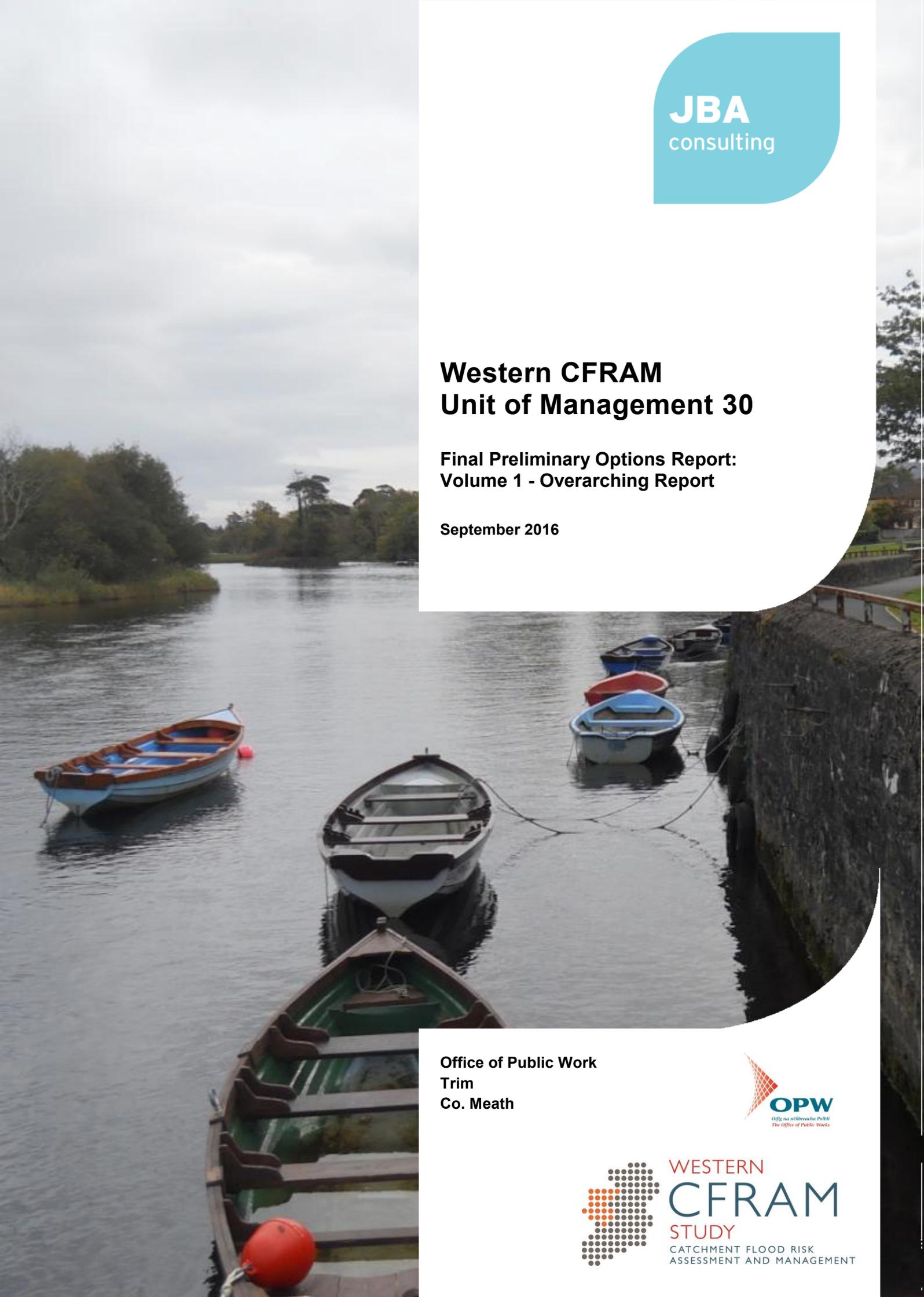


Western CFRAM Unit of Management 30

Final Preliminary Options Report:
Volume 1 - Overarching Report

September 2016



Office of Public Work
Trim
Co. Meath



WESTERN
CFRAM
STUDY

CATCHMENT FLOOD RISK
ASSESSMENT AND MANAGEMENT

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Glossary

AEP	Annual Exceedance Probability
AFA	Area for Further Assessment
CFRAM	Catchment Flood Risk Assessment and Management
CIRIA	Company providing research and training in the construction industry
DTM	Digital Terrain Model
EC	European Community
EPA	Environmental Protection Agency
FARL	FEH index of flood attenuation due to reservoirs and lakes
FRA	Flood Risk Assessment
FRM	Flood Risk Mapping
FRMP	Flood Risk Management Plan
FRR	Flood Risk Review
GSDSDS	Greater Dublin Strategic Drainage Strategy
GSI	Geological Survey of Ireland
HEFS	High End Future Scenario
HPW	High Priority Watercourse
ICPSS	Irish Coastal Protection Strategy Study
IED	ISIS Event Data file
LAP	Local Area Plan
MPW	Medium Priority Watercourse
MRFS	Medium Range Future Scenario
OPW	Office of Public Works
PFRA	Preliminary Flood Risk Assessment
POR	Period of Record
SAAR	Standard Average Annual Rainfall (mm)
SAC	Special Area of Conservation, protected under the EU Habitats Directive
SEA	Strategic Environmental Assessment
SEPA	Scottish Environment Protection Agency
SFRA	Strategic Flood Risk Assessment
SPA	Special Protection Area for birds, protected under the EU Habitats Directive
STFS	Storm Tide Forecasting Service
SUDS	Sustainable Urban Drainage Systems
T _p	Time to Peak
UNESCO	United Nations Educational, Scientific and Cultural Organisation
WFD	Water Framework Directive
WRAP	Winter Rain Acceptance Potential

1 Introduction

1.1 Western CFRAM

The Office of Public Works (OPW) has recognised that, in some areas of the country, there are significant levels of flood risk which could increase in the future due to climate change, ongoing development and other pressures. In partnership with Local Authorities, the OPW are therefore undertaking a programme of Catchment-based Flood Risk Assessment and Management (CFRAM) Studies to find solutions to manage this flood risk in a sustainable and cost effective way. The outputs from the CFRAM Studies will be catchment-based Flood Risk Management Plans (FRMP) and associated flood maps. The FRMPs will be reviewed on a six-yearly basis. The results will help long-term planning for reducing and managing flood risk across Ireland.

The Western River Basin District (RBD) covers an area of 12,193 km² in the west of Ireland extending north from the town of Gort to close to the border with Northern Ireland. It covers the majority of counties of Galway, Mayo and Sligo, along with some of County Leitrim and small parts of the counties of Roscommon and Clare. The Western RBD is subdivided into seven Units of Management (UoMs), which are based on hydrometric areas. It should be noted that the Western CFRAM Study is concerned with river and coastal flooding; groundwater flooding, which is a significant issue in some parts of the RBD, will be examined in a separate study.

This report is for Unit of Management 30, also referred to as Corrib, which covers an area of 3,113 square kilometres of the Western RBD. The area is predominantly within County Galway but there are also some small areas of County Mayo included. The Areas for Further Assessment (AFAs) in UoM30 are Ballyhaunis, Corrofin, Galway City, Oughterard, Tuam, and Claregalway. A flood scheme in Claregalway has already been approved and so this report only considers the non-structural flood management methods that may apply here.

1.2 Study background

The Inception Report for UoM 30-31 was delivered in October 2012. This report consisted of a baseline review of available data and the development of the proposed methodology for the hydrological and hydraulic modelling investigations which were subsequently completed.

The detailed development of the hydrology for UoM 30 is presented in the UoM 30-31 Hydrology Report, which was delivered in December 2014. This work developed design flows at a series of Hydrological Estimation Points (HEPs) along all watercourses to be modelled. It also provided guidance on the development of appropriate design storm hydrographs for each AFA for the purposes of the hydraulic modelling.

The findings of the hydraulic modelling investigations are summarised in the Hydraulic Modelling Report for UoM 30-31. Separate sub-reports contain a general methodology statement (Volume 1), the findings for specific AFAs or MPWs (Volumes 2a to 2g) and the mapping outputs from the study (Volumes 3a to 3g). Hydraulic models were constructed for all High Priority and Medium Priority Watercourses (HPWs and MPWs). HPWs are those watercourses that dictate flood risk within an AFA boundary as originally delineated within the Flood Risk Review (FRR) Report and finalised in the Inceptions Report. HPWs therefore extend a short distance upstream and downstream of an AFA but do not include watercourses with catchments less than 1km². HPWs were modelled to a greater level of detail than MPWs. MPWs are the watercourses which link two AFAs together and the watercourses that extend downstream of an AFA to the sea. Coastal AFAs do not have a downstream MPW associated with them. In total, 56 km of HPW and 102 km of MPW have been modelled within UoM 30, along with the coastline in Salthill and Galway City as shown in Figure 1-1. The hydraulics report summarises the main findings of the hydraulic modelling stage, sources of flood risk within each AFA, including details of the watercourses, historical flooding and flood defences.

This report presents the findings of the preliminary options investigations for UoM 30. The preliminary options investigations build on the findings presented in the hydraulic modelling reports.

Under the scope of works for the CFRAM the preferred design standard for flood mitigation methods is the 1% AEP fluvial or the 0.5% AEP tidal event. A review of the flood maps

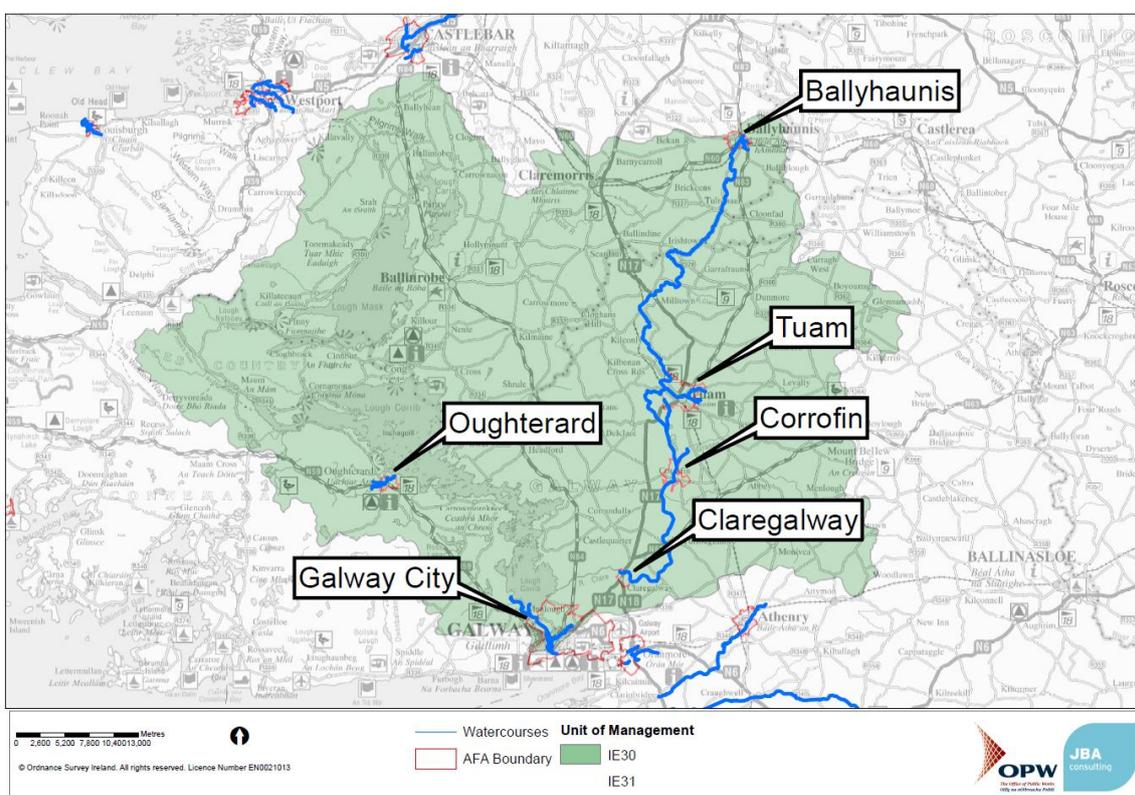
presented in the Hydraulic Modelling Report has identified those AFAs where properties are shown to be at risk of flooding within the design standard flood extents.

For those AFAs with properties at risk of flooding an assessment of viable structural flood risk management methods has been completed. This assessment is detailed in full in the adjoining AFA specific Preliminary Options Reports (Volume 2).

For all AFAs, including those AFAs with no properties at risk of flooding, an assessment of non-structural flood risk management methods, such as emergency planning and preparedness and spatial planning, has been completed.

The AFAs within UoM 30, Corrib, are shown in Figure 1-1. For UoM 30 the review of the flood extent maps confirmed there are properties at risk of flooding in the 1% AEP fluvial or 0.5% AEP tidal event in Galway City, Corrofin and Oughterard. These AFAs have been assessed for viable structural flood risk management methods and so have a specific Preliminary Options Report in Volume 2. No properties are predicted to flood in the design events in Tuam and Ballyhaunis and Athenry and these AFAs are considered for non-structural methods only and do not have an accompanying Preliminary Options Report in Volume 2.

Figure 1-1: AFAs within UoM 30



1.3 Report overview

This report is one of a series which describe the work undertaken as part of the CFRAM, and together they provide a description of the approach taken to identifying flood risk, and a discussion of the results of the analysis and potential flood management methods, where they are appropriate.

This report should be read in conjunction with the following supporting documents:

- Western CFRAM UoM 30-31 Hydraulics Report¹
- Western CFRAM UoM 30-31 Hydrology Report²

¹ JBA Consulting (2014), Western CFRAM Unit of Management 30 and 31 – Corrib - Owengowla Report, Final Report, Office of Public Works

² JBA Consulting (2014), Western CFRAM Unit of Management 30 and 31 – Corrib - Owengowla Hydrology Report, Final Report, Office of Public Works

- Western CFRAM UoM 30-31 Inception Report³
- Western CFRAM Flood Risk Review Report⁴
- Western CFRAM SEA Scoping Report⁵
- Western CFRAM SEA Constraints Report
- Western CFRAM Defence Asset Database: Handover Report and accompanying database files⁶

The reports in the suite for the Preliminary Options are:

- Western CFRAM UoM 30 - Preliminary Option Report (this report)
- Western CFRAM UoM 30- Preliminary Options Report Volume 2 – AFA Preliminary Options Report (for example –2b- Corrofin Preliminary Options Report)

The letter code associated with the deliverables in Volumes 2 will be consistent for a given AFA, so in the example above the letter 'b' applies to the Corrofin AFA in both Volume 2 of the Hydraulics Report and Volume 2 of the Preliminary Options Report in UoM 30, as shown in Table 1-1. Note, that where there is no flood risk within an AFA for the design event, there is no supporting AFA report. Instead, a discussion of non-structural methods is provided in this report.

Table 1-1: AFAs with UoM 30

AFA name	AFA code	AFA Report Volume Code
Ballyhaunis	BLH	2a (No Risk in the 1% AEP design event so no Preliminary Options AFA specific report).
Claregalway	-	(Scheme under construction)
Corrofin	CRF	2b
Galway City	GLW	2c
Oughterard	OTD	2d
Tuam	TUM	2e (No Risk in the 1% AEP design event so no Preliminary Options AFA specific report).

