understanding of the workings of the hydrological system, a lack of data and the volume of complex computations required to simulate every hydrological process can create uncertainty in climate change adaptation decisions (Murphy and Charleton, 2008). The impacts of climate change on hydrology are complex and varied. The individual characteristics of a catchment play a central role in determining the hydrological response to climate change.

The main sources of uncertainty in flood risk management are:

- Natural meteorological variability
- Observational data;
- Hydrology;
- Hydraulic model structure;
- Assessing the effects of future climate change;
- Assessing the effects of future catchment change; and
- Assessing the consequences/vulnerability.

In an effort to deal with uncertainty, any impact assessment of climate change should incorporate scenarios of change so that a number of possible futures can be accounted for. Where the different scenarios lead to divergent results, decision making in adapting to climate change becomes challenging, with traditional decision-making tools proving inadequate (Murphy and Charleton, 2008).

J. Hall *et al.* (2012) suggests that the way to deal with climate change uncertainty is to ensure 'robust' adaptation. Robust adaptation measures are measures that remain functional under a wide range of possible climate change scenarios.

Quantifying uncertainty in climate change projections is of fundamental importance for strategic approaches to adaptation and mitigation. Given the multiple uncertainties in relation to climate change and climate change adaptation, and the fact that many of these cannot be adequately quantified, ongoing research on decision-making in the face of uncertainty is needed.

An approach to assessing options and decision-making under uncertainty involves the 'scenario-neutral' approach, whereby the impact on one particular parameter (e.g., percentage increase in flood flow) is derived for all combinations over a range of plausible potential changes in two other parameters (e.g., annual rainfall and rainfall seasonality). Rather than providing one particular possible future, that is highly uncertain, the approach allows possible adaptation options to be tested for resilience in terms of the percentage of ensemble members that a given adaptation option could cater for. Such an approach has been applied in Ireland with respect to flooding (Broderick and Murphy, 2017).

APPENDIX E

ADAPTATION ACTIONS FOR FLOOD RISK MANAGEMENT ACTIVITIES

The current flood risk management activities that take place within Ireland, and that form the scope of this Plan, are set out in Section 1.5 and Appendix B herein. Each of these activities are addressed below in terms of how adaptation for the potential impacts of climate change should be incorporated and embedded for future application.

E.1 DATA COLLECTION AND FLOOD RISK ASSESSMENT

E.1.1 Hydrometric Monitoring

High quality, long-term hydrometric records are critical for observing and monitoring the effects of climate change on the hydrological regime, e.g., changes in mean sea level or flood frequency.

The EPA published a report in 2008 entitled 'Climate Change – Implementation of the Global Climate Observing System in Ireland' (EPA, 2008), which provides an assessment of the progress on actions for Ireland under the Implementation Plan of the Global Climate Observation System (GCOS), established under the United Nations Framework Convention on Climate Change (UNFCCC). The report concludes that Ireland is generally fulfilling its climate observation commitments in regard to the UNFCCC, but that there are a number of areas in which additional funding and resources are required to augment existing programmes or to put in place new monitoring initiatives in order to meet the GCOS requirements fully. The report also concludes that further assessment is required to determine national and local needs for climate change observation.

Research under the HydroDetect Project (EPA, 2013c) identified a number of hydrometric stations within the Irish Reference Network of high-quality gauging stations with limited artificial influences to facilitate more strategic monitoring of climate-driven variability and change in hydrological indicators to enable more confident attribution of detected trends. The EPA launched a National Hydrometric Review and the *Qube* flow model in 2018. Based on this, some additional stations may be required to address any data gaps in terms of regional coverage and catchment types (size, soil and geology, elevation and slope, etc.). These needs are however yet to be identified and so no additional stations are proposed at this time under this plan. However, the schematisation and performance of the network will need to be kept under review as research progresses.

Objective 1, Adaptation Action 1.A - OPW, EPA and Local Authorities, 2021 and Ongoing: Engage with findings and recommendations arising from climate change research initiatives such as the Global Climate Observation System National Committee reports (expected in the next two years) and where possible, align hydrometric monitoring objectives and resources with climate change objectives.

Enhancements in the communication of hydrometric data to emergency response authorities could facilitate a more effective response to flood events that are expected to become more frequent and/or severe due to climate change. Efforts to develop real time reporting to inform the response to extreme events for the purpose of emergency response on a national basis will therefore help mitigate the impacts of climate change over the long-term.

The hydrometric monitoring programme, in conjunction with climate projections, will also inform the need for triggering considerations of future interventions, such as adaptation to existing or planned flood relief schemes or the need for further additional measures in areas that may currently be at low risk but that are vulnerable to the effects of climate change, as described below.

E.1.2 Flood Risk Assessment

The flood risk nationally has been screened through the Preliminary Flood Risk Assessment (PFRA) to identify the areas or communities at potentially significant flood risk. The screening identified 300 communities that are home to over 3 million people, about two-thirds of the population, and include approximately 80% of the properties at risk nationally from the main sources of flooding, i.e., rivers and the sea. The 300 communities were the subject of detailed risk and impact assessments through the CFRAM Programme. This assessment included the preparation of flood maps for potential future scenarios taking into account the potential impact of climate change, as well as for the current conditions.

The 'Floods' Directive is cyclical, requiring a review, and if necessary update, of the PFRA, the flood maps and the FRMPs on a six-yearly cycle. The OPW is currently leading the second cycle of implementation of the Directive, which includes:

- a review of the national screening for flood risk, which includes indicative mapping and risk assessment for potential future risk as well as under current conditions, and,
- ongoing reviews of the flood maps prepared through the CFRAM Programme as necessary.

