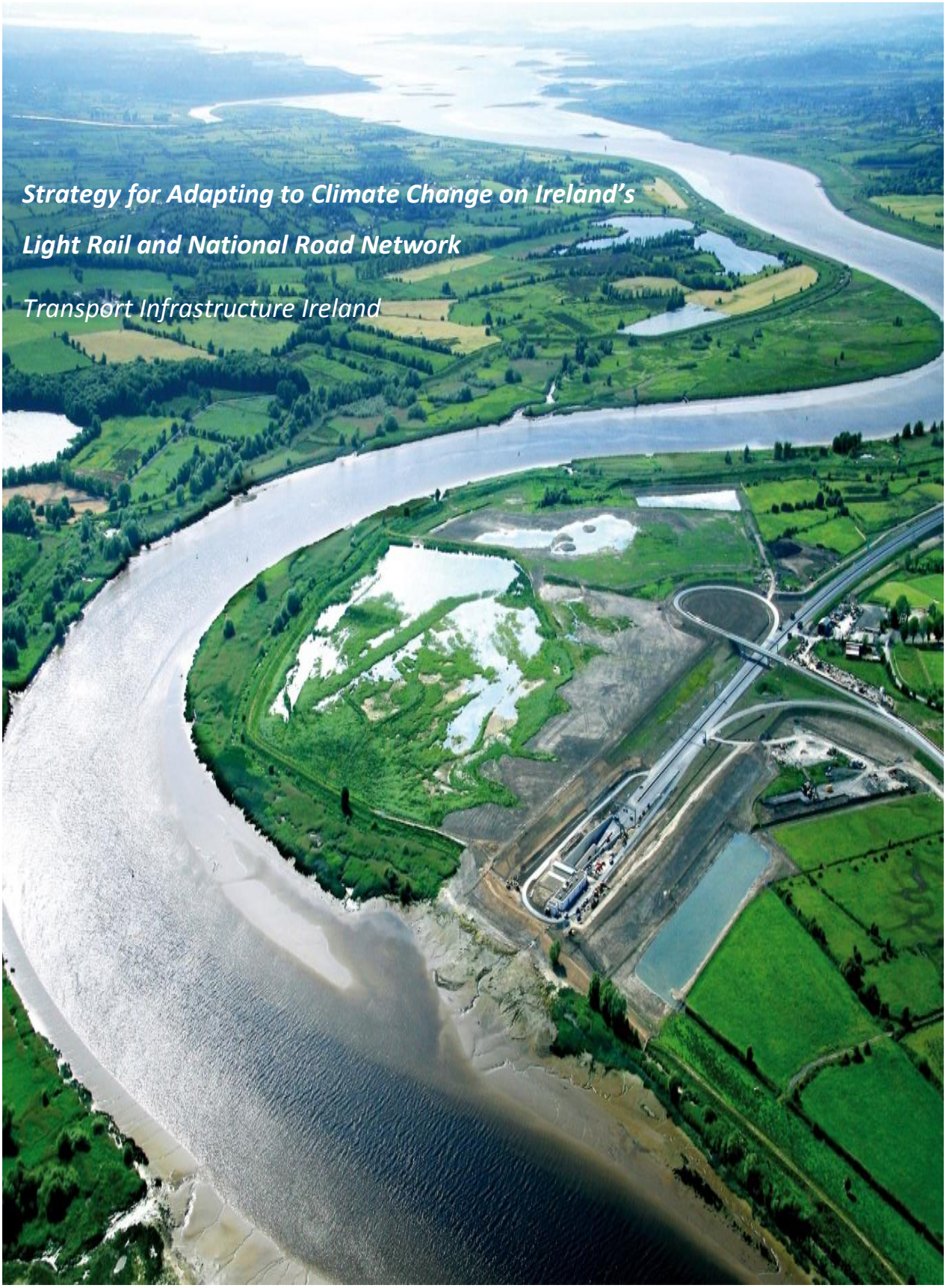
Bonneagar Iompair Éireann
Transport Infrastructure Ireland

Strategy for Adapting to Climate Change on Ireland's Light Rail and National Road Network

PSF-ENW-0003

December 2017

TABLE OF CONTENTS


Strategy for Adapting to Climate Change on Ireland's
Light Rail and National Road Network
Transport Infrastructure Ireland