1.4 Requirements of the preliminary options stage

In line with the brief the following tasks are required for this phase of the CFRAM:

- An assessment of the viability of Flood Risk Management (FRM) methods and options
- An outline estimation of costs, using basic quantities (e.g., number, length, size, height, etc.) and typical unit costs, of options.
- Determination of the outline details of primary performance criteria of the options (e.g., crest levels of walls, embankments or weirs, or conveyance, width, depth and typical gradient of channels, or approximate lead times and degree of correlation / accuracy for potential flood forecasting systems, etc.)
- Preparation of outline plans (drawings) of the options indicating the possible / probable location of works, and an indication of their vertical / horizontal scale (e.g., plan showing possible line of defence works, with indications of heights at spot points along defence line, or of the spatial extent of channel widening, with assigned required widths and depths and approximate design bed levels at spot points, or possible locations of gauges required to enable development and operation of an effective flood forecasting system)
- Where viable options have been found for an AFA and environmental option appraisal study is required and will be included in the individual POR AFA reports.

³ JBA Consulting (2012), Western CFRAM Unit of Management 30-31 – Corrib - Owengowla Inception Report, Final Report, Office of Public Works.

⁴ JBA Consulting (2012), Western CFRAM Flood Risk Review, Final Report, Office of Public Works.

⁵ JBA Consulting (2013), Western River Basin District Catchment-based Flood Risk Assessment and Management (CFRAM) Strategic Environmental Assessment, Scoping Report, Office of Public Works.

⁶ JBA Consulting (2013), Western CFRAM Defence Asset Database, Handover Report, Office of Public Works.

- Discussion of options with Local Authorities, the public (based around the second Public Consultation Day) and other stakeholders to get views on options and broad agreement on preferred options (methods)
- Discussion with Local Authority Planners on issues related to planning and development, and an outline indication of potential impacts of development on flood plains and residual risk management methods that might be appropriate for that location.

Section 2 of this report provides an overview of the spatial scales of assessment, the areas considered and outlines the depth of assessment undertaken based on the level of risk.

Section 3 and Section 4 provide a high level overview of scope and the findings of the preliminary options investigations. Section 3 presents the findings of the investigations for structural flood risk management methods which are set out in full in the relevant AFA reports in Volume 2. Section 4 discusses non-structural flood risk management methods and the recommendations for this UoM.

Section 5, 6 and 7 provide the detailed analysis of non-structural methods applicable at the UoM level. Section 5 discusses spatial planning and management policies. Section 6 discusses surface water drainage policy and the viability of Sustainable Urban Drainage systems (SUDs). Section 7 discusses the potential for flood forecasting and flood warning systems and the scope for efficiencies and wider benefits in the development of a hydrometric network.

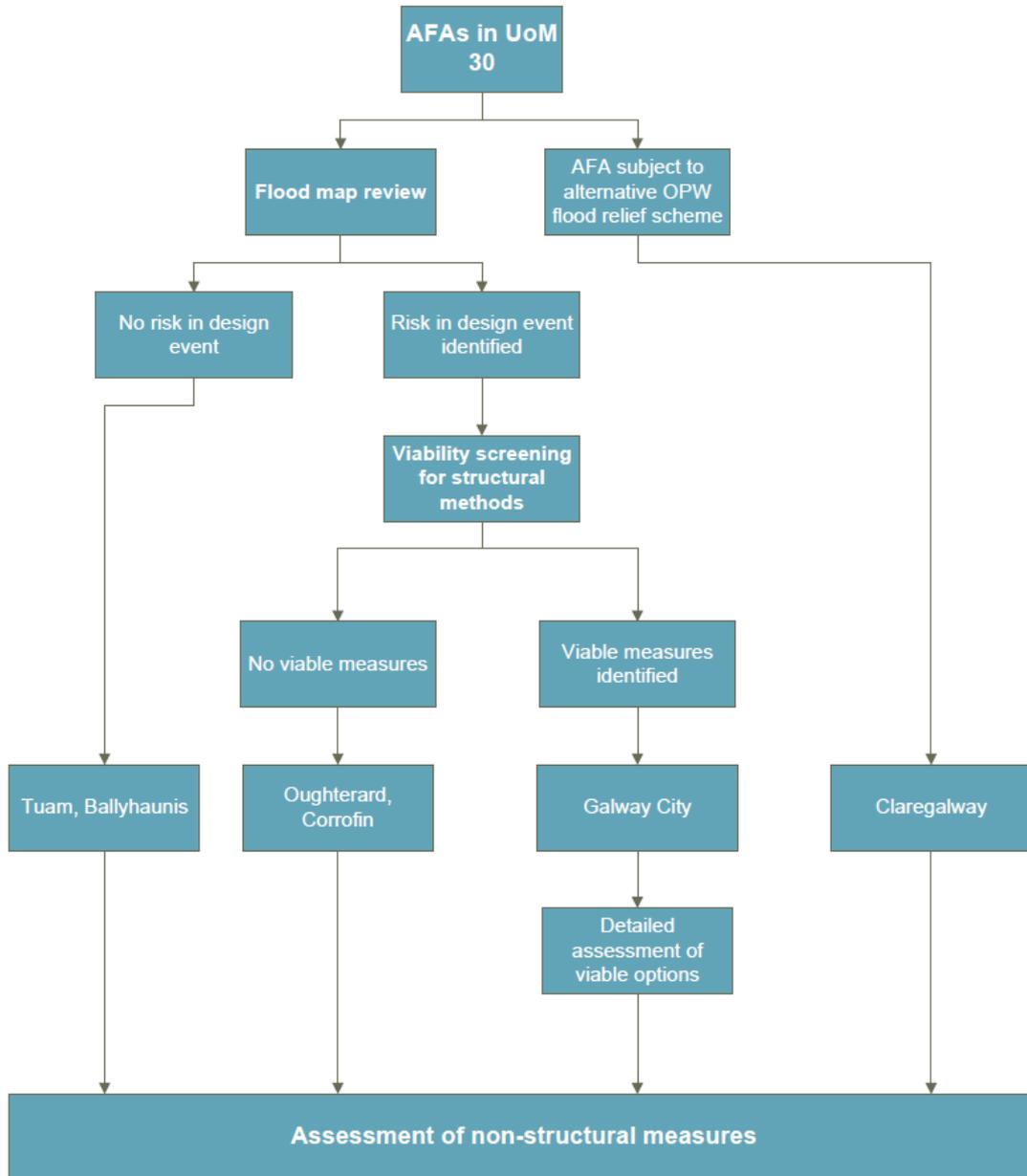
Section 7 presents the conclusions of the preliminary options report.

1.5 POR assessment process

A staged approach has been adopted for the POR assessment reflecting the increased understanding of the viability of flood risk management methods through the assessment. At each stage-end a decision is taken to confirm that proposed flood risk methods are viable. The three stages are summarised in Figure 1-2, and are as follows:

1. Flood Map Review - This stage reviewed the flood risk identified as part of the hydraulic modelling work. The preferred flood risk design standard for the WCFRAM is the 1% AEP fluvial or the 0.5% AEP tidal event. Where the relevant flood extents do not indicate there are any properties at risk of flooding within the AFA, then the AFAs have not been assessed for viable structural flood risk management methods because there is unlikely to be sufficient damages to justify an intervention to manage flood risk to the design standard. Management of residual risks will be through non-structural methods and maintenance, see Section 4.
2. Viability Screening - This stage includes the screening of structural flood risk management methods to identify where viable solutions or options exist. The key stages of work in this phase are the Screening of Methods, the Assessment of Economic Damages and the Cost Estimate of Viable Options. At the end of this stage a review is completed to confirm there is a viable structural option that will qualify for funding as part of the OPW CFRAM programme. Where there is no viable option then no further work has been completed within the WCFRAM. This does not necessarily preclude options being taken forward outside of the CFRAM programme. Regardless of the viability of structural methods, for each AFA there has also been an assessment of non-structural methods, including forecasting and warning, spatial planning and the use of sustainable drainage systems.
3. Assessment of preferred option(s) - The key stages of work in this phase are the refinement of the Cost Estimate, Environmental Appraisal of Options, Development of the Viable Option(s) and Multi-Criteria Analysis. These stages provide sufficient information to support the entry of preferred option onto OPW's priority list from where it will be taken forward, pending other funding commitments, for detailed design following the completion of the WCFRAM.

Figure 1-2: POR assessment process for UoM30



For UoM 30 the Flood Map Review confirmed there are properties at risk of flooding in the 1% AEP fluvial or 0.5% AEP tidal event in Galway City, Oughterard and Corrofin. No risk was found in the 1% AEP fluvial event in Tuam and Ballyhaunis and therefore these AFAs have not been carried forward to the screening stage. Non-structural methods for these AFAs will be covered in the Overarching Preliminary Options Report (this report). Where viable options have been found an environmental options appraisal study has been included in the relevant individual POR.

2 Spatial scales of assessment

2.1 Overview

In order to identify coherent actions and methods, the applicability of each possible method has been assessed across four different Spatial Scales of Assessment (SSA):

- The Unit of Management;
- Sub-catchments or coastal areas within the Unit of Management
- AFAs
- Flood cells

2.2 Unit of Management level

At this scale, methods that could provide benefits to multiple AFAs within the Unit of Management as a whole were considered. FRM management methods applicable at this spatial scale included:

- Planning Policy Requirements
- Flood Forecasting and Warning Systems
- Sustainable Urban Drainage systems (SUDs)
- Land Use Management
- Methods implemented under other legislation
- Requirements for additional monitoring (rain and river level / flow gauges)
- Provision of channel maintenance

The implementation of planning policies, potential for SUDs and the possibility for flood forecasting and warning systems respectively are all discussed at a catchment scale (see Sections 4, 5 and 0 respectively).

2.3 Sub catchment level

The sub-catchment SSA refers to the catchment of the principal river on which an AFA sits, and as such includes AFAs upstream and areas downstream which may benefit from a catchment level solution. Ballyhaunis, Tuam, Corrofin and Claregalway all lie on the Clare River. Methods that could provide benefits to multiple AFAs include upstream storage or flood forecasting systems. Methods proposed for an individual AFA have also been reviewed

This SSA would generally not be applicable to AFAs that are only at risk from coastal flooding, except where multiple AFAs are at risk around an estuarine area, in which case the estuary area may be treated as a Sub-Catchment SSA. This is the case with Galway City where the provision of a tidal barrage to protect the area from coastal flooding was considered in conjunction with the associated benefits from protecting other areas within the Galway Bay Estuary also at risk to flooding, namely, Oranmore and Kinvarra.

In addition, for potential for flood forecasting schemes being discussed at UoM level it will primarily be explored at a sub catchment level for Galway Bay and River Clare.

2.4 AFA level

At this scale, methods benefitting only the AFA in question were considered, even if the implementation of a given method includes works or activities outside of the AFA, i.e., elsewhere in the sub-catchment or UoM. Examples include storage upstream of the AFA, or flood forecasting and warning systems that provide no benefits to other AFAs, as well as all other FRM methods and options, such as protection methods, conveyance improvement, etc. Methods proposed at an AFA scale are discussed in detail in the relevant AFA Preliminary Options Report.

In most cases a single method to address all risk within an AFA will not be sufficient, and proposed options comprise a range of methods to address the risk in different areas within the AFA.

2.5 Flood cell level

Within an AFA there may be discreet areas of flood risk, called 'Flood Cells', that are hydraulically independent from other areas at risk within the AFA. The viability of methods will be assessed at a flood cell only if an AFA wide solution is not viable.

3 Structural flood management methods

3.1 Consideration of structural methods

The preferred flood risk design standard for the WCFRAM is the 1% AEP fluvial or the 0.5% AEP tidal event. Structural methods have only been considered for those AFAs where the current flood extents show properties at risk of flooding in these design events. This section sets out the key objectives for consideration in the identification of a preferred structural method and summarises the findings of the assessments.

Structural flood risk management methods have been considered for Galway City, Oughterard and Corrofin. Full details of the screening assessments and development of preferred options for these AFAs is set out in the AFA specific reports in Volume 2. Table 3-1 details the number of properties at risk and the present value damages to be mitigated in the 10%, 1% / 0.5% (design event) and the 0.1% AEP events for Galway City, Oughterard and Corrofin.

Table 3-1: Summary of current flood risk

AFA	Total number of properties at risk	Residential Properties at Risk	Non-Residential Properties at Risk	PVd (€)
10% AEP Event				
Galway City	20	19	1	1,465,111
Oughterard	0	0	0	0
Corrofin	1	1	0	13,442
1/0.5 % AEP Event (Design Event)				
Galway City	312	181	131	8,185,039
Oughterard	4	4	0	12,263
Corrofin	3	3	0	360,310
0.1% AEP Event				
Galway City	942	658	294	12,604,493
Oughterard	16	16	0	25,626
Corrofin	11	11	0	496,855

No structural flood risk management methods have been considered for Tuam and Ballyhaunis; non-structural methods for all AFAs are discussed in Section 4 and in further detail throughout the rest of this report.

3.2 Flood risk management objectives

The effectiveness of potential methods and options was assessed in terms of how each meets a set of Flood Risk Management Objectives. The appraisal of options against these objectives is a core design of the CFRAM process to deliver a preferred option that is appropriate and sustainable across all societal drivers. Consideration of these objectives was therefore interwoven throughout the assessment process. A basic assessment of the objectives was carried out as part of the viability screening stage with key requirements set for specific objectives for a method to be considered viable. Where viable methods or options were identified, a more detailed review of the objectives was undertaken as part of a full multi-criteria analysis.

The objectives are divided into four core criteria:

- 1) **Technical:** three objectives covering operational robustness, health and safety and adaptability to climate change.
- 2) **Economic:** four criteria covering economic risk and risk to transport infrastructure, utility infrastructure and agriculture.

3) **Social:** two objectives covering the risk to human health and life, community and social infrastructure and amenity.

4) **Environmental:** seven objectives covering the requirements of the Water Framework Directive, the Habitats Directive, flora and fauna, fisheries, landscape culture and cultural heritage.

In total there are 18 objectives against which proposed methods and options have been assessed.

Table 3-2: Flood risk management objectives

Number	Criteria	Sub- objective
1a	Technical	Ensure flood risk management options are operationally robust
1b		Minimise health and safety risks associated with the construction and operation of flood risk management options
1c		Ensure flood risk management options are adaptable to future flood risk
2a	Economic	Minimise economic risk
2b		Minimise risk to transport infrastructure
2c		Minimise risk to utility infrastructure
2d		Minimise risk to agriculture
3a (i)	Social	Minimise risk to human health and life of residents
3a (ii)		Minimise risk to high vulnerability properties
3b (i)		Minimise risk to social infrastructure and amenity
3b (ii)		Minimise risk to local employment
4a	Environmental	Provide no impediment to the achievement of water body objectives and, if possible, contribute to the achievement of water body objectives.
4b		Avoid detrimental effects to, and where possible enhance, Natura 2000 network, protected species and their key habitats, recognising relevant landscape features and stepping stones.
4c		Avoid damage to or loss of, and where possible enhance, nature conservation sites and protected species or other know species of conservation concern.
4d		Maintain existing, and where possible create new, fisheries habitat including the maintenance or improvement of conditions that allow upstream migration for fish species.
4e		Protect, and where possible enhance, visual amenity, landscape protection zones and views into / from designated scenic areas within the river corridor.
4f (i)		Avoid damage to or loss of features of architectural value and their setting.
4f (ii)		Avoid damage to or loss of features of archaeological value and their setting.