In undertaking the reviews of current and potential future flood risk, consideration needs to be given to the most up-to-date research and projections of climate change at that time from national and international sources, with use made of all appropriate and available information on flood hazard (extents, depths, frequencies, etc.). The PFRA and flood maps as updated will be published.

Objective 1, Adaptation Action 1.B - OPW, 2024 and Ongoing: 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.

Objective 1, Adaptation Action 1.C - OPW, 2020 and Ongoing: Review the flood risk, including potential impacts of climate change, for areas designated as being at potentially significant flood risk.

The relevant authorities or bodies responsible for urban storm water drainage and/or water-bearing infrastructure are also required to review the potential risk associated with the infrastructure, as part of the cyclical review of the PFRA and, where areas of potentially significant flood risk are identified, to prepare flood maps and define measures to reduce or manage the flood risk that will be included in the relevant FRMP. The review of the PFRA needs to take account of the potential impacts of climate change.

Objective 1, Adaptation Action 1.D - Local Authorities, Waterways Ireland, ESB and Irish Water 2024 and Ongoing: Through reviews of the Preliminary Flood Risk Assessment, informed by the most up-to-date research and projections of climate change, assess the potential risk of flooding from urban storm-water drainages systems and from water-bearing infrastructure.

The FRMPs are to be reviewed in 2021 and thereafter on a six-yearly cycle, to review and if necessary update the plans for the management of flood risk nationally and in areas of potentially significant flood risk. The reviews must take into account the potential impacts of climate change, again with consideration given to the most up-to-date research and projections of climate change, and the reviews of current and potential future national and local flood risk. The reviews should inform adaptation actions that may be required in the coming years for flood relief schemes previously completed (see Appendix B.2), as well as any additional measures for other areas or communities.

The review and any update of the FRMPs needs to be undertaken in coordination with the reviews / updates of the River Basin Management Plans (RBMPs) that are required under the Water Framework Directive. This is particularly important when considering Natural Water Retention Measures that may counter-act the effects of climate change by decreasing runoff and increasing groundwater recharge, as well as providing environmental benefits.

The review of the FRMPs will require a Strategic Environmental Impact Assessment and assessment under the Habitats Directive. As part of the SEA, potential adverse cumulative and in-combination environmental effects will be assessed and taken into account when considering particular adaptation measures.

The OPW will coordinate the reviews with the implementation of actions from the other priority Sectoral Adaptation Plans being developed under the National Adaptation Framework and local adaptation strategies by Local Authorities.

Objective 1, Adaptation Action 1.E - OPW, Local Authorities, Waterways Ireland, ESB and Irish Water 2021 and Ongoing: The OPW will ensure that its six-yearly review of the Flood Risk Management Plans will be informed by the most up-to-date research and projections of climate change on flooding and flood risk, and will include other sector led adaptation measures being implemented under the National Adaptation Framework.

E.1.3 Further Research

There remains, and will continue to remain for the foreseeable future, considerable uncertainty with respect to the potential impacts of climate change on the drivers of flooding, and hence on flood hazard and risk.

However, further research can improve our understanding of plausible or more likely future scenarios, and hence improve our understanding of potential climate change impacts and the associated vulnerability of communities and areas around the country to potential future changes. This, in turn, can inform appropriate adaptation planning and action.

There are certain information needs that, if addressed, can improve our understanding of potential flood risk futures, and hence enhance our adaptation efforts. These include:

- The likely range of changes, including plausible maxima, in climatic parameters relevant to flooding, in particular:
 - Extreme rainfall projections at a fine temporal and spatial resolution,
 - Projections of factors influencing sea levels, storm surge events and wave set-up,

- Improve our understanding of the response of different catchments and catchment characteristics to changes in rainfall patterns,
- Application of likely and plausible maximum changes in climatic parameters to Irish catchments, taking account of their characteristics, to determine the possible future fluvial flood hazard to Irish communities,
- Application of likely and feasible maximum changes in climatic parameters on sea levels, storm surge events and wave set-up to determine the possible future coastal flood hazard to Irish communities,
- Application of likely and feasible maximum changes in extreme short duration rainfall events to determine the possible future pluvial flood hazard to Irish communities,
- Application of likely and feasible maximum changes in climatic parameters to Irish catchments, taking account of their characteristics, to determine the possible future groundwater flood hazard to Irish communities, and
- Assessment of the flood risk and vulnerability of Irish communities through modelling of a range of likely and feasible maximum changes in flood hazard.

Elements of the above research and assessment have been undertaken through past research projects and under the CFRAM Programme. Specific research projects currently proposed or under consideration include:

- **Catchment Response:** Building on previous work undertaken by NUI Maynooth to characterise the response of catchments to changing annual and seasonal rainfall (Broderick et al, 2017), further research is being considered by the Eastern and Midlands CARO and the OPW with regards to extending this research to consider the response to changes in short-duration rainfall extremes.
- **Soil Moisture Deficit:** A research call has recently issued through the EPA Climate Research Programme in relation to soil moisture measurement. The output from this research would enhance the precision of flood forecasting modelling as part of adaptive flood risk management. This will contribute to the achievement of Action 1.A.
- **Coastal Impacts:** A research call has recently issued through the EPA Climate Research Programme in relation to the effects of climate change on sea levels, including astronomical tide levels and storm surge, and on wave climate conditions around the coast of Ireland. The outputs from this research would improve the knowledge of the potential impacts of climate change on sea level, storm surge and wave climate conditions and would provide valuable information for government bodies, local authorities and anyone involved in the planning and/or management of infrastructure, assets and flood risk around the coast of Ireland.
- **Groundwater flooding:** GSI has undertaken a groundwater flooding monitoring and mapping programme between 2016 and 2019 and is developing the first predictive groundwater flood map for Ireland (<<https://www.gsi.ie/en-ie/programmes-and-projects/groundwater/projects/gwflood/Pages/default.aspx>>)
- **Coastal Vulnerability Index:** GSI is undertaking a new coastal vulnerability mapping initiative, which will provide an insight into the relative susceptibility of the Irish coast to adverse impacts of sea-level rise. This method, based on physical parameters, was adapted to the local context to explore the relationships between drivers, (e.g.: sea level rise), geological boundary conditions and the coast's responses.