1.0 STRATEGY FOR ADAPTING TO CLIMATE CHANGE – WHY?

Ireland's climate is changing and the indications are that further, more profound, changes are likely. The Intergovernmental Panel on Climate Change (IPCC) provides the most comprehensive scientific assessment of climate change. [(1)] The driving forces behind the changing climate, greenhouse gas (GHG) emissions, have a major influence on future climate scenarios. Future changes are dependent on how the governments address current and future emissions rates. A range of climate scenario models can be used to predict future climate trends but all indicate that changes are inevitable without significant intervention.

Controlling GHG emissions is central to limiting impacts on climate. Ireland is currently committed to reducing GHG emissions under the European Union (EU) Effort Sharing Decision (Decision No 406/2009/EC) for the years 2013–2020. Ireland's 2020 target is to achieve a 20% reduction of non-Emissions Trading Scheme (non-ETS) sector emissions (i.e. agriculture, transport, the built environment, waste and non-energy intensive industry) on 2005 levels. Annual binding limits are set for each year over the period 2013–2020. The annual limits establish a linear pathway required to meet the 2020 target.

Recently, the Environmental Protection Agency (EPA) has estimated new annual limits and a 2020 target for Ireland which incorporate methodological changes, underpinning GHG emission inventories and projections. [(2)] It is now estimated that non-ETS sector emissions are projected to be 4–6% below 2005 levels by 2020, which is significantly less than the specified target of 20%. Two scenarios are assessed: the *With Existing Measures* scenario (no additional policies beyond those in place in 2015) and the *With Additional Measures* scenario (includes implementation of the National Energy Efficiency Action Plan). For the period 2013–2020, Ireland is expected to cumulatively

exceed its obligations by 13.7 million tonnes carbon dioxide equivalent (Mt CO_2eq) with existing measures and 11.5 Mt CO_2eq with additional measures.

Initially, post-2020 obligations in excess of the range of expected outcomes for 2020 will inevitably lead to severe compliance challenges early in the following decade and beyond. In this context, Ireland is not on track towards decarbonising the economy in the long term, in line with the Climate Action and Low Carbon Development Act 2015,* and will face steep challenges post-2020 unless further polices and measures are put in place, over and above those envisaged between now and 2020. (2)

Ireland's climate is changing with more intense rainfall events predicted for the future; therefore, Ireland's infrastructure needs to become more resilient to these predicted impacts.

Ireland has developed a National Climate Change Adaption Framework. (3) Adaptation to the impacts of climate change requires action to both manage the risks and to prepare mitigation plans to reduce vulnerabilities. It has become an essential component of long term, strategic economic planning. An integrated approach, involving stakeholders, is essential. The Minister for Transport, Tourism and Sport is required to prepare a Sectoral Adaptation Plan under this framework. The document, entitled 'Developing Resilience to Climate Change in the Irish Transport Sector', (4) was published in November 2017. The measures outlined here, in this document, have been incorporated into this publication.

In addition, Ireland's first National Mitigation Plan (5) was published in July 2017. This document sets out proposals to reduce Ireland's national GHG emissions.

In response to this framework document and to predicted climatic change scenarios, Transport Infrastructure Ireland (TII) is preparing to adapt and is currently developing strategies for various climatic events that will impact the national road and light rail network. The construction and maintenance of national road and light rail infrastructure has taken on a new meaning in the last decade as a result of a global coordination of climatic models and predicted changes in climatic parameters. Climatic factors such as increases in rainfall have been factored into the design of attenuation systems and conveyance systems on national road schemes for several

* http://www.irishstatutebook.ie/eli/2015/act/46/enacted/en/html

years. However, the main challenges facing TII, in relation to the national road network, relate to the fact that a large proportion of the network consists of "legacy" roads evolved from historic routes that are often constrained by physical or environmental conditions. The Dublin light rail transit system (Luas) is constructed on the city's roads and is, therefore, prone to many of the same climatic factors impacting the national roads.

Likely impacts in Ireland may not be as severe as those predicted in other European countries but will include more frequent flooding, an increased risk of landslides, pavement degradation and potential storm damage.