3.3 Screening of viable structural methods

The screening assessment has been completed against a long list of structural methods. The structural methods assessed, depending on relevance to any given AFA, are as follows:

- Storage (single or multiple site flood water storage, flood retardation, etc.)
- Flow diversion (full diversion / bypass channel, flood relief channel, etc.)
- Increase conveyance (in-channel works, floodplain earthworks, removal of constraints / constrictions, channel / floodplain clearance, etc.)
- Construct flood defences (walls, embankments, demountable defences, etc.)
- Rehabilitate, improve existing defences
- Relocation of properties
- Localised protection works (e.g., minor raising of existing defences / levels, infilling gaps in defences, etc.)

The viability screening assessment has considered methods against a progression of key objectives. Methods must be found to be, in the following order:

- Technically viable - the method results in an appropriate reduction in flood risk
- Economically viable - the method is not cost prohibitive in comparison to the damages predicted to arise from flooding
- Environmentally sustainable - the impacts of the method on the environment can be expected to be managed
- Socially acceptable - the method does not have an overtly negative impact on the local community
- Safe - the method does not increase risk to life to the community.

The criteria against which methods have been screened and the screening threshold which indicates a failure to meet a certain criterion are set out below. Methods which fail to meet the

relevant threshold of an objective have been 'screened out' and are not assessed against the remaining objectives.

3.3.1 Technical

For a method to be technically viable it must first be relevant to the site in question. For example, an embankment cannot be proposed where there is insufficient space to construct one.

For methods that are relevant to the site, the scale and extent of the works required to manage flood risk to the design event has been determined and are set out in the screening table. Where these dimensions and or quantities are realistic in the context of the site, the method is considered technically viable. For example, the volume requirement for a storage area is determined and then the upstream catchment searched for suitable locations. Where no such locations can be identified then the method as a standalone option is screened out on technical viability.

Where the method is considered technically unviable as a standalone, but viable in conjunction with other methods, the reduced scale and extent of the method is presented.

3.3.2 Economic

For technically viable methods a cost estimate for the works has been derived. This has then been compared with the economic benefits associated with the removal of flood risk in a given flood event. The economic benefits have been extracted for all return period flood events so the threshold of extensive flooding can be easily understood and the scope for methods below the design standard quickly appraised.

Methods with a benefit cost ratio of greater than 1, i.e. flood damages avoided with the method in place exceed the costs to construct it, are considered to be economically viable. Methods where this is not the case are screened out on economic viability.

To avoid rejecting methods at this stage that could be of interest in the wider discussion of future flood risk management in an AFA, either as a result of climate change or through alternative funding mechanisms, the costs estimates have excluded allowances for preliminaries, unmeasured items, archaeology and land purchase / compensation.

3.3.3 Environmental

The environmental screening has made use of the SEA scoping report. At this stage, screening on this criterion has been for information purposes only as mitigation methods may be available where a detrimental impact is identified. However, where it is clear that a particular method would require application of the IROPI⁷ process and at least one alternative method is available then the method is not considered to be environmentally viable and has been screened out.

3.3.4 Social and cultural

The approach taken to the cultural criteria of the screening is similar to that undertaken for the environmental criteria. The screening is predominantly for information purposes and a method has been rejected only on the basis that it would have a significant detrimental impact on the area with little scope for mitigation and there are viable alternative approaches available. In most cases, confirmation of a method's unacceptability needs to be obtained through the consultation process. It is therefore important not to screen methods out on the assumption that the local community values alternative social constraints over the negative impacts of ongoing flood risk.

For example, a permanent wall of 2m height will most likely not be acceptable through an amenity site but a community may be willing to accept a permanent wall of 1.2m that provides a reduction in flood risk with appropriate efforts to incorporate the wall into the surroundings.

3.3.5 Health and safety

Designers can make decisions that significantly reduce the risks to safety and health during the construction stage and during subsequent operation and maintenance. They are therefore a key contributor to construction health and safety.

⁷ IROPI - Imperative Reasons of Overriding Public Interest, as defined by the Habitats Directive - requires there to be no alternative to the method / option which has been shown to result in detrimental impacts to a Natura site.
WCFRAM UoM 30 Preliminary Options Report - Overarching Report v3.0

Health and safety risks during construction and operational stages have been assessed at a high level to confirm if it could be mitigated or managed. Where this is not considered to be the case then the methods have been screened out. This screening assessment is an initial check for health and safety concerns. Where methods have been carried forward as part of a viable options a Design Health and Safety Risk assessment has been completed.

3.4 Viable structural flood risk management methods in UoM 30

Structural methods have been investigated for Galway City, Corrofin and Oughterard only. A summary of the findings of the screening assessment is presented in Table 3-3.

The aim of the screening assessment was to identify viable, structural methods from which flood risk management options for the AFA as a whole have been developed.

Figure 3-1 to Figure 3-6 present the technically viable structural flood risk management methods identified for Galway City, Corrofin, and Oughterard. None of these methods were found to be economically viable with respect to current levels of flood risk.

Table 3-3: Summary of viable structural flood risk management methods in UoM 30

AFA Name	Options for screening	Conclusion ⁸
Corrofin (Volume 2b)	<p>Construction of raised embankments</p> <p>This option will construct raised embankments around all 5 properties.</p>	Not economically viable BCR 0.49
<p>Figure 3-1: Technically viable methods identified for Corrofin</p>		
Galway City (Volume 2c)	<p>Flood Containment</p> <p>This option involves the placement of quay defence walls in order to protect against the 0.5% AEP design event with an average wall height of 1.2m required. This includes a freeboard allowance of 0.3m. The quay walls would extend from the dock continuing along Long Walk and Spanish Arch. The properties in</p>	Economically Viable (BCR 1.0)

⁸ BCR - Benefit Cost Ratio. A ratio greater than 1 was needed to allow an option to be developed further.
WCFRAM UoM 30 Preliminary Options Report - Overarching Report v3.0

the Claddagh area, along Grattan road and Father Griffin would be provided protection also by placing a quay wall along the Claddagh basin and Nimmo's pier. property line defences and localised raising in Salthill.

Figure 3-2: Technically viable methods identified for Galway

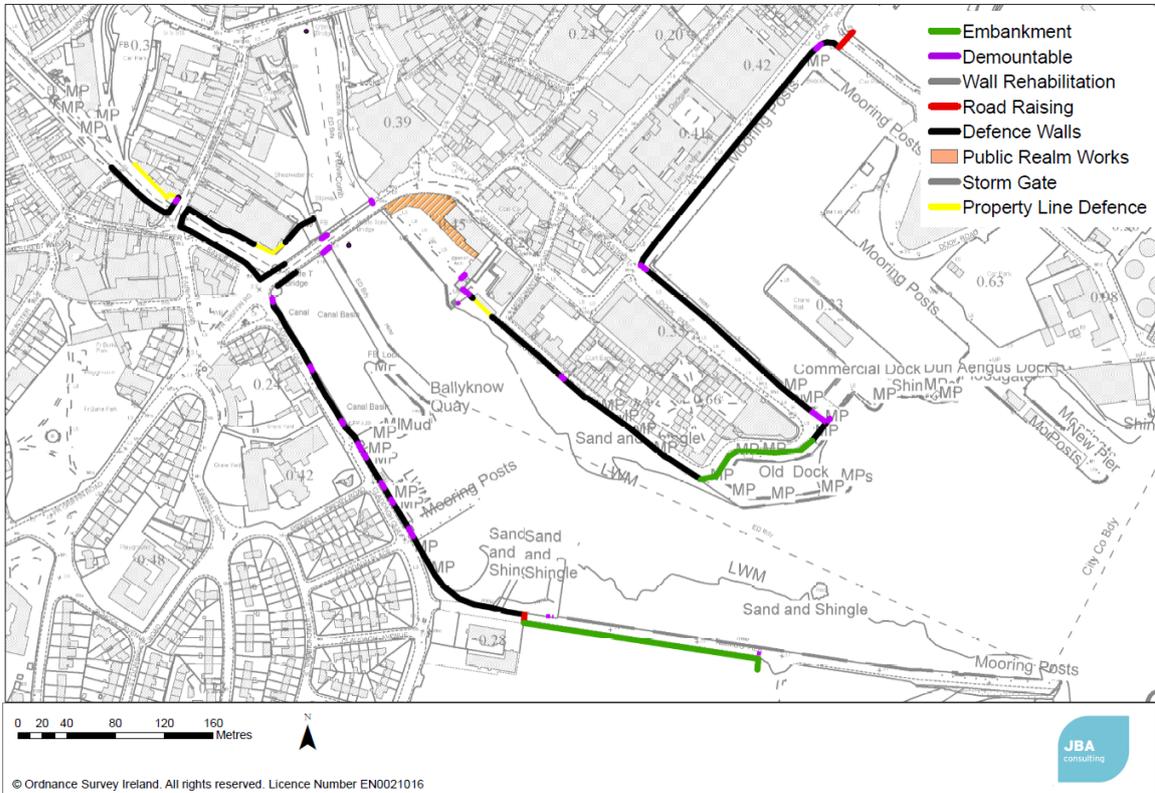
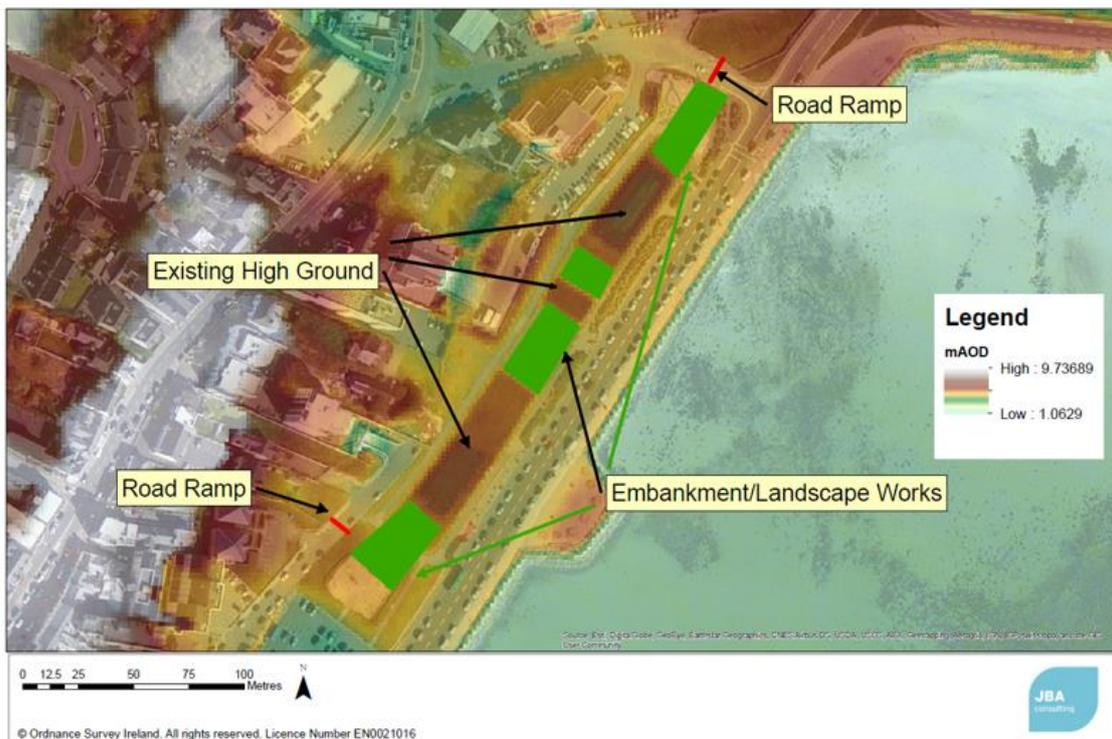


Figure 3-3: Technically Viable methods identified for Salthill (Area 1)

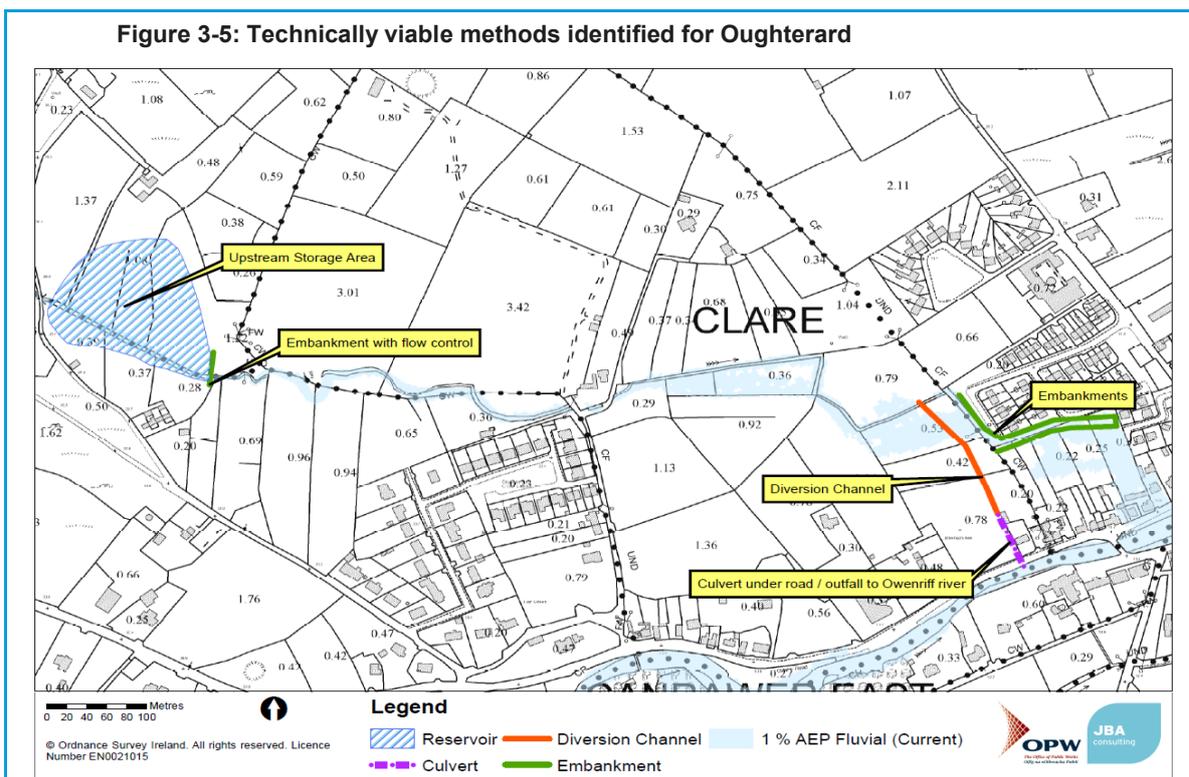


Figure 3-4: Technically Viable methods Salthill (Area 2)



Oughterard (Volume 2d)	<p>Upstream Storage</p> <p>This option would involve creating an upstream storage area by the construction of a storage embankment and hydrobrake.</p>	Not economically viable - BCR 0.08
	<p>Flow Diversion Channel</p> <p>This option will create a 200m bypass channel from the Tonweeroe to the Owenriff</p>	Not economically viable - BCR 0.03
	<p>Embankment / Walls</p> <p>A 320m embankment and 30m (1.2high) wall to cut off the flow routes to the properties</p>	Not economically viable - BCR 0.05

Figure 3-5: Technically viable methods identified for Oughterard



3.5 Climate Change

The development of flood risk management options must be cognisant of the implications of climate change on the area protected. The OPW, as lead agency for flood risk management in Ireland, requires that methods be constructed either to accommodate or be adaptable to increasing flood risk associated with climate change. In reality there is not often the economic justification based on flood risk in the present day to design and construct a scheme to accommodate an uncertain level of flood risk in the future. Options therefore need to be adaptable to increased flood risk.