Objective 1, Adaptation Action 1.F - EPA, Met Éireann, Geological Survey Ireland, Irish Water & OPW, Ongoing: Improve, through research, the understanding of the potential impacts of climate change on the climatic parameters that can influence flooding and flood risk management.

E.2 CAPACITY BUILDING

In the context of climate change, capacity building is developing the technical skills and institutional capabilities to adapt to a changing climate (IPCC, 2014). An organisation with adaptive capacity has the ability to craft and adopt new means to achieve its goals as circumstances change.

The OPW will continue to maintain and enhance the internal adaptive capacity through ongoing training and staff development. In that regard, the OPW and its staff continue to build an understanding of expected climate-change and adaptation approaches relating to flood risk management. Climate adaptation will continue to be embedded in the normal course of business and inform its decisions.

The OPW is an important source across Government and the public sector of technical information, advice and support on climate change impact on flood risk and flood risk management. The OPW will continue to be available and provide opportunities, working with other Sectors and the local authorities, including through their network of Climate Action Regional Offices, to help build awareness and capacity with its partners, stakeholders and local communities in relation to the impacts of climate change on flood risk, and that can inform them on their strategies, approaches and opportunities for adaptation.

Objective 1, Adaptation Action 1.G - OPW, 2019 and Ongoing: Publication of the PFRA, as reviewed and updated, and of the most up-to-date flood maps for current and potential future scenarios.

Objective 1, Adaptation Action 1.H - OPW, Ongoing: The OPW will continue to strengthen its adaptive capacity and further embed adaptation within work processes and decision-making.

Objective 1, Adaptation Action 1.I - OPW, Ongoing: The OPW will continue to support Local Authorities, including through their network of Climate Action Regional Offices, and other Sectors to help further build awareness and capacity in relation to the impacts of climate change on flood risk and possible adaptation opportunities led by other sectors.

As noted under Section E.1.1, building capacity within the hydrometric programme is required to monitor climate impacts to inform future research and analysis, as well as flood risk management planning with regards to activating future adaptive interventions.

E.3 FLOOD RISK PREVENTION

Spatial planning is critical to the successful management of climate change impact to flood risk management. The Guidelines on the Planning System and Flood Risk Management (DEHLG/OPW, 2009) provide a clear, transparent framework for forward planning and development management with due consideration of flood risk.

The guidance on zoning is based on existing risk, but with a recommendation that a precautionary approach be taken to potential future risk including the potential impacts of climate change, stating that “A Precautionary approach should be applied, where necessary, to reflect uncertainties in flooding datasets ... and the ability to predict the future climate ...”, and that “Development should be designed with careful consideration to possible future changes in flood risk, including the effects of climate change ... so that future occupants are not subject to unacceptable risks”.

This approach, of assuming current conditions but taking account of potential future conditions, is necessary due to the uncertainty as to what the future changes to the flooding regime will be. However, it is this uncertainty that equally makes provision for future change difficult to implement efficiently and effectively, and it is not possible to define a prescribed set of measures to implement the precautionary approach that would be applicable in all locations. Notwithstanding this, there are a range of options that can be considered and implemented as appropriate in a given location, taking account of the potential future changes to the flooding regime and the Flood Zones as defined in the guidelines:

- Leave potential future floodplains clear of development (e.g., de-zone areas, zoning areas as green space or as recreational playing fields, requiring potentially higher-risk lands in future scenarios to be zoned as green space within a zoned parcel of land, etc.),
- Define minimum floor levels such that potential future increase in flood extent and level will not cause internal flooding,
- Ensure that sufficient space is provided and kept free of development to permit the construction of flood defences in the future, if necessary,
- Ensure that access and egress to a zoned / developed area will still be possible in a safe manner during floods, under potential future flooding regimes, and
- Set policies or objectives that require flood resilient or resistant building standards (including traditionally built buildings), or ensure that land-use/development is adaptable to become either flood resilient or resistant or could be converted to a lower vulnerability land use in the future.

Which of the above measures, individually or in combination, are most appropriate for a given area will depend heavily on the local context and the potential increase in flood extent, depth and level. However, such information on potential future flooding can be derived through an appropriate flood risk assessment, informed by the flood maps prepared through the CFRAM Programme where available. This assessment should inform decision-making and suitable adaptation requirements within the planning and development management processes.

Where regeneration or development in or around town centres is deemed necessary in flood prone areas, and has been deemed appropriate through the Justification Test as set out in the Guidelines, then consideration of suitable flood risk management measures for the development should take account of potential future increases in flood extents and levels. This includes areas that may currently benefit from flood protection, where the standard of protection may fall in the future, as discussed in Section E.4.1.

Objective 3, Adaptation Action 3.A - DHPLG, OPW & Planning Authorities & Developers, Ongoing: Ensure that potential future flood information is obtained and/or generated through a Flood Risk Assessment (FRA) that is then used to inform suitable adaptation requirements within the planning and development management processes in line with the Guidelines on the Planning System and Flood Risk Management (DEHLG/OPW, 2009).

Consideration needs to be given to the potential for increased intensity of rainfall when designing drainage systems and urban storm water drainage systems for new development. This is discussed further in Section E.4.3.

E.4 FLOOD PROTECTION

This Plan addresses the requirements for both existing and future flood relief schemes.