2.0 IRELAND'S ROAD NETWORK

The national road network plays an essential role in modern Ireland. Typically, structures on the network such as bridges have a life expectancy of 120 years. TII must, therefore, design for climatic conditions, extending into the next century.

Currently, there is 5,306km of national road in Ireland. It comprises 2,649km, designated as National Primary Road, and 2,657km, designated as National Secondary Road. National Primary Roads are numbered from M1 to M50 and National Secondary Roads are numbered from N51 to N87.

Contained within the national road network are the Motorway/Dual Carriageway sections, totalling 1,210km of road (916km Motorway and 294km Dual Carriageway). Approximately 328km of these sections are maintained under existing Public Private Partnerships (PPPs) and 588km are maintained directly by TII through Motorway Maintenance and Renewals Contracts (MMaRC), with the remaining 294km maintained through local authorities.

TII is responsible for three tunnels as part of the National Motorway Network: the Dublin Port Tunnel (M50), Jack Lynch Tunnel (N40) and the Limerick Tunnel (N18).

In 2001, the EIRSPAN bridge management system was introduced to coordinate and integrate activities such as bridge inspections, repairs and rehabilitation work to ensure optimal management of the national road structure stock.

Transport Infrastructure Ireland is responsible for maintaining part of the motorway network and carries out this function through Public Private Partnerships and Motorway Maintenance and Renewals Contracts.

3.0 DUBLIN'S LIGHT RAIL TRANSIT SYSTEM (LUAS)

The Luas network consists of the Luas Red Line and the Luas Green Line. The Luas Red Line extends from Tallaght, in the south west of Dublin, through the city centre, to The Point in Dublin's Docklands. The line has two spurs, a short spur branching off at Busáras stop to serve Connolly railway station and a spur branching off the line near Cookstown to serve Saggart. The line consists of twin tracks and is 20.5km in length overall. The Luas Green Line extends from Bride's Glen in the south east of Dublin to Broombridge in the north west of the city. The line comprises single and twin tracks with a length of 21.9km.

Depot and stabling facilities for the Luas Red Line are located at Red Cow and for the Luas Green Line at Sandyford and Broombridge. The Red Cow depot consists of a maintenance and repair workshop building, servicing and washing facilities, and a large stabling area, capable of accommodating up to 47 trams. This depot also includes the operator's administrative offices, the central control room, and the main offices of the vehicle and infrastructure maintenance contractors.

Similar facilities exist at Sandyford and Broombridge except that only limited office accommodation is provided and there is no central control room, although local control facilities are provided. The stabling areas are capable of accommodating up to 44 trams. TII manages Luas through a series of operating and maintenance (vehicle and infrastructure) contracts.

4.0 CLIMATIC CHANGES IN IRELAND

Global climate model simulations carried out in Ireland provide an update on the expected change in the Earth's climate. The global results form part of Ireland's contribution to the IPCC AR5 report. Data from this model and other global models are then downscaled over Ireland to update the projections for the future Irish climate. [6] The key findings for Ireland's future climate are as follows:

- A continuation of the warming trends observed from 1981 to 2010, with a predicted increase of 1.5°C by 2050
- Milder but wetter winters, with an increase of up to 14% in precipitation
- A decrease in summer precipitation, with a predicted decrease of up to 20%

- The frequency of heavy precipitation events will increase up to 20% during winter

The predictions for Ireland's future climate will include an increase in average temperatures, wetter winters, drier summers and an increase in heavy precipitation events.

4.1 Impacts on infrastructure

4.1.1 National road network

Over recent years, it has become apparent that TII's main climate change focus in the future will be on increased rainfall intensity, which has the potential to result in increased road flooding. It is not economically viable to construct a road network that is completely resilient to flood events as this would involve raising the level of the roads to a height that would entail excessive costs. Every effort is made during the planning phase to reduce the impacts of flood events and, where feasible, the roads are raised above flood plains. This means that for extreme storm events with intense rainfall, a certain level of flooding is inevitable. There are already indications that more intense rainfall events on the network are resulting in flooding, therefore, creating problems for traffic safety and traffic flow. Flooding also impacts on the integrity of the road structures. The effects of potential increases in groundwater levels are significant for road drainage and pavement foundations. The Strategy for Adapting to Climate Change on Ireland's Light Rail and National Road Network therefore, focuses on the effects of more intense rainfall and increased levels of groundwater, and how TII can develop action plans so that the incidence of road closures due to flooding can be minimised.