Climate change impacts in all AFAs. However, in Galway City, climate change impacts are related to sea level rise. Although climate change is not indicated to increase flood risk to currently undeveloped land in these AFAs there is the potential for flood depths to increase by up to 1m (under the high end future scenario) in areas of existing development.

For AFAs where no options have been identified as being viable under the current scenario, it is recommended that future CFRAM cycles include a review of changes in flood risk, at which time the justification for promoting methods may have increased.

4 Non-structural methods

Non-structural flood risk management methods represent a suite of tools that can help people to live with flood risk in the short term and encourage sustainable decisions in the long term. They do not include hard structural methods and so will not remove flood risk, but they can significantly reduce the risk of flooding to life and the impacts of flooding, enabling a speedy recovery following an event. They are usually cost effective when compared to structural methods.

4.1 Planning development and control

4.1.1 Spatial planning and impacts on development

In November 2009, the Department of the Environment in conjunction with the OPW issued 'The Planning System and Flood Risk Management - Guidelines for Planning Authorities'. Its primary purpose was to aid authorities in ensuring flood risk was, and remains, a key consideration in preparing development plans, local area plans and in the assessment of planning applications. A review of the Development Plans, Local Area Plans and other spatial planning documents has been carried out for each AFA and the UoM as a whole. Section 5 details the findings and discusses the potential land use, spatial planning and development management policies, which are summarised in Table 4-1.

The assessment has focused on three main areas:

- A review of current policy and guidance with recommendations for future development plan cycles;
- A review of current land use zoning against the CFRAM Flood Zones. This recognises that most development plans were completed prior to the CFRAM Study and were based on indicative flood risk information;
- A review of climate change impacts on land use zoning and future development.

Table 4-1: Summary of spatial planning considerations taking into account current and future flood risk

	Current flood risk	Future flood risk
Ballyhaunis	One area to the south, currently zones for Industry shows some risk of flooding from a 1% flood event. Generally, all other land at flood risk is zoned for water compatible uses such as agricultural & amenity	Flood Zone B increases considerably in MRFS. It would be appropriate to undertake an SFRA to ensure the development plan zoning objectives are sustainable in the future and consider re-zoning land which is within future Flood Zones
Claregalway	Currently a scheme is under construction for Claregalway. Policies for development in areas protected by the proposed flood alleviation scheme should be put in place to manage the residual risks, should structural flood defences fail or be exceeded (overtopped).	No Future flood mapping available for Claregalway
Corrofin	No development plan available for Corrofin however Flood Zone A & B extents do show inundation of properties in the Ballybanagher area only	A limited increase in the future across Corrofin with slight increases in the extent of Flood Zones A & B.
Galway City	Generally, lands within Flood Zone A & B comprise of existing development or water compatible uses however areas zoned for mixed/general community services and strategic reserve are at risk of flooding and encroach Flood	Generally, a limited increase in flood risk in the future is identified however existing residential properties west of the city centre show increased risk of flooding from a 0.1% AEP MRFS tidal flood event. Some light residential

	Zones A & B (tidal flooding).	zoned lands along the northern section of the city show increased risk of flooding.
Oughterard	Generally, all land at flood risk is zoned for water compatible uses, however there is an area on the left bank of the Owenriff river that is zoned in conflict with Flood Zone B.	A limited increase in the future across Oughterard with slight increases in the extent of Flood Zones A & B.
Tuam	Generally, lands within flood zones are zoned as water compatible however significant areas, to the west and east of the town centre are zoned as residential (R2) and existing residential within Flood Zone A	A limited increase in the future across Tuam with slight increases in the extent of Flood Zones A & B.

4.1.2 Sustainable drainage systems (SUDs)

Sustainable drainage is a design philosophy that uses a range of techniques to manage surface water as close to its source as possible. Sustainable Drainage Systems (SUDs) are designed with three objectives in mind:

- To control the quantity and rate of run-off from a development;
- To improve the quality of the run-off;
- To enhance the nature conservation, landscape and amenity value of the site and its surroundings.

Section 6 discusses the potential development of sustainable urban drainage systems for each AFA, which is summarised in Table 4-2.

Table 4-2: Summary of applicability of SUDS within the AFA

AFA	Applicability of SUDS
Ballyhaunis	Infiltration treatment likely to be appropriate across the AFA. Potential for regionally based attenuation areas has been identified.
Claregalway	Low infiltration capacity indicated, although pockets of well-draining soil are identified. Potential for regionally based attenuation areas has been identified.
Corrofin	Infiltration treatment likely to be appropriate across the AFA. Limited potential for regionally based attenuation.
Galway City	Infiltration treatment likely to be appropriate across the AFA, but probably less successful to the north of the N6. Limited potential for regionally based attenuation, but opportunities for SuDS to be sought on a site by site basis.
Oughterard	Infiltration treatment likely to be appropriate across the AFA. Potential for regionally based attenuation areas has been identified.
Tuam	Infiltration treatment likely to be appropriate across the AFA. Potential for regionally based attenuation areas has been identified.

4.1.3 Building regulations / planning conditions

It may be possible to mitigate risk of damage from flood inundation using appropriate construction techniques and materials. A timber stud partition covered with plasterboard with low level electric wiring would require complete replacement if the property flooded, however solid concrete walls covered with tiles and high level electrical wiring makes a property more resilient to flooding, with quick and lower cost clean up required. In the absence of funding for a full scheme such methods can be utilised to reduce the damage.

The Guidelines for Planning Authorities should prevent inappropriate development in areas at risk of flooding, but some development may still go ahead despite the Guidelines. Certain building regulations and planning conditions could be adopted to ensure structures are flood

resilient through specified construction methods and the types of building fabrics used. Similarly, construction outside but close to the Flood Zone B extent may be susceptible to increases in flood risk as a result of climate change, and applying such building regulations would reduce the potential impact in the future.

4.2 Flood preparedness

4.2.1 Flood forecasting and warning systems

Flood forecasting and flood warning can be an effective part of the flood risk management response, providing an early warning to local residents and response groups in times of emergency. In conjunction with other flood management methods, such as flood gates, it allows time for improved flood resilience of properties where more substantial schemes have not been justified or are not feasible. It can usually be implemented in the short-medium term and provides opportunities to raise public awareness of flood risk and so improve community preparedness. Full discussion on the potential to implement flood forecasting, and the required lead times, is provided in Section 7 and a summary of the recommendations is provided in Table 4-3.

Table 4-3: Recommendations for flood forecasting systems

Fluvial forecasting systems	
Ballyhaunis	No system required as currently no risk of fluvial flooding.
Tuam	No system required as currently no risk of fluvial flooding.
Corrofin	A flood warning system for the River Clare / Corrib based on the existing gauged network is technically viable but currently is not economically viable.
Claregalway	A flood warning system for the River Clare / Corrib based on the existing gauged network is technically viable but currently is not economically viable.
Oughterard	The current flood risk is on a small tributary and it is not technically viable to attain the advance warning times.
Galway City	A flood warning system for the River Clare / Corrib based on the existing gauged network is technically viable but currently is not economically viable.
Coastal forecasting system	
Galway City	By tying into the national storm surge model developed by the OPW warning can be provided in Galway City. A wave overtopping model is required for Salthill

4.2.2 Emergency response planning

Until such time as flood prevention schemes are built, the existing level of risk will remain unless a flood response plan can ensure necessary actions are taken and all vulnerable residents can be safely evacuated and accommodated. Well prepared and executed emergency plans can significantly reduce the impact of flood events. Galway County Council has produced a Major Emergency Plan, which incorporates a "Flooding Sub Plan".

For example, Galway's plan includes the following:

- That Galway Council are monitoring flood levels and weather conditions on a continuous and multi-agency basis and nominated staff are on call at a local level.
- Galway County Council will maintain a database of previously identified areas under severe flood threat. As part of the WCFRAM, flood extent, depth and hazard maps have been produced that can be used to inform the local authorities of areas of significant risk.
- Emergency plant and materials are maintained at strategic locations.
- During periods of severe flooding the Galway County Council website will be used to indicate flood affected areas.

4.2.3 Targeted Public awareness

Individuals and communities that are aware of any prevalent flood risk are able to prepare for flood events and take appropriate actions in advance of, during and after a flood to reduce the harm and damages a flood can cause.

In 2005, the OPW launched the Plan, Prepare and Protect campaign that provides general, practical advice to homeowners, businesses and farmers on what they can do to prepare against flooding. The Report of the Flood Policy Review (OPW, 2004) recommends that local authorities should assume responsibility for the local dimension of the flood risk education programme, including raising awareness of individual and business interests considered to be at risk and assisting with preparations to minimise risk.

4.3 Individual property methods

4.3.1 Individual property resilience

Resilience methods are those that are undertaken inside a property to reduce damage caused by floodwaters. Flood resilience, or wet proofing, accepts that floodwater will enter the building and allows for this situation through careful internal design such as raising electrical sockets and fitting tiled floors so that the building can quickly be returned to use after the flood. Resilience methods may be suitable for properties vulnerable to repeated flooding where the depth of flooding exceeds 600 mm (CIRIA 2007).

4.3.2 Individual property protection

Flood resistance, or dry proofing, techniques prevent floodwater from entering a building. This approach includes, for example, using flood barriers across doorways, closing airbricks and raising floor levels. These methods may be deployed or constructed within the immediate curtilage of a property, or become a component of the building's fabric. Property resistance methods may be appropriate in areas that frequently flood to shallow depths (below 600mm), and where community-scale defences are unlikely to be a viable option. When floodwater exceeds this level it may be more appropriate to allow water into a property and to use flood resilience methods instead.

4.3.3 Summary of findings for individual property methods

Table 4-4 summarises the flood depths in properties in the design event and the recommendations for individual property protection.

Table 4-4: Recommendations for individual property protection

AFA Name	No. of properties with depths:		Recommendations
	< 600mm	> 600mm	
Corrofin (Volume 2b)	2	1	The costs of a community scale option are prohibitive for Corrofin given the current level of flood risk. Individual property methods should be considered.
Galway City (Volume 2c)	301	11	The number of properties at risk of flooding means a community scale option will be more cost effective in Galway City
Oughterard (Volume 2i)	4	0	The costs of a community scale option are prohibitive for Oughterard given the current level of flood risk. Individual property methods should be considered.

4.4 Maintenance

Excess vegetation or the blockage of channels with natural and/or dumped materials can reduce the conveyance capacity of a watercourse, increasing water levels in the event of a flood and hence increasing the flood risk in the surrounding area.

Rivers can be divided into three main categories when it comes to maintenance:

- Arterial Drainage Rivers - Where the Office of Public Works have completed a drainage scheme under the Arterial Drainage Acts, 1945 and 1995, there is a statutory requirement to maintain the drainage works forming part of the scheme. These drainage works include watercourses, embankments and other structures. Watercourses are

subject to siltation and erosion, among other processes, and embankments are subject to settlement and erosion. Ongoing maintenance activities are of a cyclical nature. Annual maintenance works schedules are compiled to prioritise drainage works based on a rate of deterioration and the risk arising. As shown in Figure 4-1 the Corrib Arterial Drainage Scheme affects most of the catchment in UoM30. The effects of Arterial Drainage will be less pronounced in Galway City due to the effect of Lough Corrib, although the Corrib and associated canals have been subject to significant engineering work. There are possible groundwater interactions between the Corrib and Moy Arterial Drainage Schemes through the karst groundwater systems along the border of County Mayo and Galway.

- **Drainage Districts** - Many local authorities have a statutory responsibility for the maintenance of Drainage Districts under the Arterial Drainage Act, 1925. However, the Report of the Flood Policy Review Group (2004) states "A major difficulty for local authorities in fulfilling this obligation has been a lack of funding. Only minor investment has been possible and many Drainage Districts have fallen into disrepair." Figure 4-1 shows the areas within UoM 30 that are covered by drainage districts. The Corrib Headford scheme is the only drainage district in UoM 30.
- **Other** - These are rivers that are currently not under an arterial drainage schemes and drainage districts. Maintenance responsibility lies with the riparian owner in these cases.