E.4.1 Flood Relief Schemes

Existing Flood Relief Schemes

As of the end of 2018, the OPW had completed 43 flood relief schemes. As sea levels continue to rise, and if river flood flows and levels rise as a result of the impacts of climate change, the standard of protection offered by these flood relief schemes will be reduced.

The potential impacts of climate change on the standard of protection of the existing, completed flood relief schemes was assessed under the CFRAM Programme. As the potential impacts of climate change evolve over the coming decades, this assessment can in time inform planning for how the potential decrease in standard of protection can be managed, where no provision for climate change was made during design or construction.

Options for adaptation include:

- Enhance or amend the existing scheme to maintain the standard of protection,
- Introduce other measures to maintain the standard of protection, and
- Maintain the existing scheme, accepting that standards of protection will fall, and introduce other measures to manage or reduce the increasing flood risk.

As with schemes under design and construction, there is no 'one size fits all' approach to adaptation. The choice of option will depend on many factors, such as the impact of climate change, potential rate or degree of reduction in the standard of protection and the consequences of this, and the costs, benefits, impacts and acceptability of each option.

Examples of such future adaptation actions might include tidal barriers for some of our large towns and cities situated on the coast or estuaries, or upstream storage for communities prone to fluvial risk. These future adaptation actions may not be required, viable or environmentally or socially acceptable at this time, with alternative viable and effective measures applied in the interim, but will need to be assessed in the future in relevant areas as the flood risk increases.

The need for such interventions will be triggered through the 6-yearly review cycle of flood risk, as required under the EU 'Floods' Directive (see Actions 1.B to 1.E). These regular reviews will be informed by observations of sea level rise and changes in rainfall patterns and flow regimes through the hydrometric monitoring programme (see above and Action 1.A) and the climate projections current at that time (Action 1.F). The trigger points can be identified in a timely manner to allow for the analysis, design and construction processes.

While maintenance of completed schemes, to protect the current standard of protection will continue, a thorough assessment of the adaptation measures for each will be required over the coming decade. This assessment will be location specific and will inform future investment in adaptation of these schemes, taking account of their condition and possible costs of adaption versus replacement.

Objective 2, Adaptation Action 2.A - OPW, 2027: Assessment of appropriate adaptation measures for those existing flood relief schemes, where climate change may in time impact the current standard of protection.

Ongoing and Planned Flood Relief Schemes

Apart from the flood relief schemes proposed in the FRMPs, the OPW currently has 35 other schemes in design, planning or under construction. Provision for climate change has been included in the design of these schemes; either through the 'Adaptive' or 'Assumptive' approach (see below), where the economic cost-benefit analysis provided for the marginal adaptation costs.

The CFRAM Programme identified that 34,500 assessed properties have a 1% chance of experiencing a significant flood event in any year and that 95% of these properties can be protected against these flood events with flood relief schemes. All 118 additional schemes set out in the FRMPs to be built over the coming decade through the Government's €1bn investment in flood relief took into account how adaptable the proposed scheme might be to cope with the potential impacts of climate change. Progressing this programme will achieve the greatest return for Government investment, both nationally by targeting flood risk investment where the impact from flood risk is greatest and regionally by utilising OPW and Local Authority capacity to deliver schemes.

For the 118 new flood relief schemes, a requirement has been set to assess the adaptation options to the potential impacts of climate change as part of the detailed scheme development, design and implementation, and for a Scheme Adaptation Plan to be prepared for each Scheme on foot of these assessments. The assessment and Scheme Adaptation Plan should determine the most robust, 'no regrets' strategy and design for short-term investment in flood risk management measures, taking account of the range of mid- to long-term future investments that may be necessary. This will help ensure that future flood relief works are sustainable and resilient to change.

The assessment of alternative adaptation approaches and options may be done making use of methods such as decision-tree analysis in conjunction with multi-criteria analyses and economic cost-benefit assessments. There is no 'one-size-fits-all' approach to applying adaptation to a flood relief scheme. A range of factors can influence what the preferred option or range of options might be, including:

- Changing degrees of risk for changing flood flows or levels into the future,
- the costs of works to address current risk, and of taking different approaches to dealing with the potential impacts of climate change as below, taking account of the need to maintain a positive benefit-cost ratio for any proposed scheme
- what is most appropriate now to deal with the existing risk,
- the location of the works and how they might impact on local amenity and the environment
- the nature of the works and whether they can be adapted in the future, or would need full replacement
- what alternative steps might be available in the future to address rising hazard and/or risk

Possible adaptation measures for a scheme could include:

- A) The Assumptive Approach, where an allowance is built into a scheme now (e.g., additional height to a defence or additional capacity to a channel or culvert).
- B) The Adaptive Approach, whereby the measure is designed and built now to permit future changes (e.g., future increases in height of a defence or increases of conveyance capacity of a channel). Note that future increases in height of a defence may be demountable where it would not be acceptable / appropriate to install higher permanent defences

- C) The adoption of alternative or additional measures in the future to address changes in risk patterns (e.g., building a new defence to cut off a new flow path arising from increases in flood flows / levels, implementation of catchment runoff control measures (e.g., storage or NWRMs) or removal of assets from the at-risk areas)
- D) Acceptance of rising flood probabilities and enhancing non-structural responses to flooding (improved flood forecasting, emergency response and/or resilience)

A Scheme may adopt two or more of the above approaches for different elements of the scheme, as appropriate to the context of each, and/or for different time horizons / degrees of climate change impact.

Each scheme will therefore be subject to an assessment of adaptability for future climate change within its particular context, and, as appropriate, provisions will be made in the design and construction of the schemes to cater for potential future changes. The Brief for the detailed development of the schemes includes a requirement for a Scheme Adaptation Plan that will set out how climate change has been taken into account during the design and construction, and what adaptation or alternate measures might be needed and when into the future.