Climatic changes will impact on Ireland's motorway network.
Flooding impacts are the biggest concern.

Additional impacts also need to be considered and the types of impacts may include the following:

- Flooding due to failure of flood storage systems
- Pluvial flooding
- Coastal flooding
- Fluvial flooding
- Erosion of road base
- Pavement deterioration
- Bridge and culvert scouring
- Landslides
- Embankment failure
- Debris flow

- Rock fall
- Impacts of increased soil moisture levels impacting on roads, bridges tunnels, etc.
- Differential settlements
- Aquaplaning
- Decrease in skid resistance

4.1.2 Light rail

The location of Luas in relation to the potential for fluvial and coastal flooding suggests that there will be an additional risk to this infrastructure. Flooding events could also impact on depots and substations. Luas also crosses bridge structures over rivers in the city which includes further climatic risk factors. In addition, there are risks associated with the following:

- Pluvial flooding
- Bridge scouring
- Landslides
- High temperatures
- Embankment failure
- Debris flow
- Rock fall
- Severe winds
- Severe frosts/snow

Severe winds pose a risk to the electrical supply network and the overhead conductor system (OCS) and pantograph (connection between the tram and the electrical supply). Prolonged severe frosts can impact the rails with a build-up of ice in the tracks. Excessive heat can result in sagging of the OCS and buckling of the rails.

Any of these impacts could lead to road or rail closures; a strategy for both managing the risks and the preparation of mitigation plans to reduce vulnerabilities, form the basis of this document.

4.2 How is TII preparing for climate change?

4.2.1 National road network

TII is a longstanding member of the Conference of European Directors of Roads (CEDR). Membership of CEDR allows for co-operation at a European level to facilitate the exchange of research data, experience and information and to analyse and discuss all road-related issues, especially infrastructure management, traffic and transport, financing, legal and economic problems, safety, environment, and research in all of these areas.

Through CEDR, group strategies for dealing with climate change have been developed and are being implemented in a number of European countries, especially those facing more profound climatic impacts.*

The first CEDR transnational research programme in 2008, 'Road Owners Getting to Grips with Climate Change', focussed on issues such as winter maintenance, impacts on road pavements, risk assessment and flooding. The objective of this research programme was to investigate issues related to climate change adaptation and provide tools for road authorities to identify and prevent future problems to road infrastructure.

The models developed as part of this programme have assisted TII in identifying areas of the national road network prone to flood risk and identifying where action should be taken to reduce flooding vulnerability.

The second transnational programme in 2012, 'Road Owners Adapting to Climate Change', concentrated on providing road owners with adaptation technologies and the models and tools to support decision-making concerning adaptation measures for the road infrastructure. This entailed;

a) identifying and modelling climate change effects on national motorway networks to provide a unified input database,

b) the development and implementation of risk-based vulnerability assessment of transnational motorway networks (TEN-T), and,

c) development and application of adaptation technologies.

The outcomes of these two research programmes led to the development of a third programme in 2015 entitled "Bringing Research from Desk to Road. This programme centres on integrating climate change into decision-making processes and implementing existing research into practice. Specifically, this programme covers areas such as;

a) the economic costs associated with integrating climate change into decision-making,

b) embedding climate change into practice and procurement,

c) developing a transnational approach to water management in the face of climate change, and

d) driver behaviour in a changing climate.

4.2.2 Light rail

TII, in association with Transdev, has developed a Luas Severe Weather Management Plan. (7) This plan sets out TII's and Transdev's (the company responsible for operating Luas) pre-determined actions to providing a

* http://www.cedr.fr/home/

response system to a severe weather event occurring on the Luas system. The plan provides a framework for managing responses to any weather event that has the potential to seriously disrupt Luas services. The plan is largely based around the preparedness and response activities in relation to severe snow/freeze thaw and flood events.

4.3 What is a climate-related event in relation to the national road and light rail network?

TII defines a climate-related event, as an incident that results in the closure or partial closure of a road or light rail line for one hour or more e.g. flooding. This is in line with the definitions adopted by other CEDR members. When followed up, if investigations indicate that the flooding event was related to blockages of the drainage network then it will not be recorded as a climatic-related event.