Figure 4-1: Arterial drainage rivers and drainage districts

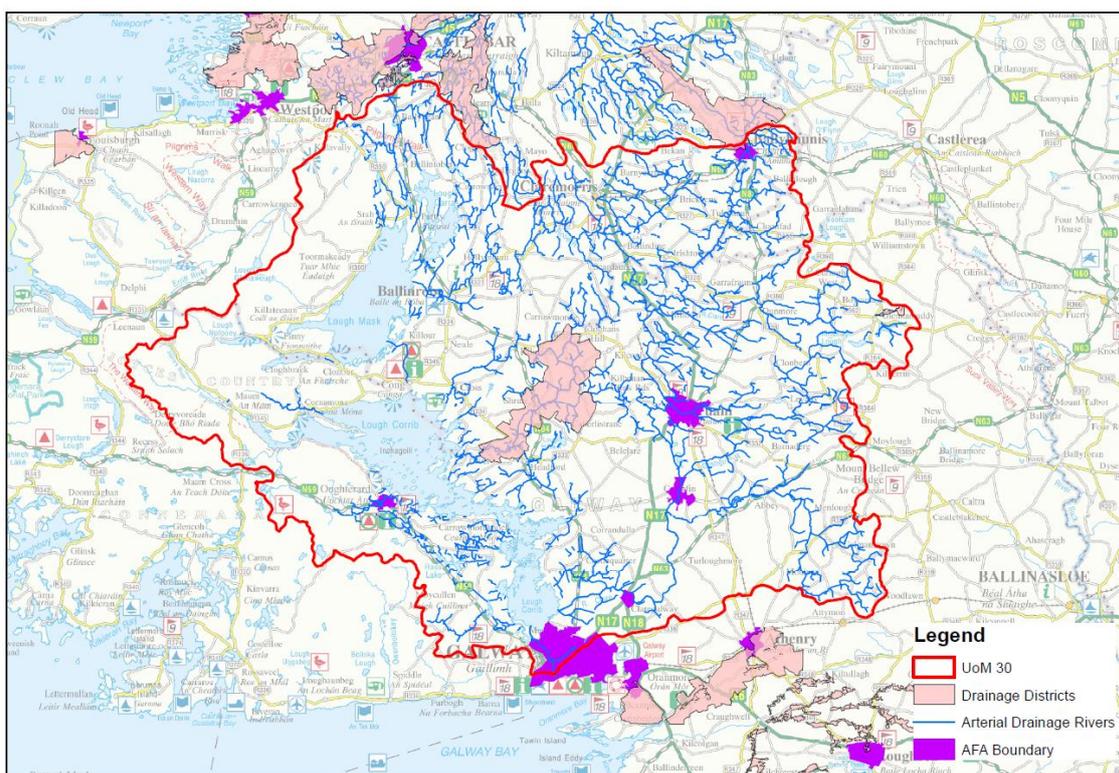
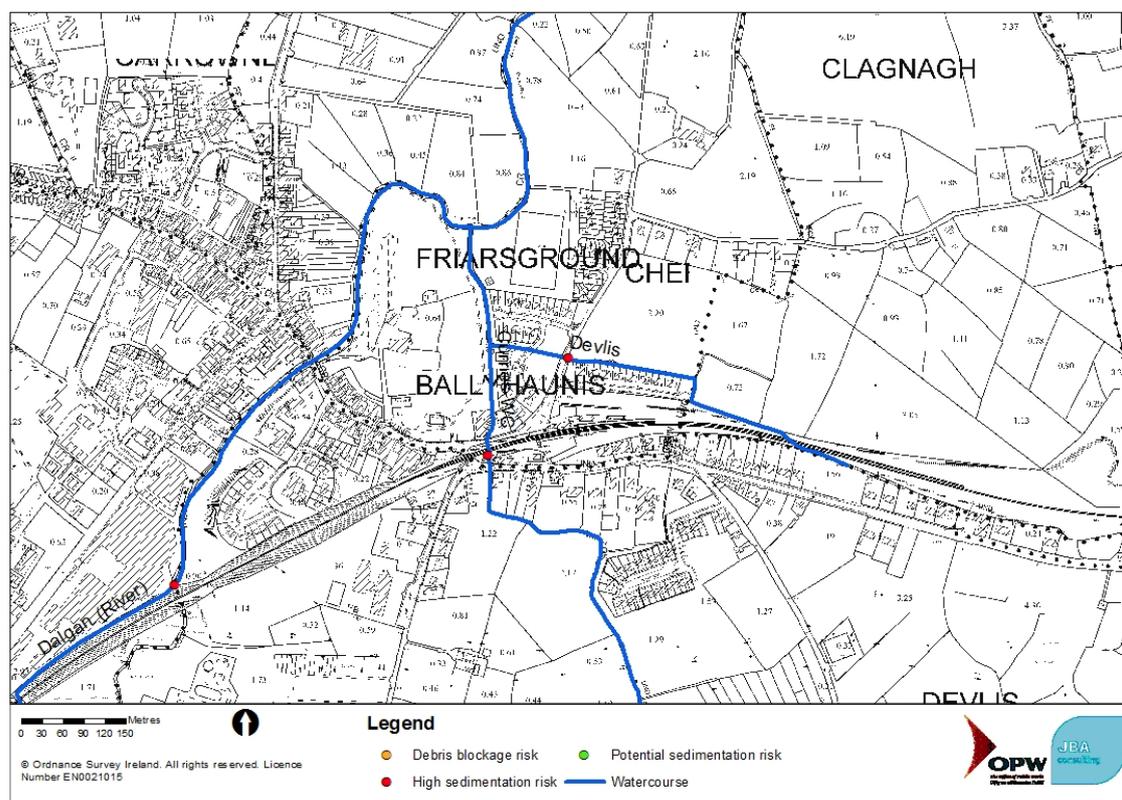


Table 4-5 summarises the maintenance considerations for each AFA.

Table 4-5: Maintenance considerations for each AFA

AFA Name	Site overview	Recommendations
Ballyhaunis	<p>The hydromorphic audit has identified there is evidence of gravel and silt deposition on the Curries watercourse between the N60 and railway embankment crossing. Under present conditions this has been shown not to result in flood risk. The impact of changes to the geomorphology of the watercourse, and in particular greater gravel accumulations could have an impact on flood risk in the future.</p> <p>Blockage of culverts and small span bridges has the potential to increase flood risk on any watercourse. In Ballyhaunis the culvert on the Devlis watercourse below Station Rise, looks particularly prone to blockage, with evidence of dumping of household waste, coupled with natural debris in the upstream channel. If the culvert blocked.</p> <p>No formal or informal effective defences or walls were identified in Ballyhaunis.</p>	<p>The AFA is covered by the Corrib - Clare arterial drainage scheme maintenance and its responsibility lies with the OPW and should be subject to regular maintenance, under the arterial drainage act. Consideration should be given to the key structures that have been identified as susceptible to blockage.</p>

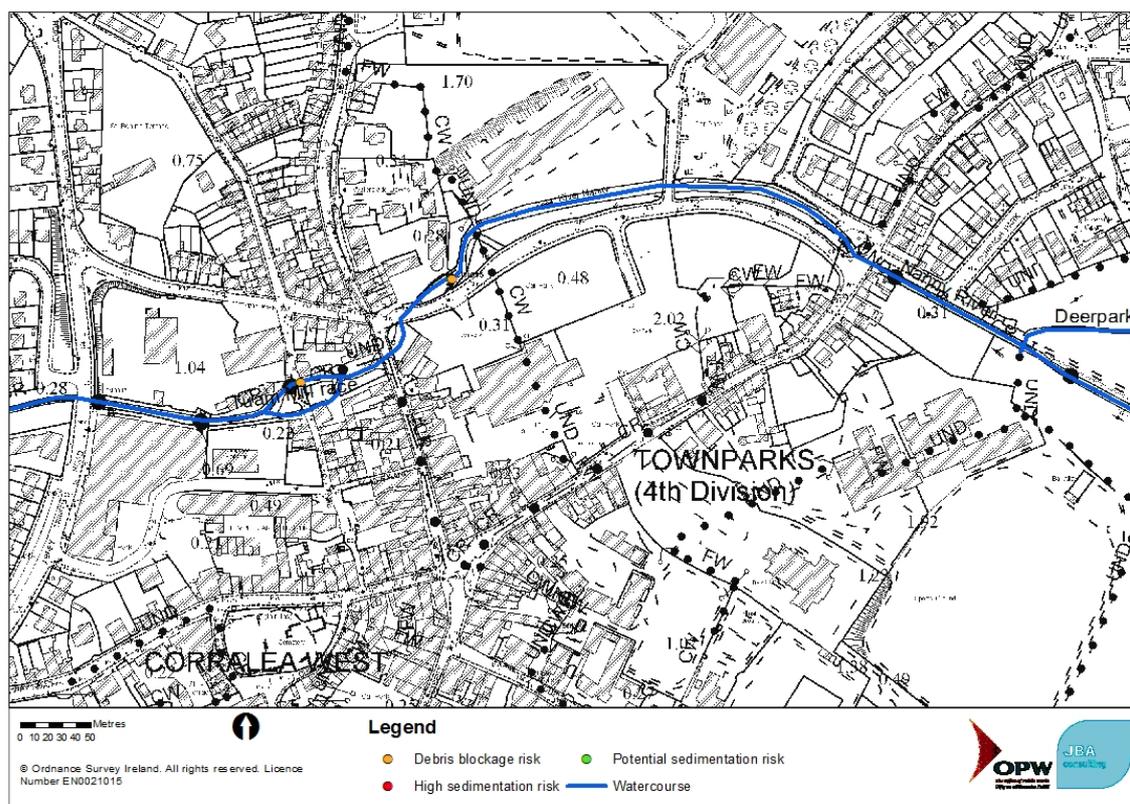
Figure 4-2: Maintenance Sensitive Structures in Ballyhaunis



Tuam	<p>The hydromorphic audit has identified two areas susceptible to blockage. Blockage of culverts and small span bridges has the potential to increase the flood risk of a</p>	<p>The AFA is covered by the Corrib - Clare arterial drainage scheme maintenance and its responsibility lies with the OPW and should be subject to regular maintenance, under the arterial drainage act. Consideration should be</p>
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<p>watercourse. In Tuam the culverts along the Nanny watercourse look particularly prone to blockage. If one of the culverts did block water would back up in the channel, before potentially causing flooding. However, where it does occur it is likely that culvert blockage will increase flood risk to properties.</p> <p>No formal or informal effective defences or walls were identified in Tuam.</p>	<p>given to the key structures that have been identified as susceptible to blockage.</p>
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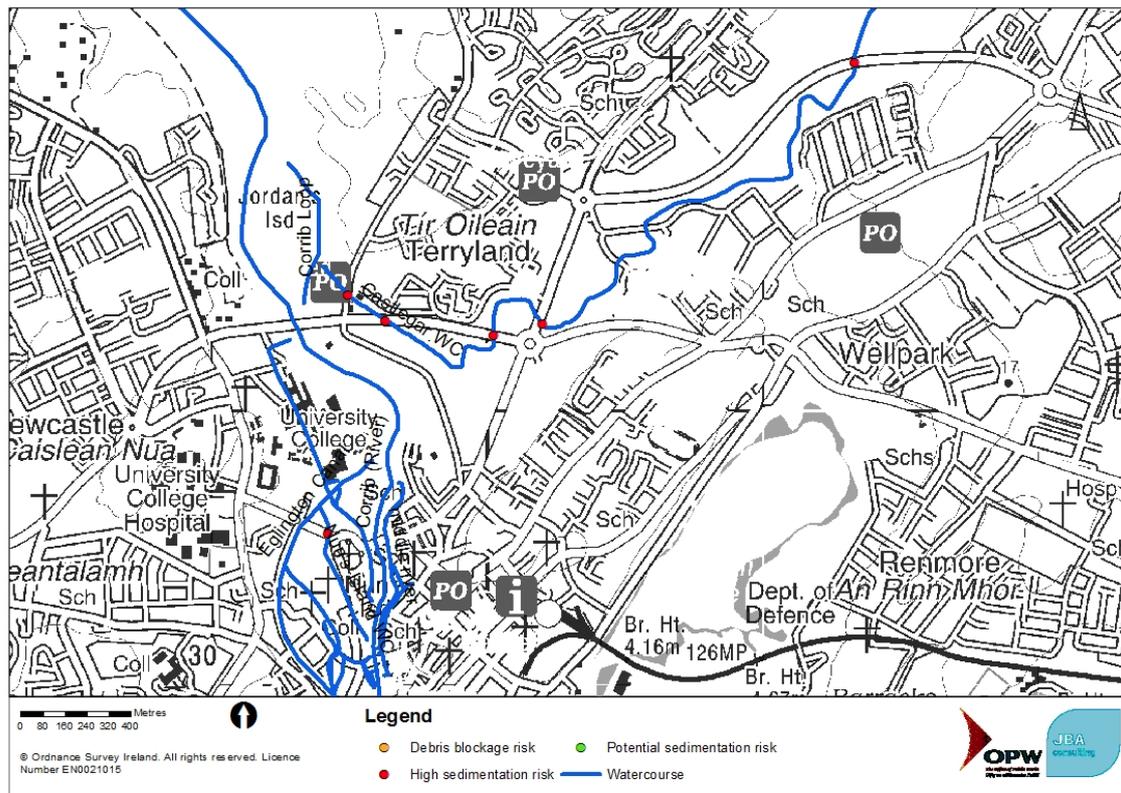
Figure 4-3: Maintenance Sensitive Structures in Tuam



<p>Corrofin</p>	<p>The hydromorphic audit has not identified any reaches susceptible to sedimentation processes or blockage risk.</p> <p>No formal or informal effective defences or walls were identified in Corrofin.</p>	<p>The AFA is covered by the Corrib - Clare arterial drainage scheme maintenance and its responsibility lies with the OPW and should be subject to regular maintenance, under the arterial drainage act.</p>
<p>Claregalway</p>	<p>A flood relief scheme is under construction for the town and any maintenance will be covered under the arterial drainage act</p>	<p>No further action required</p>
<p>Galway City</p>	<p>The River Corrib is part of the Corrib Arterial Drainage Scheme and so maintained under the Arterial Drainage Acts. Further enhanced structure maintenance to the culverts and culvert inlets could potentially increase the structure capacity through the removal of fine sediment deposits.</p>	<p>The OPW, Lough Corrib Trustees, Galway Port and Galway City Council have all responsibility in some part of Galway City. Engagement between these groups is important for maintenance regimes to be effective. Consideration should be given by all parties to incorporating the key structures identified into a priority monitoring schedule ahead of the formalisation of maintenance responsibilities for these watercourses.</p>

	<p>The hydromorphic audit has identified that of the Castlegar River which is a tributary of the main River Corrib river has a high risk of sedimentation.</p> <p>A number of formal effective defences have been identified in Galway City. There is dyke/embankment along dyke road that has been classified as in fair condition, a retaining wall on the right bank on the river Corrib, upstream of salmon bridge weir is classified in good condition and a small portion of the quay wall between Bridge Street and Wolfe Tone Bridge is in fair condition</p> <p>Blockage of culverts and small span bridges has the potential to increase flood risk on any watercourse. In Galway City, the canals are slow moving and from various site visits and survey results it is clear that some of the structures are heavily blocked. If these culverts blocked, water would back up in the channel, before overtopping onto into the urban area putting properties at increased risk of flooding. It is possible that blockage of these structures would exacerbate flood risk to adjacent properties</p>	<p>Blockage of structures along the canal have been noted. These structures should be included on a register of structures requiring frequent inspection and maintenance.</p> <p>The dyke road embankment is a vital defence to many areas and this should be maintained effectively going forward. It is recommended that all formal effective defences along the River Corrib be maintained to ensure the current standard of protection.</p>
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Figure 4-4: Maintenance Sensitive Structures Galway City



Oughterard

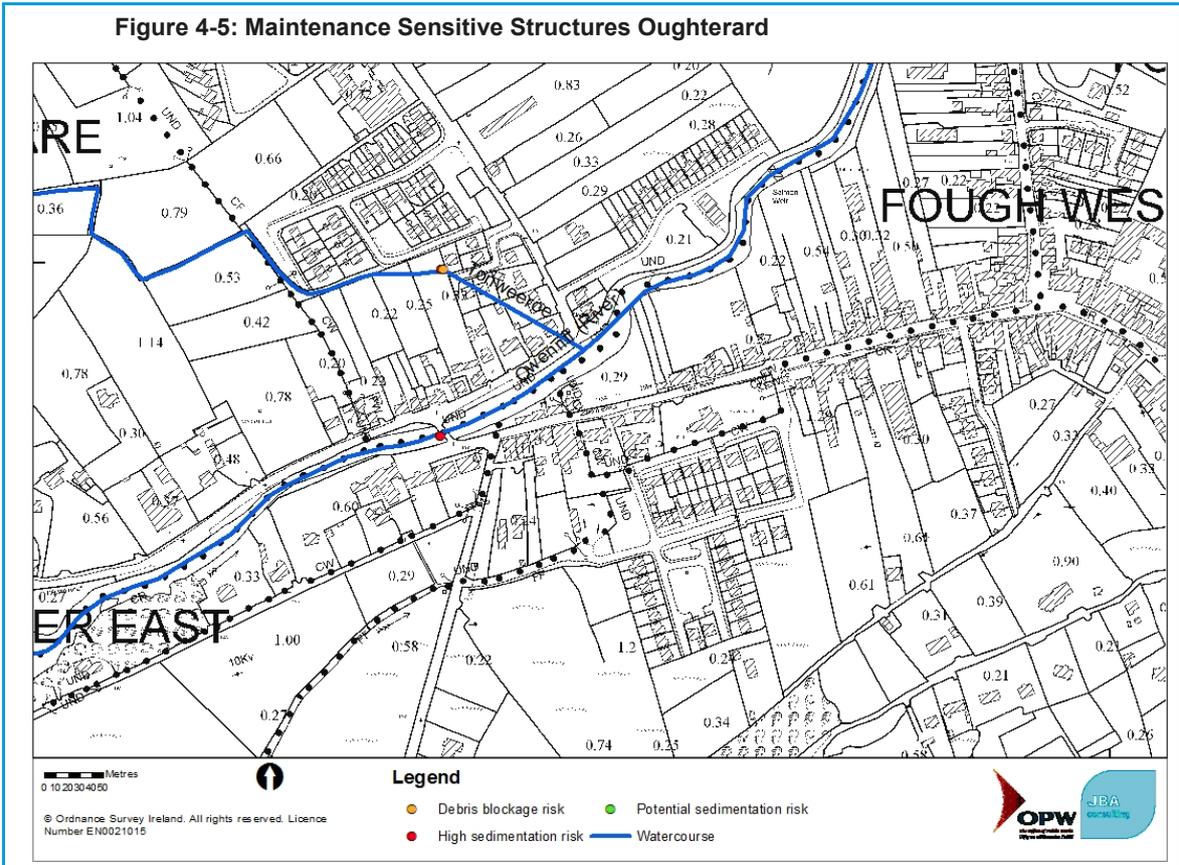
Both the Owenriff and Tonweeroe watercourse are part of the Corrib-Headford arterial drainage scheme. Under the 1945 the OPW has responsibility to maintain the scheme.