Ongoing monitoring of climate change indicators and projections will be required to identify when 'trigger points' may be reached necessitating the need for further investments or action.

Objective 2, Adaptation Action 2.B - OPW, 2019 and Ongoing: The Brief for the detailed development of flood relief schemes to include a requirement for a Scheme Adaptation Plan that will set out how climate change has been taken into account during the design and construction, and what adaptation measures might be needed and when into the future.

Local Flood Relief Schemes

The OPW's Minor Flood Mitigation Works and Coastal Protection Scheme provides funding to Local Authorities to undertake minor flood mitigation works or studies, costing up to €750,000 each, to address localised flooding and coastal protection problems within their administrative areas. Local Authorities are required to maintain these schemes, when built.

Local authorities should consider climate change when developing local flood relief solutions that are submitted for funding under the OPW Minor Flood Mitigation Works and Coastal Protection Scheme, although the scale of the assessment should be proportionate to the scale of works and degree of flood risk.

Objective 2, Adaptation Action 2.C - Local Authorities, Ongoing: Proposals submitted under the Minor Works Programme should take account of the potential impacts of climate change to ensure, where possible, that any measures proposed are adaptable to possible future changes.

Green Infrastructure

NWRMs are a form of Green Infrastructure aimed at reducing overland runoff and/or increasing the attenuation of flows down a river system. Such measures can have a wide-range of benefits including for water quality, sediment control, climate mitigation through carbon sequestration, biodiversity and also flood reduction.

The OPW is involved in a number of initiatives involving NWRMs that are relevant to the Draft Biodiversity Sectoral Climate Change Adaptation Plan, as below, and is working with the EPA to explore mechanisms for promoting Integrated Catchment Management that would include NWRMs and to assess the potential for NWRMs as part of the development of the 118 flood relief schemes identified in the FRMPs.

Objective 3, Adaptation Action 3.B - OPW & Other Stakeholders in Catchment Management, Ongoing: The OPW, in coordination with other relevant stakeholders, will continue to enhance its knowledge and capacity with regards to NWRMs and will assess the potential for NWRMs as part of the development of the future flood relief schemes.

Potential Future Flood Relief Schemes

In addition to the flood relief schemes proposed under the FRMPs, the need for further, additional schemes or other flood risk management measures may arise over the coming decades for other communities, where the current level of risk is low, due to the projected increases in flood risk. Some of the communities that would be vulnerable to future increases in flood risk and where potential future interventions may be required have been identified through the future scenario analysis under the CFRAM Programme, as set out in Appendix E of the FRMPs that are available from www.floodinfo.ie.

The trigger points to commence consideration of such future interventions can be identified and activated in the same manner as the future adaptation actions that may be required in relation to communities benefitting from existing flood relief schemes.

Costs of Adaptation

The aim of adaptation is to promote future resilience in a cost-effective manner. While adaptation measures should reduce future costs to preserve the required standard of protection, they will typically require additional costs in the short-term. While the actual marginal costs for adaptation will depend on the local context and the approach taken, an indicative analysis has shown that typically the adaptive approach, as described above, has a lower short-term cost than an assumptive approach, i.e., providing for future enhancements (such as increasing wall heights) has a lower short-term cost than including the enhancement now.

It should be noted that while the 'Do Nothing' option will have the lowest short-term cost, future adaptation may require full replacement costs for some types of measure, e.g., flood defence walls or culverts for additional conveyance, which could be significantly more expensive in the long-run than making provision now.

The approach to, and hence costs of, adaptation for each scheme can only be determined within its particular context, and so cannot be set out herein.

Cost benefit analysis is a key economic appraisal technique under the Public Spending Code and is best practice in the appraisal, implementation and evaluation of capital projects and programmes, and is applied to flood relief schemes implemented by the OPW. The inclusion of potential future damages in the cost benefit analysis, together with a multi-criteria analysis of other adaptation benefits with regards to social, cultural and environmental impacts, would greatly inform a rigorous assessment of the appropriate adaptation approaches for the schemes.

Objective 2, Adaptation Action 2.D - OPW & DPER, 2021: The inclusion of potential increases in flood damages as part of the economic cost-benefit analysis for future flood relief schemes will be reviewed.

E.4.2 Drainage Districts and Arterial Drainage Schemes

Increased land saturation and water-logging may occur on lands benefitting from drainage schemes during winter months if winter rainfall increases. There is, however, no evidence currently available of the degree of increase in saturation or water-logging that may arise in potential futures, and the detrimental impact this could have on agricultural production is uncertain, which may be addressed through future research (see Section E.1.3).

The statutory requirements with respect to the maintenance of the drainage capacity of the Arterial Drainage Schemes and the Local Authority's Drainage Districts is to maintain these schemes to their design performance levels. Therefore no additional actions to change practice or increase capacity are proposed under this Plan.

Embankments that form part of the OPW's Arterial Drainage Schemes are also maintained to their design standard, through a rolling maintenance programme. A review of the potential impacts of climate change on the performance of the Arterial Drainage Scheme embankments needs to be planned, outside of the routine maintenance, particularly in those areas where property may be flooded in the event of over-topping of these embankments.

Objective 2, Adaptation Action 2.E - OPW, Ongoing: Progress a review of the current and future effectiveness of the protection provided by existing Arterial Drainage Scheme embankments to urban developments.

E.4.3 Urban Storm Water Drainage and Water-Bearing Infrastructure

Where the relevant authorities or bodies responsible for urban storm water drainage and/or water-bearing infrastructure plan for and develop further infrastructure, the potential future impacts of climate change should be taken into account in the location and design of the assets. This consideration should include potentially increasing flood risk from rivers, the sea and other sources (that may put the asset and/or its performance at risk), as well as the capacity of the infrastructure to cope with potentially increasing capacity requirements, such as the capacity of storm water drainage systems to cope with more intense rainfall, or the capacity and safety of naturally-fed reservoirs.