4.4 Consultation with stakeholders

The Office of Public Works (OPW) is the lead State body for the coordination and implementation of Government policy on the management of flood risk in Ireland (Catchment Flood Risk Assessment and Management (CFRAM)). The national CFRAM programme commenced in Ireland in 2011.* The OPW works in close partnership with the local authorities in delivering the objectives of the CFRAM programme. The OPW has developed draft flood maps under the national CFRAM programme and, with its partners, through other projects to provide a general overview of the flood risk in the future across Ireland from rivers and extreme sea levels.

TII engages with several stakeholders including local authorities, Inland Fisheries Ireland (IFI), the OPW and the National Parks and Wildlife Service (NPWS) on maintenance and flood-related issues, and the development of climate-related protocols.

Transport Infrastructure Ireland is adapting to the effects of climate change by implementing flooding protocols and developing strategic action plans.

* http://www.cfram.ie/

5.0 TII'S STRATEGY FOR ADAPTING TO CLIMATE CHANGE

5.1 National Road Network

The strategy for adapting to climate change on the national road network is based on the approach developed by the CEDR technical working group and it is developed under the following headings:

- Management
- Improvement
- Prevention
- Cooperation

TII is also examining the impacts of climatic events on surface and groundwater resources and environmental measures are an integral part of TII's strategy for adapting to climate change. TII is continually maintaining and renewing road pavements and road assets such as signage, crash barriers and noise barriers. Adaptation to climate change is included in drainage designs by allowing for future increases in rainfall intensities and volumes.

5.1.1 Managing flood events

When a motorway has to be closed due to flooding, TII, in cooperation with the emergency services, call-out services and authorities, manage the situation to reduce the impact and inconvenience caused to the public. This is achieved by the following:

- Cooperating and communicating with the emergency services through the Motorway Traffic Control Centre (MTCC), where the road network is managed and traffic control facilities are coordinated. The centre operates a number of services including:
  - Advanced traffic management systems
  - Electronic messages to road users
  - Incident management
  - Emergency Roadside Telephone network
  - Roadworks' scheduling
- Informing road users about the flood incident through the MTCC, using their services
- Coordinating an efficient clean-up operation through the MMaRC. There are 10 maintenance depots, strategically located throughout the country, containing equipment to deal with flood events as well as providing storage and dispersal points for salt to augment the local authorities in emergency situations
- Targeting strategic sections through the MTCC in the event of more than one flood event, to ensure that road sections with the greatest economic importance are prioritised

5.1.2 Improvement

Where flood events lead to road closures, the event is analysed to investigate the cause of the flooding and explore what mitigation measures are required to reduce the risks of a future event, following a protocol outlined in the following section.