The likelihood of blockage to the culvert passing beneath the housing estate on the Tonweeroe river has been highlighted. The existing low capacity of the structure and a poorly designed trash screen on the upstream face increase the risk of blockage if not maintained.

The AFA is covered by the Corrib - Headford arterial drainage scheme maintenance and its responsibility lies with the OPW and should be subject to regular maintenance, under the arterial drainage act.

An appropriate maintenance regime is required along with upgrading the trash screen to one which is adequately designed and allow access for maintenance.

Figure 4-5: Maintenance Sensitive Structures Oughterard



4.5 Natural Flood Management

Natural flood management (NFM) is the use of existing features in the landscape or changes to land use management to attenuate flood events in the upstream catchment. Examples of this may be areas of active floodplain which if planted with woodland can slow the progress of a flood peak or encouraging farmers to plough fields horizontally across hills to prevent the creation of fast runoff channels.

Based on recent UK research, NFM has a greater influence on peak flows, surface runoff and hydrograph shape for smaller catchments and on more frequent lower magnitude floods. For larger catchments the direct influence on less frequent, more severe floods are less noticeable. However, NFM methods will have a prolonged effect on catchment sediment budgets and channel morphology and change the river response for floods of all magnitudes. For example, reduced fine sediment transport from upstream to downstream will increase capacity of lower energy reaches and structures and so reduce the frequency of maintenance and the resilience of these reaches to flood events.

Natural flood management methods focus on source control and hence are situated away from the known flooding areas, which are usually located within the towns. The identification of opportunities needs to consider the full drainage catchment upstream of these areas and so needs to approach the problem at a macro scale initially before more focussed proposals can be developed. To assist in future proposals for natural flood management a series of maps have been developed using available national datasets to inform which methods may be viable in which locations. The maps are strategic and are intended to support future investigations, they do not guarantee that natural flood management methods will be viable in the locations identified but they should preclude those areas where they are not likely to be viable.

4.5.1 Screening Maps

Natural flood management methods focus on source control and hence are situated away from the known flooding areas, which are usually located within the towns. The identification of opportunities needs to consider the full drainage catchment upstream of these areas and so needs to approach the problem at a macro scale initially before more focussed proposals can be developed. To assist in future proposals for natural flood management a series of maps have been developed using available national datasets to inform which methods may be viable in which locations. The maps are strategic and are intended to support future investigations, they do not guarantee that natural flood management methods will be viable in the locations identified but they should preclude those areas where they are not likely to be viable

The approach adopted for assessment reflects the methodology used by the Scottish Environment Protection Agency (SEPA) as set out in Identifying Opportunities for Natural Flood Management (December 2013). Five natural flood management objectives have been assessed by SPEA⁹ in Scotland and are relevant to Western Ireland due to the similar range of catchment, topographic and climatic conditions. These objectives and a set of natural flood management methods associated with these objectives are presented in Table 4-6.

Table 4-6: Natural flood management objectives and methods (from SEPA)

Objectives	Methods
Runoff reduction	Woodland planting (including upland, floodplain, riparian, gully or cross slope woodlands)
	Creation/restoration of non-floodplain wetlands
	Agricultural and upland drainage modifications (e.g. upland drain blocking)
	Land and soil management practices (e.g. ploughing along the contour of the land or soil aeration)
Floodplain storage	Reach and floodplain restoration
	Floodplain and riparian woodlands
	Instream structures (e.g. large woody debris and

⁹ SEPA (2013) Identifying Opportunities for Natural Flood Management (http://www.sepa.org.uk/media/33480/natural_flood_management_2013.pdf).
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	boulders)
	Reach restoration (e.g. remeandering)
	Offline storage areas and washlands
Sediment management	Reach restoration (e.g. remeandering)
	Sediment traps
	Bank restoration (e.g. riparian planting, green bank restoration)
Estuarine surge attenuation	Restoration of intertidal habitats including managed realignment
Wave energy dissipation	Beach management (e.g. beach recharge)
	Sand dune restoration
	Restoration of intertidal habitats including managed realignment

Screening maps have been developed to identify locations where existing conditions suggest there is an opportunity to reduce flooding through the mechanisms outlined. For the purposes of the WCFRAM, maps have been produced for the runoff reduction, floodplain storage and sediment management mechanisms only, the methodology for which is set out in the following Sections. Opportunities for natural flood management associated with estuarine surge attenuation and wave energy dissipation are limited to specific AFAs and so have been discussed at an AFA level only.

4.5.2 Runoff reduction

The runoff reduction screening maps are a composite of four key determinants of runoff potential, namely soils, rainfall, topography and land use. The datasets used as the basis for the analysis are shown in Table 4-7.

Table 4-7: Datasets used in the runoff reduction screening maps

Data	Source
Soils	Irish National Soils Map, 1:250,000k, V1b(2014). Teagasc, Cranfield University. Jointly funded by the EPA STRIVE Research Programme 2007-2013 and Teagasc.
Rainfall	Annual 1981 to 2010 average rainfall on a 1 x 1 km grid, Met Eireann.
Topography	Informar Digital Terrain Model (DTM). This is the Office of Public Work's National Digital Height Model (NDHM), flown between 2007 and 2009. This 5m resolution DTM was supplied by the Office of Public Works in 2013.
Land use	CORINE landcover map, Environment Protection Agency, 2012.

Each dataset has been simplified to a 500m grid, with the most frequent occurrence of the underlying data in any given grid cell assumed to be representative of that cell. The data has then been reclassified into four sensitivity classes reflecting runoff potential, very low, low, moderate and high, and a score of 1 to 4 assigned to these respectively. High, and a score of 4, relates to the data associated with the greatest runoff potential, for example the steepest terrain. The mean of all the scores for each grid cell has been calculated and opportunities for runoff reduction identified using the matrix in Table 4-8.

Table 4-8: Combined sensitivity score classifications

Mean sensitivity value	Potential for runoff reduction
>3.25	High
2.75-3.25	Moderate
2.25-2.74	Low
<2.25	Very Low

4.5.3 Floodplain storage

The potential for increased floodplain storage has been investigated through screening for two mechanisms, the potential to re-naturalise watercourses where they have been over managed and the potential to increase roughness in the floodplain.

OPW's blue line river network has been used as the basis for this analysis. The dataset has been split into 500m reaches and the sinuosity of each reach calculated. In this case sinuosity is the ratio of the length of the channel to the distance between the upstream and downstream points of the channel. A sinuosity value of 1 means the channel is straight. This dataset has then been cross referenced against channel slope, determined using the National Digital Height Model, and classified for potential for re-naturalisation. Straight gentle channels are classified high and are considered to have the greatest potential for re-naturalisation. The screening map again reports at the 500m grid cell size with the highest classification in any cell used to determine the classification of the cell. OPW's arterial drainage network needs to be considered in conjunction with this screening tool and so has been overlain to highlight those cells where re-naturalisation may conflict with the requirements of the drainage programme.

Increased roughness in the floodplain has been assessed using two similar approaches. Initially a high level assessment applicable for the WCFRAM area as a whole has been used. This has cross referenced those land uses where woodland planting would increase floodplain roughness against a 500m grid of channel slope. Where the land use is suitable for woodland planting, the slope classification determines the potential for floodplain storage, in all other cases the potential for increased floodplain roughness is assumed to be very low.

The second approach has used the benefitting land maps and the flood extent maps produced through the CFRAM programme as an alternative to slope. These maps only cover the arterial drainage network and the HPWs and MPWs modelled in the WCFRAM but provide data on the floodplain of these watercourses. A 500m grid has been overlain on these extents and the percentage of the cell which is wet used to determine the potential for floodplain roughness. Again where the land use is suitable for woodland planting, the percentage wetness classification determines the potential for floodplain storage, in all other cases the potential for increased floodplain roughness is assumed to be very low.

4.5.4 Sediment management

The sediment management maps are sourced from the hydromorphology assessment completed as part of the WCFRAM directly. This work assessed the upstream catchments of all HPWs where sediment issues were identified. Source conditions were classified as stable, incised but stable, incised valley bottom with reworking and extensive valley side inputs. The screening maps highlight those source catchments identified as either of the latter two categories as having potential for sediment management methods.

4.5.5 Mapping outputs

When using these maps it is important to remember different natural flood management methods are effective at different scales, Figure 4-6.

Figure 4-6: Catchment scale classification of natural flood management methods

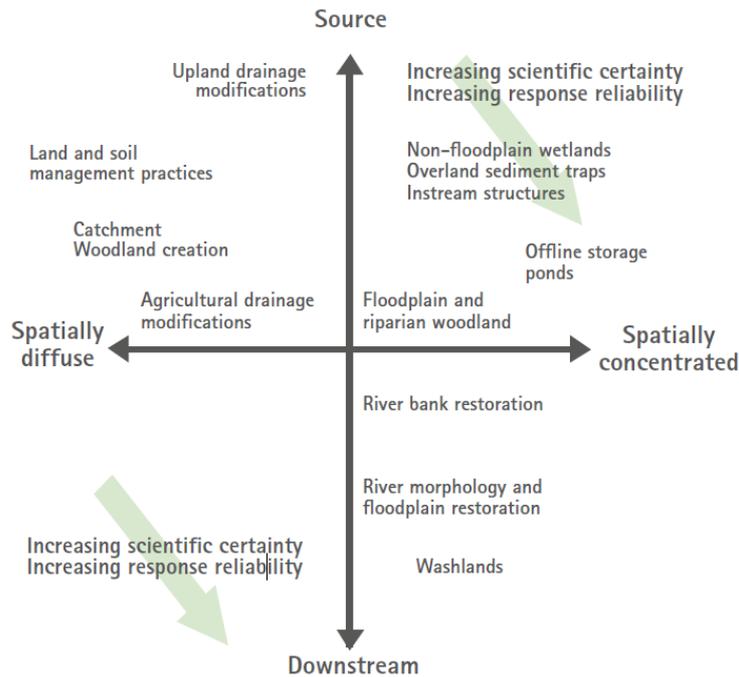


Figure extracted from SEPA Natural flood management hand book¹⁰ and adapted from Thorne et al¹¹.

Runoff reduction and sediment management methods will only have observable benefits at the small catchment scale and so efforts to implement these should be focussed in small catchments upstream of known flood risk areas. Floodplain storage methods are located further downstream in the catchment and so may have more observable effects in larger catchments. In both cases to produce observable changes in very large catchments will require widespread implementation of such methods. This will only be achieved over time and current focus should be on identifying opportunities that will deliver benefits in the short term.

Figure 4-7 to Figure 4-10 show the results of the screening assessment for UoM 30 and a short comment on suitability is provided below each map.

¹⁰ Natural Flood Management Handbook, Scottish Environmental Protection Agency, December 2015.

¹¹ THORNE, C., EVANS, E., and PENNING-ROWSELL, E. (2007). Future Flooding and Coastal Erosion Risks. London: Thomas Telford Ltd.