Objective 3, Adaptation Action 3.C - Local Authorities, Irish Water, ESB and Waterways Ireland, Ongoing: The planning and design of future assets should take into account, and be adaptable to, the potential future impacts of climate change.

As the planning authorities responsible for ensuring sustainable development, the Local Authorities should ensure that appropriate conditions are applied to ensure that the urban storm water drainage systems for new developments are adaptable to the potential future impacts of climate change. This may include storage ponds, permeable paving to reduce runoff and other forms of sustainable drainage systems that can have benefits to water quality, ecology and amenity as well as for flood risk reduction, as well as considering the conveyance and storage capacity of traditional piped systems. Irish Water has a role in avoiding future urban storm-water flooding by managing future connections to existing networks.

Objective 3, Adaptation Action 3.D - DHPLG & Local Authorities, in Consultation with Irish Water, Ongoing: The requirements for urban storm water drainage systems for new development should take into account the potential future impacts of climate change, including consideration of the use of sustainable drainage systems.

E.5 PREPAREDNESS

In some instances, it may not be possible to reduce the likelihood or severity of flooding to a community at risk. However, actions and measures can be taken to reduce the consequences of flooding, i.e., reduce the risk to people and damage to properties and other assets. Action can also be taken to make sure that people and communities are prepared for flood events. This can be achieved by being aware of and preparing for the risk of flooding, knowing when floods are likely to occur, and by taking actions immediately before, during and after a flood.

Non-structural measures, such as flood risk preparedness, response and resilience, are inherently adaptable as they typically involve little or no physical infrastructure. Some aspects of this activity however would require a degree of adaptation under increased frequency and severity of flooding, such as:

- the need for the provision of increased resources to respond to more frequent flood emergency events requiring response and/or a greater response requirement to more severe events, or,
- the need for increased technical resources (pumps, demountable barriers, etc.) to respond to more widespread and/or severe events.

The promotion of public awareness of their individual and community's flood risk and preparedness for flood events needs to be continued and adapted to climate change. This should include promoting the importance, to being able to measure flood risk and develop flood risk management measures, of people reporting flooding events through the OPW's National Flood Event Database (www.floodinfo.ie).

Objective 2, Adaptation Action 2.F - OPW & Local Authorities, Ongoing: Maintain and update on an ongoing basis the National Flood Event Database (www.floodinfo.ie).

The establishment of the Flood Forecasting Service is an important resource to support non-structural measures by further improving emergency response and community resilience. It will also give the further evidence to help consider the feasibility for Government to support other possible mitigation measures including Individual Property Protection. Pending its establishment the OPW and Local Authorities should maintain, and where possible improve, the operation of existing flood forecasting and warning systems, including the Tide and Storm Surge Forecasting Service.

Objective 3, Adaptation Action 3.E - Met Éireann, OPW, DHPLG & Local Authorities, Ongoing: Progress the establishment of the national flood forecasting and warning service.

A high level of Community Resilience was visible during the recent flooding events where communities and individuals worked successfully, over a sustained period in many cases, with the Local Authorities and other bodies to defend the homes and properties at risk of flooding. People came to the assistance of their neighbours and helped ensure that normal life continued, as much as possible, in flood affected areas.

The Framework for Major Emergency Management, which was developed and approved in 2006, highlights the importance of resilient communities and notes that the Principal Response Agencies (PRAs) can play an important role in the development and strengthening of resilient communities as part of their mitigation efforts. Educating and informing the public on possible emergencies is a vital element of that process. Community resilience is, therefore, one of a range of community development issues that should be addressed at a local and regional level between the Local Government structures available to the State and the PRAs.

Supporting communities to become more aware of and build resilience to flood events will be an important part of the non-structural solutions for flooding in the future, as well as harnessing the potential of communities in the response phase. It is clear that, in addition to sectoral designations as “communities”, those who are at risk of flooding in different parts of the country may be defined as “communities” also and would benefit from a resilient community approach.

The Department of Housing, Planning, and Local Government and the Department of Rural and Community Development are researching how community resilience may be advanced within the overall field of emergency management and is further developing this aspect as part of the overall review of the Framework of Major Emergency Management. This research will help to inform the framework through which community resilience for flood risk management can be supported.

Objective 3, Adaptation Action 3.F - DHPLG, DRCD & D/Defence, Ongoing: Progress research on how community resilience may be advanced within the overall field of emergency management and further develop this aspect as part of the overall review of the Framework of Major Emergency Management.



APPENDIX F

CROSS-SECTORAL IMPACTS RELATED TO FLOODING AND FLOOD RISK MANAGEMENT

TABLE F-1: IMPACTS OF FLOODING ON OTHER SECTORS

[NOTE: Flooding will cause a risk to people in all circumstances, and so this is not included in the list for each sector]

SEAFOOD	
Increased flows from rivers impacting on assets and water quality	- Increased ocean acidification from rivers causing damage to inshore / estuary shell fish and fish farms
Processing Sites and Urban Runoff	- Increased coastal flooding causing damage to processing and harbour facilities - Surface water run-off from coastal processing sites and urban areas causing pollution