5.1.3 Flood Management Protocol

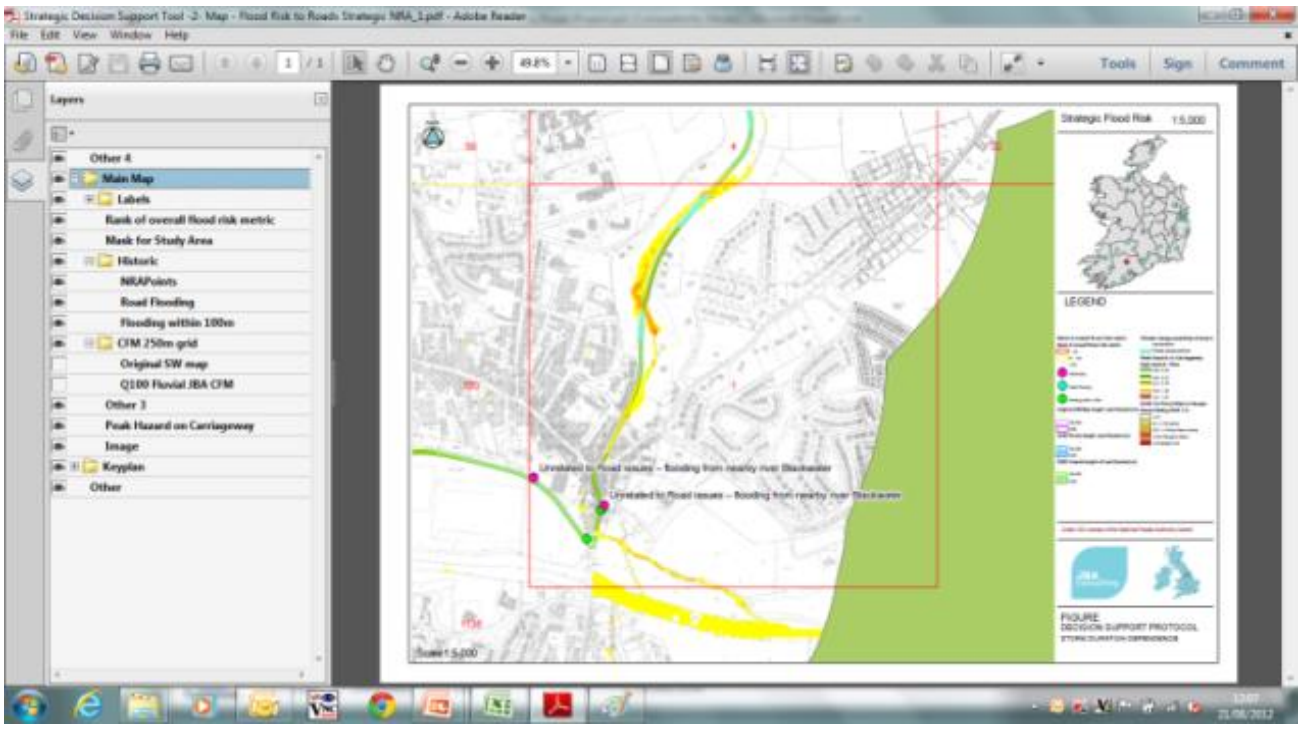
As flooding is considered to be the principal climate change threat to the national road network, TII has focused on this issue and developed a comprehensive protocol for addressing flooding on the road network.

The Protocol Assessment is based upon the flood risk metrics and flood history derived from a strategic tool. [8] The aim is to allow an individual appraisal of sites that have been highlighted as potentially being at risk of flooding. The process involves four phases of investigation and is centred on deriving a meaningful interpretation of the risk metrics, concluding with mitigation and management options.

Phase 1 is applied to all sites assessed and provides a review of the flood risk metrics and historic information. It is intended that the user should familiarise themselves with the site through the use of the strategic tool PDFs, geographic information system (GIS) mapping, Ordnance Survey Ireland (OSi) mapping and Google Street View (or simply from personal experience of the site). In many cases, it is possible to gain additional information through viewing the area from the available Internet mapping sources, particularly Google Street View. Phase 1 concludes by outlining the path for further assessment; either highlighting that a site visit is required to define risk more clearly and/or complete a Structure, Culvert or Drainage Assessment.

In general, if there is potential for structural blockage and high velocity then the scour flag is triggered. In combination, a site based Bridge or Culvert Assessment is triggered if it is thought that there is a risk of flooding in relation to a structure. If the main source of flood risk is thought to be due to Pluvial (Surface Water) sources and/or drainage issues then a drainage assessment is triggered. There are individual forms for Culvert/Bridge/Drainage Assessments and these result in suggestions for mitigation and management.

Phase 2 (actual site visit) is triggered to assess a potential cause of flooding at the site (Culvert, Bridge or Drainage Assessment) or investigate the cause of flooding further if it is not initially clear from the Phase 1 appraisal. Culvert, Bridge and Drainage information is contained within the individual Forms, and the Protocol Assessment Record can summarise the findings. Phase 2 will then potentially trigger a more detailed assessment under Phase 3 (if required) or simply move to the Phase 4 mitigation and management recommendations.