Figure 4-7: Runoff reduction NFM screening map for UoM 30

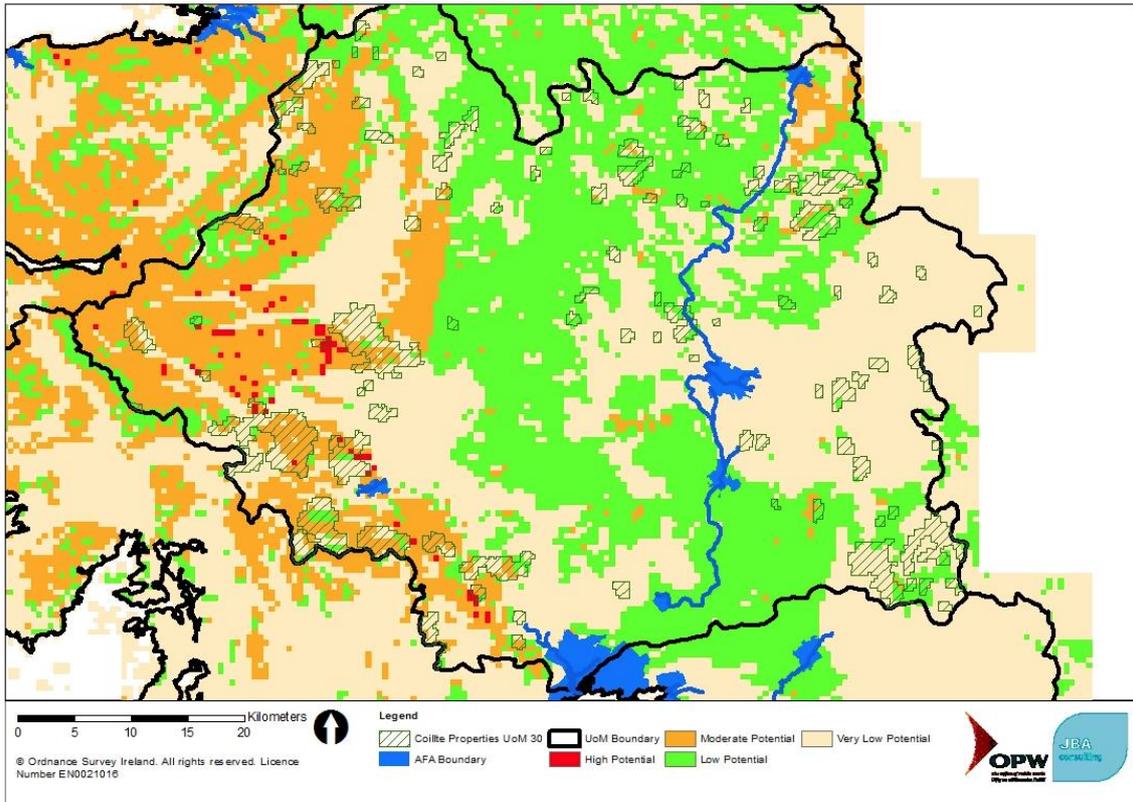


Figure 4-8: Re-naturalisation NFM screening map for UoM 30

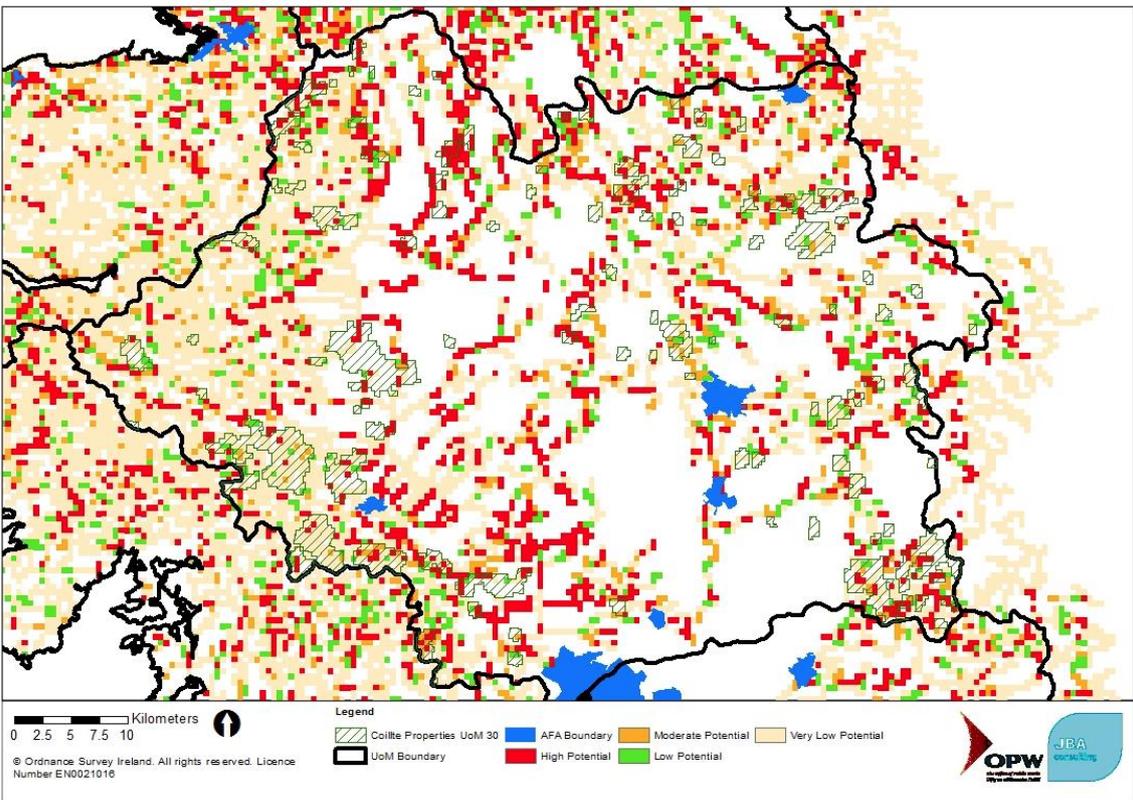


Figure 4-9: Floodplain storage NFM screening map using slope for UoM 30

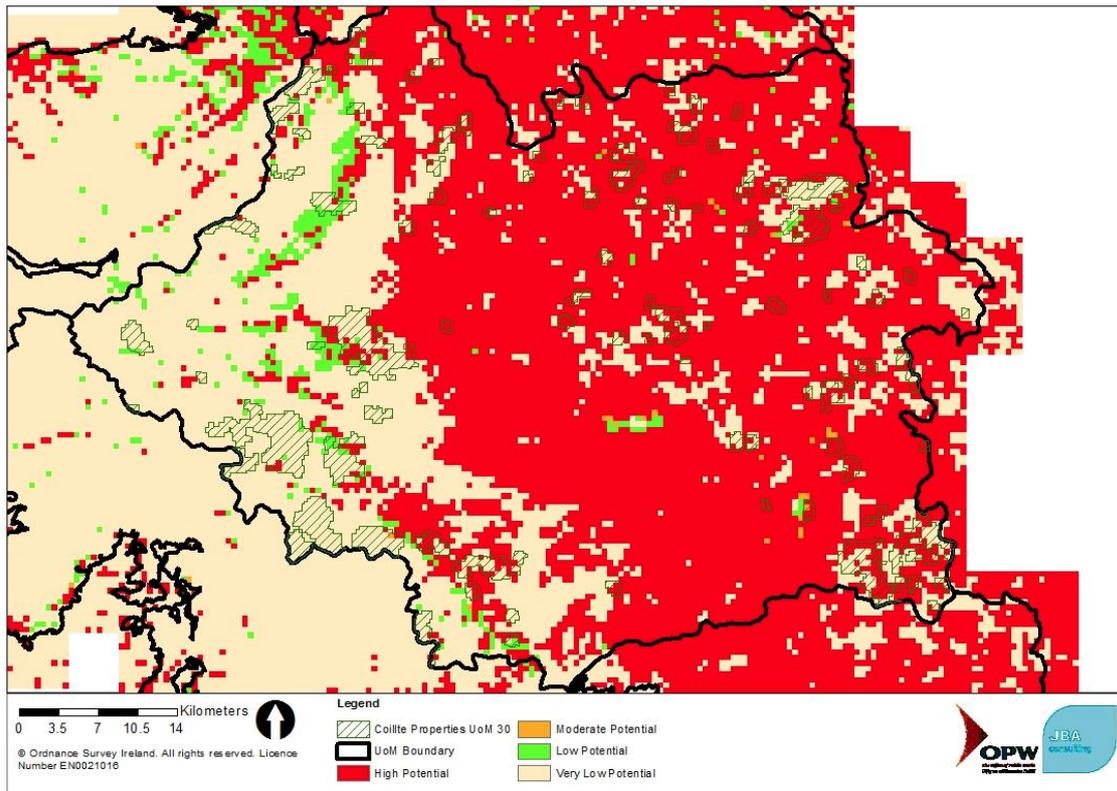
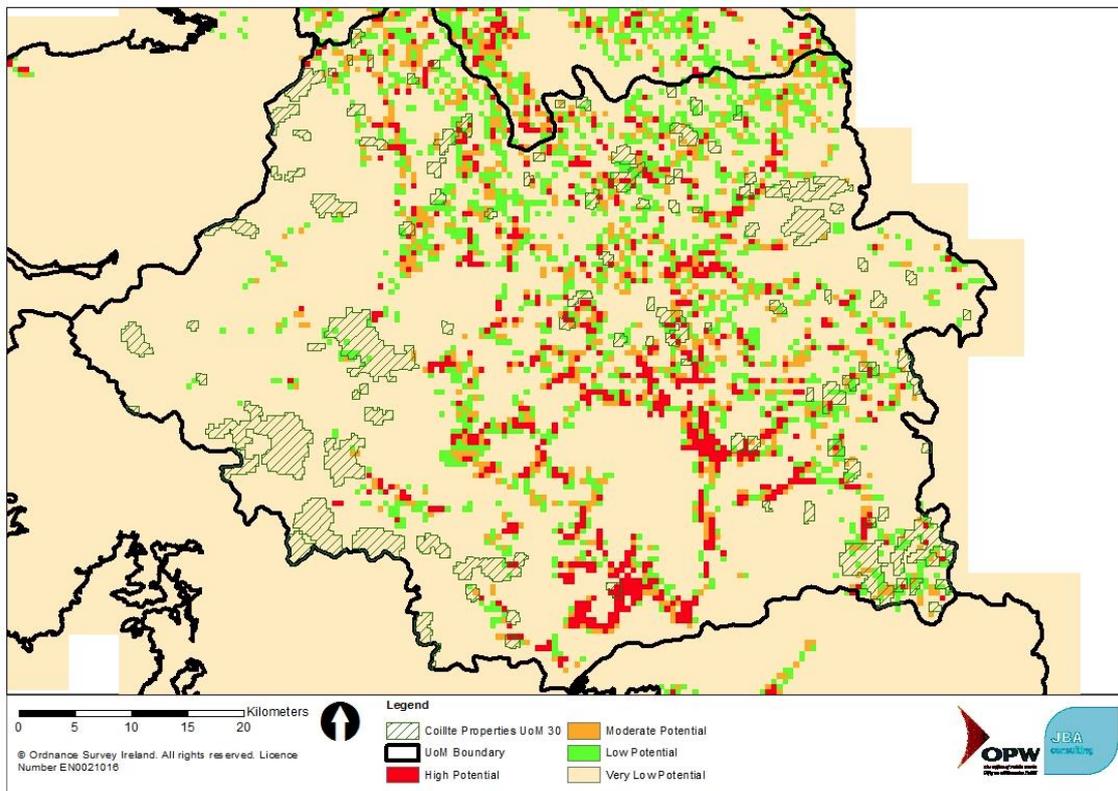


Figure 4-10: Floodplain storage NFM screening map using flood extents for UoM 30



4.5.6 Appropriate natural flood management objectives

Runoff reduction

Figure 4-7 shows there is little potential for runoff reduction natural flood management methods. This reflects the fact that much of the catchment has a relatively gentle gradient and the soils are WCFRAM UoM 30 Preliminary Options Report - Overarching Report v3.0

not sensitive to degradation. The main waterbody in the UoM 30, the River Clare which flows through the AFA's of Ballyhaunis, Tuam, Corrofin and Galway City has limited potential for runoff reduction methods.

The greatest potential is to the west of the catchment, in the 12 bens area of Connemara upstream of Oughterard AFA where the runoff reduction potential is classified as Moderate. Upstream of Oughterard, natural flood management has the potential to reduce peak flood flow and delay the time to peak. The upstream catchment is small and has been partially subject to Arterial Drainage works.

The main constraint to Oughterard is the blanket bog and different types of lakes, both features of interest of the Connemara Bog Complex SAC. The conservation objectives for these are very specific and detailed. However approximately 50% of the catchment area to Oughterard does not drain from the SAC. This is comprised of a number of smaller tributaries that drain either direct through Oughterard or into the river or lakes upstream. For the catchment in the SAC NFM methods cannot impact upon the conservation objectives, but where the blanket bog is in poor condition or has been/is drained there is an opportunity for NFM and habitat restoration. For the tributary catchments not in the SAC, then the land use is a mix of lesser quality bog, low value agriculture and scrub. The habitat quality is much less favourable and there is more potential for habitat improvement which may also improve the conditions of the SACs and WFD status. There is high potential for runoff reduction NFM on these catchments. Natural flood management should be easier to implement where land use and land cover is consistent across the catchment, as wide ranging suites of methods do not need to be analysed. Figure 4-7 shows high potential in the vicinity of Clonbur.

Currently, there is significant forestry in the upstream catchment of Oughterard. Forest can play an important role in flood risk management as a method to reduce runoff and methods include woodland planting (including upland floodplain, riparian, gully or cross slope tree shelters). There is limited area within the Oughterard catchment that is not covered already by forestry or within an SAC reducing the potential for runoff reduction.

Floodplain storage

To the east of UoM 30 the influence of ground water is a big constraint to floodplain storage.

Figure 4-8 suggests there may be potential for re-naturalisation of channels within UoM 30. Any areas of High or Moderate potential for re-naturalisation upstream of Corrofin, Tuam and Ballyhaunis should be investigated further for methods that consider introducing meanders and increasing the use of floodplain to attenuate flows. However, as significant river reaches within UoM 30 fall under the arterial drainage scheme and specifically upstream of the identified AFA's, this will significantly reduce the scope for the implementation of re-naturalisation within UoM 30. Also cultural heritage is a constraint to renaturalisation of rivers in AFAs for example the canal and Wolf Tone Bridge in Galway and Oughterard Bridge.

Figure 4-9 indicates there is significant scope for increasing floodplain storage based on slope and land use alone. Figure 4-10 reduces the extent to which this may be applicable but still indicates there are areas within the Corrib catchment where natural flood management methods to increase floodplain roughness will be viable. These methods would only benefit Corrofin, Claregalway and Galway and given the duration of an event on the Clare/Corrib River and the influence of Lough Corrib it is possible such works would not attenuate flows. Given the extensive coverage of the arterial drainage network and hence the relevance of the benefitting land maps Figure 4-10 is considered the more applicable of the two maps.

The Corrib Arterial Drainage Scheme does not include any embankment works, however there may have been ad-hoc embankments built upon the river banks from deposited spoil from drainage and maintenance works. These have not been identified in the above catchment screening assessment and could present opportunities to reconnect floodplains through partial opening of embankments where appropriate. Given the limited forestry currently to the east of UoM 30 there is potential for tree lines, hedgerows, etc. to slow down flood peaks and temporarily store water locally.

Detailed consideration of the frequency of floodplain flooding will be necessary to ensure that locations with a high potential for floodplain storage have sufficient extra capacity to make a difference.

Sediment management

The hydromorphic audit of watercourses upstream of AFAs found no evidence of significant sediment inputs to the HPWs and so no specific map of these catchments has been produced for UoM 30.

Managing soil structure and permeability can reduce the frequency of "muddy floods" where surface runoff and overland flood flow routes collect and transport sediment already mobilised by surface water ponding and waterlogged soils. Heavy machinery and livestock can compact soil reducing the ability of the soil to store and infiltrate water. Crop, vegetation and tree cover can improve soil conditions.

Currently, there is limited forestry in the Clare catchment. Forestry and trees are useful because the planned planting of tree strips, hedgerows and woodland management has the potential to reduce sediment runoff and inputs to rivers. Buffer zones and filter strips along watercourses would also help reduce sediment input. This would in turn maintain channel capacity and reduce maintenance requirement of the arterial drainage channels which may help maintain or potentially reduce slightly flood risk to the AFAs in the long term.

Estuarine surge attenuation

There is one estuary within UoM 30, Galway Bay which there may be an opportunity to increase attenuation and so reduce the risk of tidal flooding. The potential for increased attenuation within this bay is reliant upon volume limited tidal flood risk within Galway. To determine if this is the case the 0.5% AEP tidal flood extents for these AFAs, which modelled a tidal profile, have been compared to the Irish Coastal Protection Strategy Study (ICPSS), which extrapolated the extreme sea levels landward. Volume limited tidal flood risk would show up as a reduced flood extent in the WCFRAM AFA modelled extents.

For Galway this is not the case, however this is likely a function of the coastal modelling of this AFAs which applied extreme sea levels along the shoreline. To properly assess the attenuating nature of the Galway Bay will require an offshore tidal model to be developed to represent tidal propagation along the bays. The coastline within Galway is hard engineered with normal tidal levels reaching the tow of the structure so opportunities are limited. The Galway Bay SAC and SPA pose potential constraints to implementing natural flood management methods to achieve greater estuarine surge attenuation. If methods were to compliment or form part of the conservation objectives of these Natura 2000 sites, then they would be providing flood management and biodiversity benefits and should be considered.

Wave dissipation

Flood risk from wave overtopping has been investigated in Salthill, within UoM 30. Salthill promenade is currently lined with rock armouring that acts to dissipate waves on approach and this should be maintained.

4.5.7 Summary of Natural Flood Management

Table 4-9 summarises the findings of the review of viable natural flood management methods within UoM 30.