AGRICULTURE	
Increased fluvial / ground-water flooding of land and farms	- Damage to Farm Houses and Farm Buildings - Loss of Crops: Loss of Income, Loss of Fodder - Detrimental Impacts on Animal Welfare - Anxiety / Stress for Farmers / Landowners - Restricted Access to Lands / Dwellings - Increased Runoff of Nutrients / Pollutants from farm land, yards, slurry tanks, etc. causing pollution of water courses
Increased flooding of agri-business properties	- Damage to Properties - Interruption of Service – Loss of business - Anxiety / Stress to Business Owners
Reduced drainage / water-logging of lands in winter	- Reduced Crop Output, Food Price increase - Reduced Use of Land for Grazing: Increased Supplement / Fodder Costs
Loss of soils	- Reduction in Crop Production - More Suspended Soils/ Nutrient / Pollutants in water courses - Erosion of river banks due to high flows in water courses

FORESTRY

Increased fluvial / ground-water flooding of Forestry sites	<ul style="list-style-type: none">- Loss of Tree crop / reduced yield / Reduction of quality in timber- Isolation of sites cut off by floods- Runoff of nutrients into nearby water courses
Increasing flooding of Storage yards and commercial facilities	<ul style="list-style-type: none">- Damages to commercial properties- Damages to stockpiles of timber- Runoff of pollutants / debris from yards into water courses / pollution and blockage risk

BIODIVERSITY

Increased fluvial / ground-water flooding	<ul style="list-style-type: none">- Loss / Stress on species due to inundation- Loss / Reduction of Habitats- Flooding causing impairment of ecosystems- Increased risk of conveyance / distribution of invasive and none native species- Deterioration of water quality due to increased runoff of nutrients / pollution- Access to sites impaired or prevented
Increased coastal flooding	<ul style="list-style-type: none">- Damage to sand dunes habitats- Erosion damage to coastal habitats- Loss of space / habitat / species due to sea level rise (coastal squeeze)- Loss of space / habitat /species due to salt water intrusion

BUILT & ARCHAEOLOGICAL HERITAGE

Increased fluvial / groundwater flooding

- Damage or loss of Heritage sites in river flood plains
- Access routes to heritage sites damaged / restricted or removed
- Increased management costs at sites for flood clean-up or implementation of flood resilience /protection
- Increased erosion / removal soil cover / protection to underground archaeology
- Increased erosion / removal of soil cover can reveal undiscovered archaeology
- Consider potential flooding impacts on designed landscapes

Coastal Flooding

- Damage or loss of coastal heritage sites
- Access routes to heritage sites damaged / restricted or removed
- Increased management costs at sites for flood clean up or implementation of flood resilience /protection.

TRANSPORT INFRASTRUCTURE

Increased fluvial / groundwater flooding

- Damage to Bridge Structures, Culverts and Embankments
- Damage / Closure / Disruption to the transport networks, ports, airports, etc.
- Increased traffic volumes on diversion roads
- Increased management of network during a flood event
- Increased travel times for users of transport network and facilities
- Access for emergency services
- Road and Rail safety issues
- Increased risk of culvert blockage due to debris in road runoff
- Increased costs for flood risk assessment of current and proposed infrastructure
- Requirement to consider flood resilience in new and proposed infrastructure

Coastal Flooding

- Closure / Damage to Ports
- Increased costs for flood risk assessment of current and proposed infrastructure
- Requirement to consider flood resilience in new and proposed infrastructure

ELECTRICITY AND GAS NETWORKS

Increased fluvial / groundwater/ coastal flooding

- Flood damage to electricity and gas generation and distribution infrastructure
- Loss or interruption of supply to critical infrastructure such as water supply pumps, hospitals, etc.
- Risk to life from damaged infrastructure, fallen poles, etc.
- Stress / anxiety to public caused by loss or disruption of electricity / gas supply
- Damage / structural risk to water retaining structures such as hydroelectric dams
- Risk to wind farms sites – foundation damage, runoff from hill sites
- Increased costs for Flood Risk Assessment of current and proposed infrastructure
- Requirement to consider flood resilience in new and proposed infrastructure

COMMUNICATIONS NETWORKS

Increased fluvial / groundwater flooding /sea level rise

- Flood damage to communications assets and networks
- Loss or interruption of supply to critical infrastructure such as water supply pumps, hospitals etc.
- Increased costs for Flood Risk Assessment of current and proposed infrastructure
- Risk to maintenance and response crews in flooded areas due to hidden /unforeseen hazards
- Health risk to maintenance and response crews from contaminated floodwaters
- Requirement to consider flood resilience in new and proposed infrastructure

WATER SERVICES INFRASTRUCTURE

Increased fluvial / groundwater flooding

- Flood damage to water and waste water treatments plants, pumping facilities and the distribution network
- Loss or interruption of supply to critical infrastructure such as water supply pumps, hospitals, etc.
- Risk to maintenance and response crews in flooded areas due to hidden /unforeseen hazards
- Pollution of raw water intakes at water treatment plants
- Contamination of private and public boreholes
- Health risk to maintenance and response crews from contaminated floodwaters
- Increased costs for Flood Risk Assessment of current and proposed infrastructure
- Increased cost associated with Flood Risk Assessment / flood resilience for new and proposed infrastructure
- Damage / structural risk to water retaining structures such as reservoirs with possible downstream flood risk

WATER QUALITY

Increased fluvial / groundwater flooding

- Discharge of pollution from combined sewer overflows
- Overflowing of waste water treatment plant particularly if connected to combined sewers
- Increased sediment load during floods

HEALTH

Increased fluvial / groundwater flooding	<ul style="list-style-type: none">- Flood damage to health care facilities (hospitals, care centres, etc.)- Contamination of private and public boreholes- Contaminated flood waters due to flooding of waste water facilities and sewer overflow- Stress and anxiety to land and properties owner at risk of flooding- Risk for responding emergency crews as an ambulance / doctors to flood sites
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TOURISM (additional sector not included in NAF)