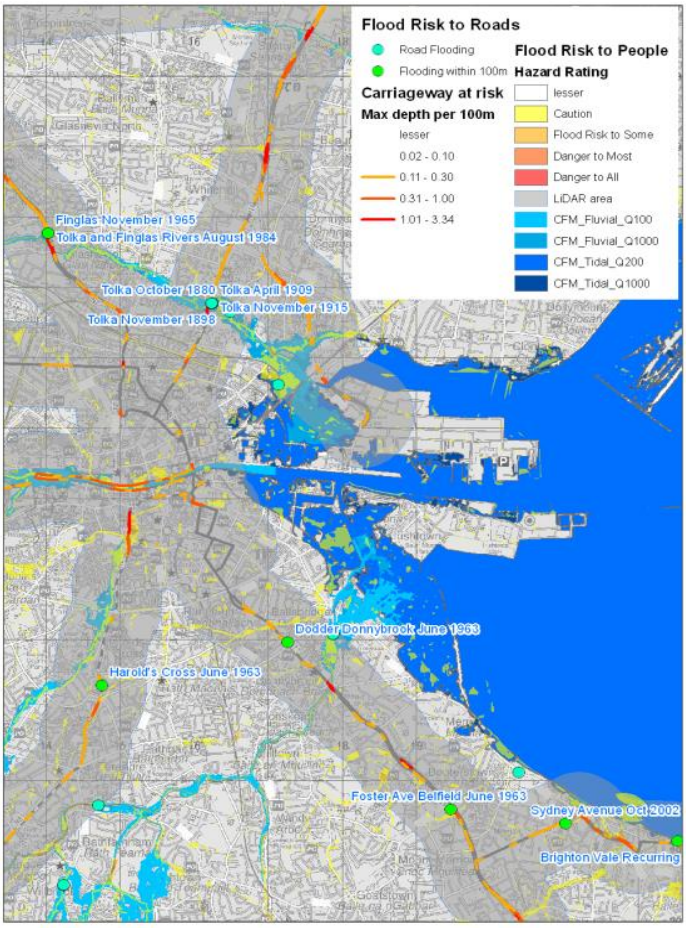


Phase 3 consists of a bespoke detailed assessment with the aim of providing sufficient additional information as required to implement any mitigation or management scheme. An example would be detailed hydraulic modelling of a culvert or bridge structure to allow for the effective capacity design for exceedance; it may also include for detailed drainage system modelling and subsequent design.

Phase 4 clearly states the resulting management and mitigation measures, and recommendations that have been developed as part of the phased assessment process. This can range from simple management procedures to more detailed reconstruction solutions, in the most extreme cases. The promotion of flood warning systems should be investigated further in most cases as there is significant underutilised potential in this area.

5.1.4 Creating a database of flood events

A database of flood events is being developed, documenting the extent and duration of the flood event, the emergency measures adopted to deal with the event and the consequences in relation to damage caused and impacts on traffic. This database will be used for preparing for further events and improving strategy for future implementation.



5.1.5 Implementing mitigation measures

Where flooding is a result of maintenance issues related to the drainage design such as blockages in pipes or culverts or clogging of assets, e.g. filter drains, then mitigation will involve clearance of blockages or complete renewal of the filter drain.

A cost-benefit analysis is carried out to assess the benefits of constructing new or enlarging the capacity of storm attenuation systems. The construction of new attenuation ponds will often involve additional land take and is not always feasible, especially in more urbanised areas.

5.1.6 Coordination with relevant authorities

In all cases, cooperation with the relevant authorities, such as the local authorities and the OPW, in any mitigation measures and analysis of events is essential.

5.1.7 Prevention

Although climatic events are inevitable on Ireland's road network, there are measures that can be taken to minimise, and in some cases prevent, significant disruption as follows:

- Identifying hot spots and preparing action plans. This process involves monitoring specific locations, investigating mitigation measures and carrying out improvements, if required
- Participating in the legislative process and delivering on legislation requirements, related to the impacts of climate change on the network
- Enhancing the maintenance and rehabilitation programme
- Ensuring that future schemes take full account of climate change in planning and construction

- Continuing TII's policy of funding research on climate-related issues and ensuring such research has practical applications
- Continuing active participation and sharing of knowledge with European partners through the CEDR technical group on climate change

5.2 Light Rail Network

5.2.1 Luas Severe Weather Management Plan

The objectives of the Luas Severe Weather Management Plan are as follows:

A. Provide a safe, reliable and consistent level of public transport – establish that the appropriate response plans (Transdev or Maintenance Contractors) have been activated and tested to provide a safe, reliable and consistent level of public transport.