Increased fluvial / groundwater flooding	<ul style="list-style-type: none">- Flooding of tourist accommodation sites, particularly mobile homes- Negative publicity resulting in a reduction of tourists- Flooding of walking and cycling trails along river banks- Damage to flood banks creating a possible hazard for visiting tourists- Damage to mooring facilities- Impact on angling areas or infrastructure- Negative effect on water-based activities on inland waterways
Coastal Flooding	<ul style="list-style-type: none">- Flooding of tourist accommodation at coastal sites- Negative publicity resulting in a reduction of tourists- Flooding of walking and cycling trails along shorelines- Damage to mooring facilities at Harbours and Piers- Limited access to Ireland's offshore islands

TABLE F-2: IMPACTS OF OTHER SECTORS ON FLOODING AND FLOOD RISK

SEAFOOD	
Construction of production facilities at Harbours and Piers	<ul style="list-style-type: none"> - Development of commercial facilities in flood prone areas increasing potential for flood damage and/or risk elsewhere - Development of shipping lanes, berthing facilities impeding conveyance - Development of hard shoreline or other processes impeding the natural flushing process for sediment / sands - Improper disposal of dredging material impeding conveyance and natural process in estuary or harbour

AGRICULTURE	
Land Drainage Improvements	<ul style="list-style-type: none"> - Drainage of marginal lands resulting in quicker and increased flows in rivers - Construction of embankments along river banks in reduction of attenuation on flood plains
Increased development of Farmyards and Agriculture production facilities	<ul style="list-style-type: none"> - Development of farm facilities in flood prone areas increasing potential for flood damage and/or risk elsewhere - Generating of more hard surface resulting in more water entering the river network - Debris and other material washed into watercourses causing blockages at bridges and culverts
Land use management / farming practice	<ul style="list-style-type: none"> - Natural water retention measures creating storage reducing runoff and flooding downstream - Planting across floodplains attenuating flood plain flow - Planting along contours (e.g., hedgerows) reducing runoff and soil loss - Increased stocking levels causing soil compaction resulting in greater run off - An inappropriate use of land management practices could lead to significant losses in soil carbon causing increased overland flow and surface water runoff to ditches, streams and watercourses.
Increased crop production	<ul style="list-style-type: none"> - Reduction of grass cover causing greater run off - Reduction of grass cover causing more soil material to enter watercourses and impede flow and conveyance - Drills and ridges in fields resulting in the creation of flood flow paths (particularly if direction is downhill)

FORESTRY

More intense forestry activities	<ul style="list-style-type: none"> - Ploughing of furrows / drills following ground contours to maintain runoff conditions in accordance with good forest practice - Harvesting of large swaths of mature trees has the potential to result in greater runoff. All felling must adhere to the Felling & Reforestation Standards (maximum coupe size is 25 ha) - Potential for washing of woody material into drains and culverts causing blockages. Felling & Reforestation Standards require the removal of woody debris falling into drains during felling operations - Potential for compacting of soils with machinery thus creating more impermeable surfaces. Felling & Reforestation Standards require the selection of appropriate machines, the use of brush mats and the management of extraction, to avoid soil damage - Greater runoff has the potential to result in landslides with possible blockages of drains and water courses. Felling & Reforestation Standards aims at controlling runoff from felling sites - Strategic woodland creation and appropriate forestry management practices can contribute to flood reduction (natural water retention measures)
Development of compounds and roadways	<ul style="list-style-type: none"> - Increasing hard surface / compacted surface areas causing greater run off - Upland retention areas or woody debris dams can reduce run off

BIODIVERSITY

Improvement, creating of wetland habitats	<ul style="list-style-type: none"> - Natural water retention measures reducing runoff and flooding downstream - Runoff reduction from preservation of bogs and management of wetland habitats - Potential barrier to physical flood risk management interventions
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TRANSPORT INFRASTRUCTURE

- | | |
|-------------------------|---|
| Road, Rail Construction | <ul style="list-style-type: none">- Construction of bridges and culverts without Section 50 consent could cause an increased flood risk- Construction of road / rail embankments across floodplains can impede flow increasing flood levels upstream- Road / rail drainage can create greater flows entering into watercourses- Lack of maintenance to SuDs and other water retention devices can lead to an increased flood risk. |
|-------------------------|---|

ELECTRICITY AND GAS NETWORKS

- | | |
|-------------------------------|--|
| Development of Infrastructure | <ul style="list-style-type: none">- Development of assets in flood prone areas increasing potential for flood damage and/or risk elsewhere- Construction of hydro-electric dam and other water storage structures creates a potential flood risk- Development of wind farms in upland area could result in landslides and greater runoff |
|-------------------------------|--|

COMMUNICATIONS NETWORKS

- | | |
|-------------------------------|---|
| Development of Infrastructure | <ul style="list-style-type: none">- Development of assets in flood prone areas increasing potential for flood damage and/or risk elsewhere- Development of communications masts in upland area could result in landslides and greater runoff |
|-------------------------------|---|

WATER QUALITY

- | | |
|---|---|
| Achievement of environmental objectives | <ul style="list-style-type: none">- Potential barrier to physical flood risk management interventions |
|---|---|

WATER SERVICES INFRASTRUCTURE

Development of Infrastructure

- Development of assets in flood prone areas increasing potential for flood damage and/or risk elsewhere
- Development of water storage reservoirs creates a potential flood risk
- Breakages / bursts / leaks on large pipe networks could cause a flood risk

HEALTH

Development of Infrastructure

- Development of facilities in flood prone areas increasing potential for flood damage and/or risk elsewhere

TOURISM (additional sector not included in NAF)

Development of Visitors Facilities and Protection Structures

- Development of facilities in flood prone areas increasing potential for flood damage and/or risk elsewhere
- Creation of walking and cycling trails along shorelines and river banks and in floodplains impeding flow routes



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