B. Communications link and status – establish and maintain communication links to the Lead Agency (be it the Local Authority or the relevant Government Department). Provide the travelling public with up to date and accurate information.

C. Support (strategic and/or tactical) – establish whether Transdev and their Maintenance Contractors require additional support and provide such support where possible and appropriate.

5.3 Energy and carbon assessment

TII is committed to improving energy efficiency and developing a better understanding of the carbon impacts associated with the construction and operation of the national road and light rail networks. Commissioned research studies have examined embodied and operational carbon on pilot road schemes, in Ireland, with a view to implementing a carbon emissions assessment and comparisons of future schemes. Embodied carbon is carbon emissions related to the extraction, processing, manufacturing, transportation and use of construction materials for road and light rail construction. Operational carbon is related to the consumption of energy and traffic emissions over the life cycle of the networks.

TII has developed a country-specific calculation tool for assessing life cycle carbon emissions for national road and light rail infrastructure projects in Ireland. It is used for assessing "embodied" and "operational carbon" and is a requirement for the development of all future national road and light rail projects. The tool is primarily

used by consultants as part of the planning process for new road and light rail projects and, as such, it is aligned to integrate with the existing planning and design cycles for national road and light rail projects. The outputs from the tool allow TII and scheme designers to compare and evaluate the life cycle carbon impacts of multiple design options for any given road or light rail scheme. This tool facilitates a carbon assessment of the various planning, construction, operation and maintenance phases as well as decommissioning and disposal.

The National Energy Efficiency Action Plan 2009 – 2020 [9] is Ireland's first national energy efficiency policy and sets Ireland a target of delivering 20% energy savings by 2020. In response to these targets, TII has identified a number of energy efficiency initiatives for both national road and light rail projects, e.g. TII is involved with pilot studies, examining public lighting and developing a public lighting value management assessment tool along with a guidance document.

5.4 Environmental considerations

TII is constantly reviewing standards to adapt to climate influences and environmental objectives. TII's drainage standards have recently been extensively modified to allow for the construction of more sustainable solutions to road runoff such as the use of constructed wetlands and grassed channels. These standards have also been modified to take account of increased rainfall and environmental objectives of the receiving environment, specifically surface and groundwaters. Many of Ireland's rivers are now areas of special conservation (Natura 2000 sites) and even though traffic volumes are low and impacts of runoff are considered to be low, special care is given to any road runoff in these areas during construction and operation.

6.0 REFERENCES

[1] **IPCC.** *Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. Geneva: IPCC, 2014.

[2] **Environmental Protection Agency.** *Ireland's Greenhouse Gas Emission Projections 2016–2035.* Wexford: Environmental Protection Agency, 2017.

[3] **Department of the Environment, Community and Local Government.** *National Climate Change Adaptation Framework.* Dublin: Department of the Environment, Community and Local Government, 2012.

[4] **Department of Transport, Tourism and Sport.** *Developing Resilience to Climate Change in the Irish Transport Sector.* Dublin: Department of Transport, Tourism and Sport, 2017.

[5] **Department of Communications, Climate Action and Environment.** *National Mitigation Plan.* Dublin: Department of Communications, Climate Action and Environment, 2017.

[6] **Met Éireann.** *Ireland's Climate: the road ahead.* Dublin: Met Éireann, 2013.

[7] **Transport Infrastructure Ireland, Transdev.** *Luas Severe Weather Management Plan.* Dublin: Transport Infrastructure Ireland, Transdev, 2015.

[8] **B. Hankin, R. Bryant, V. O'Malley.** *02 - Identification and Management of Flood Risk to the National Road Network. National Hydrology Conference 2012.*

[9] **Department of Communications, Energy and Natural Resources.** *Maximising Ireland's Energy Efficiency. The National Energy Efficiency Action Plan 2009–2020.* Dublin: Department of Communications, Energy and Natural Resources, 2009.

Bonneagar Iompair Éireann
Transport Infrastructure Ireland

Ionad Ghnó Gheata na Páirce,
Stráid Gheata na Páirce
Baile Átha Cliath 8, Éire

Parkgate Business Centre,
Parkgate Street,
Dublin 8, Ireland

www.tii.ie

info@tii.ie

+353 (01) 646 3600

+353 (01) 646 3601