Table 4-9: Summary of natural flood management methods in UoM 30

NFM flood reduction objective	Scope	Methods
Runoff reduction	The screening maps do not highlight any sub-catchments where runoff reduction NFM methods are likely to be beneficial. Further investigations into land management practises in the Oughterard catchment are suggested.	Woodland planting Land management including soil and bare earth improvements, changing agricultural field drainage
Floodplain storage	There may be opportunities for floodplain naturalisation in the catchments upstream of Tuam and Corrofin. Further investigations into the viability of such schemes, mindful of arterial drainage responsibilities, is recommended. Increasing the roughness in the floodplain	Deciduous tree strips and hedgerows Removal of arterial drainage maintenance spoil heaps to improve floodplain connectivity River and floodplain restoration

	could benefit Corrofin and Claregalway. Forestry can be used to the East to temporarily store water locally.	
Sediment management	The hydromorphic audit did not identify any catchments upstream of HPWs with significant sediment loading. Planting of tree strips, hedgerows and woodland management has the potential to reduce sediment runoff and inputs to rivers to the east of UoM 30.	Deciduous tree strips and hedgerows Reduced grazing or stock levels Reduced and managed use of heavy farm machinery Reach restoration
Estuarine surge attenuation	Potential to reduce surge attenuation and tidal propagation in the Corrib Estuary and Galway Bay, subject to conservation objectives of the Natura 2000 sites. Only applicable to Galway.	Creation/restoration of intertidal areas.
Wave energy dissipation	Rock armouring should be maintained along Salthill promenade maintain current risk.	-

The costs and benefits of implementing and managing natural flood management have not been assessed. There is low flood risk justification for natural flood management methods to be undertaken now in UoM 30. Natural Flood Management methods have the potential to mitigate against the flood risk impacts of climate change, specifically more intense rainfall and storm surges. Natural flood management is unlikely to be able to mitigate against the rise in sea levels. There are notable multi-functional benefits from natural flood management in UoM 30 which include:

- Reduced urban flood risk in AFAs (greatest benefit likely from AFAs with smaller upstream catchments).
- Reduced flood risk to agricultural land in the floodplain of the River Clare/Corrib (increased time to peak, reduced peak flow and extent, reduced frequency of flooding).
- Reduced disruption from flooding of rural areas and infrastructure outside of AFAs.
- Designated habitats and species, will be subject to less fine sediment deposition and reduced disturbance during maintenance activity.
- Reduced frequency and cost of channel and structure maintenance work. Funds can be allocated to managing other flood risk locations and priority activities.
- Improved catchment soil conditions throughout catchment.
- Provision of natural capital.
- Carbon storage (forestry and peatlands)

4.6 Flood related data collection

The ongoing collection of hydrometric and meteorological data, and data on flood events as they occur, will help to continually improve the preparation for, and response to flooding. Further data collection will allow for model uncertainty to be reduced over time and the impacts of climate change to be monitored. In Unit of Management 30 there are a number of key areas of model uncertainty linked to data uncertainty.

There is a wide spread of gaugings at the Corrofin gauge and it is suggested that is because of a backwater effect from the Abbert confluence downstream. The modelling has not shown this to be significant but there are also turloughs in this area which may be contributing to elevated river levels. Further investigation could help understanding of the situation, but such detailed groundwater assessment is outside the scope of the CFRAM. Ideally, additional monitoring of water levels would be required downstream of the gauge location to understand the variation of water surface profile through that area; it is likely that this effect would only be seen during extreme events.

In Tuam the Nanny and Suileen models are based on hydrology derived without direct gauge data in their respective catchments. The hydrology is based on donor catchments from a pooling

group of catchments with similar characteristics. Therefore, the flow estimates are based on a best fit estimate as they have not been confirmed by gauged data. It is recommended a river gauge be installed in both catchments.

5 Spatial planning and impacts on developments

5.1 Overview of planning policy

5.1.1 The 'Planning System and Flood Risk Management'

The 'Planning System and Flood Risk Management' describes good flood risk practice in planning and development management. Planning authorities are directed to have regard to the guidelines in the preparation of Development Plans and Local Area Plans, and for development control purposes.

The objective of the 'Planning System and Flood Risk Management' is to integrate flood risk management into the planning process, thereby assisting in the delivery of sustainable development. For this to be achieved, flood risk must be assessed as early as possible in the planning process. Paragraph 1.6 of the Guidelines states that the core objectives are to:

- *avoid inappropriate development in areas at risk of flooding;*
- *avoid new developments increasing flood risk elsewhere, including that which may arise from surface run-off;*
- *ensure effective management of residual risks for development permitted in floodplains;*
- *avoid unnecessary restriction of national, regional or local economic and social growth;*
- *improve the understanding of flood risk among relevant stakeholders; and*
- *ensure that the requirements of EU and national law in relation to the natural environment and nature conservation are complied with at all stages of flood risk management".*

The guidelines aim to facilitate *'the transparent consideration of flood risk at all levels of the planning process, ensuring a consistency of approach throughout the country.'* SFRAs therefore become a key evidence base in meeting these objectives.

The 'Planning System and Flood Risk Management' works on a number of key principles, including:

- Adopting a staged and hierarchical approach to the assessment of flood risk;
- Adopting a sequential approach to the management of flood risk, based on the frequency of flooding (identified through Flood Zones) and the vulnerability of the proposed land use.

The sequential approach and Justification Test

Each stage of the FRA process aims to adopt a sequential approach to the management of flood risk in the planning process.

Where possible, development in areas identified as being at flood risk should be avoided; this may necessitate de-zoning lands within the plan boundary. If de-zoning is not possible, then rezoning from a higher vulnerability land use, such as residential, to a less vulnerable use, such as open space may be required.

Where rezoning is not possible, exceptions to the development restrictions are provided for through the Justification Test. Many towns and cities have central areas that are affected by flood risk and have been targeted for growth. To allow the sustainable and compact development of these urban centres, development in areas of flood risk may be considered necessary. For development in such areas to be allowed, the Justification Test must be passed.

The Justification Test has been designed to rigorously assess the appropriateness, or otherwise, of such developments. The test is comprised of two processes; the Plan-making Justification Test and the Development Management Justification Test. The latter is used at the planning application stage where it is intended to develop land that is at moderate or high risk of flooding for uses or development vulnerable to flooding that would generally be considered inappropriate for that land.

Figure 5-1 Sequential approach principles in flood risk management



Source: The Planning System and Flood Risk Management (Figure 3.1)

Figure 5-1 shows which types of development, based on vulnerability to flood risk, are appropriate land uses for each of the Flood Zones. The aim of SFRA is to guide development zonings to those which are 'appropriate' and thereby avoid the need to apply the Justification Test.

Table 5-1 Matrix of vulnerability versus Flood Zone

	Flood Zone A	Flood Zone B	Flood zone C
Highly vulnerable development (Including essential infrastructure)	Justification test	Justification test	Appropriate
Less vulnerable development	Justification test	Appropriate	Appropriate
Water-compatible development	Appropriate	Appropriate	Appropriate

Source: Table 3.2 of The Planning System and Flood Risk Management

Scales and stages of flood risk assessment

Within the hierarchy of regional, strategic and site-specific flood-risk assessments, a tiered approach ensures that the level of information is appropriate to the scale and nature of the flood-risk issues and the location and type of development proposed, avoiding expensive flood modelling and development of mitigation methods where it is not necessary. The stages and scales of flood risk assessment comprise:

- **Regional Flood Risk Appraisal (RFRA)** – a broad overview of flood risk issues across a region to influence spatial allocations for growth in housing and employment as well as to identify where flood risk management methods may be required at a regional level to support the proposed growth. This should be based on readily derivable information and undertaken to inform the Regional Planning Guidelines.
- **Strategic Flood Risk Assessment (SFRA)** – an assessment of all types of flood risk informing land use planning decisions. This will enable the Planning Authority to allocate appropriate sites for development, whilst identifying opportunities for reducing flood risk. This SFRA will revisit and develop the flood risk identification undertaken in the RFRA, and give consideration to a range of potential sources of flooding. An initial flood risk assessment, based on the identification of Flood Zones, will also be carried out for those areas which will be zoned for development. Where the initial flood risk assessment highlights the potential for a significant level of flood risk, or there is conflict with the proposed vulnerability of development, then a site specific FRA will be recommended, which will necessitate a detailed flood risk assessment.

- **Site Specific Flood Risk Assessment (FRA)** – site or project specific flood risk assessment to consider all types of flood risk associated with the site and propose appropriate site management and mitigation methods to reduce flood risk to and from the site to an acceptable level. If the previous tiers of study have been undertaken to appropriate levels of detail, it is highly likely that the site specific FRA will require detailed channel and site survey, and hydraulic modelling.

5.1.2 West Regional Development Plan

The West Regional Development Plan (2010-2022) is supported by a Regional Flood Risk Appraisal and covers Galway County and City, Mayo and Roscommon County Councils. The plan includes:

- A review of sources of flood risk information; it should be noted that the RFRA pre-dated the CFRAM, although the PFRA had been published.
- The identification of appropriate policy responses for priority urban areas, including areas that transcend administrative boundaries and where there appears to be significant flood risk;
- Suggested policies for sustainable flood risk management which will be incorporated into the Regional Planning Guidelines (RPGs); the SFRA for the various development plans will be reviewed against these recommended objectives and opportunities for strengthening existing policies and objectives will be highlighted.
- Guidance on the preparation of City and County level SFRA in association with City & County Development Plans and the management of surface water run-off within new development, highlighting significant flood risk issues, potential infrastructure investment requirements and the need for co-operation between planning authorities and identifying any need for more detailed assessment.

Of the five towns and cities discussed in the RFRA as potentially being at risk of flooding, Galway City and Tuam are found in UoM30. The RFRA notes that a number of smaller towns with the Region have also been identified as vulnerable to flooding, but none have been named.

5.1.3 County, city and local area development plans

UoM30 covers three County Councils; namely Galway County, Galway City and Mayo County. Only Ballyhaunis is within County Mayo. The plans relevant to each AFA are detailed in Table 5-2. A preliminary review of the plans is included in the following sections, along with a review of the data sources used to inform the preparation of the SFRA. For all AFAs in UoM30 a review of current and future flood risk has been carried out to highlight any potential conflict between land use zonings and Flood Zones, based on the CFRAM outputs. Finally, on the basis of the flood risk review, recommendations for the review and amendment of the operative plans have been made.

Table 5-2: Operative development plans relevant to UoM30

County	Plan	Date	UoM 30 AFAs covered
Galway County	Galway County Development Plan	2015-2021	Claregalway Corrofin Oughterard Tuam
	Claregalway Local Area Plan	2005-2011	Claregalway
	Oughterard Local Area Plan	2006-2012	Oughterard
	Tuam Local Area Plan	2011-2017	Tuam
Galway City	Galway City Development Plan	2011-2017	Galway City
	Draft Galway City Development Plan	2017-2022	Galway City
Mayo	Mayo County Development Plan	2014-2020	Ballyhaunis
	Ballyhaunis Local Area Plan	2010-2016	Ballyhaunis

5.2 County Galway

5.2.1 Galway County Development Plan 2015-2021

The Galway County Development Plan 2015-2021 is supported by a Stage 1 SFRA, published in February 2015. The SFRA includes a comprehensive summary of flood data, and presents this on a series of countywide maps. However, there is no interpretation or guidance in its application to determining land zoning, and limited use of historical flood information.

It is recommended that the SFRA is expanded to provide guidance on the level of detail required in a flood risk assessment for specific sites, and the consideration that should be given to freeboard and climate change, amongst other factors. In some locations there may be culverts which are vulnerable to blockage and would result in an increased level of risk and it is advisable that these are either specifically highlighted or general advice is included.

Future iterations of the SFRA / Development Plan should also include the CFRAM data and more detailed historical flood information. Any specific recommendations in relation to the options development process should be carried forward from the CFRAM as well.

The policies and objectives recommended in the SFRA are comprehensive, and have been carried through to the Development Plan. However, without additional guidance and a clear vision of where land uses are appropriate, application of the policies and objectives is open to interpretation.

The Galway County Development Plan is supported by a number of Local Area Plans, which cover the following towns; Headford, Portumna, Ballinasloe, Athenry, Bearna, Claregalway, Clarinbridge, Clifden, Craughwell, Gort, Kinvarra, Loughrea, Maigh Cuilinn, Oranmore, Oughterard, Tuam and the Gaeltacht. The LAPs for non-AFAs within UoM30, and LAPs outside UoM30 have not been reviewed in this report. Where an LAP does not include a specific SFRA, it draws on the assessment carried out through the SFRA for the County Development Plan.

5.2.2 Claregalway

Local Area Plan 2005-2011

Claregalway is classified as "other villages" in the Galway County Development Plan 2015-2021. The status of the Claregalway Local Area Plan 2005-2011 is "to be commenced"

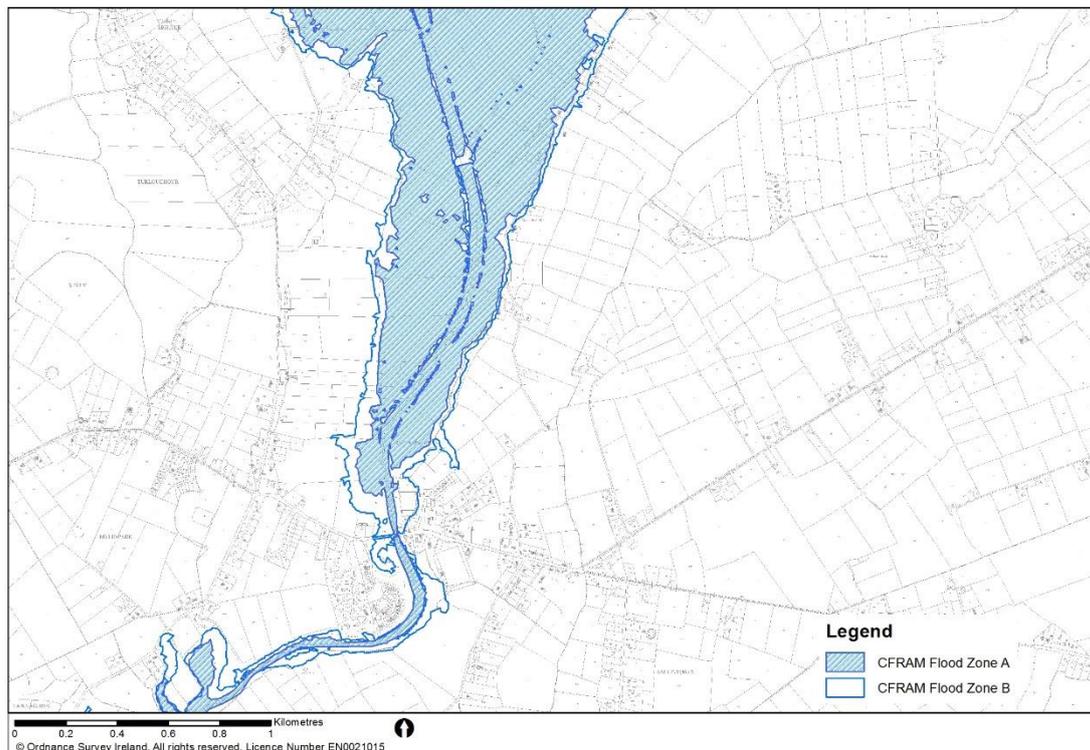
There is no SFRA for the Claregalway Local Area Plan and so falls within the Galway County Development Plan. Flood Zones for Claregalway should be based upon the current best flood mapping available, which at this stage will be from the flood alleviation scheme flood modelling. Policies for development in areas protected by the proposed flood alleviation scheme should be put in place to manage the residual risks, should structural flood defences fail or be exceeded (overtopped).

5.2.3 Corrofin

Local Area Plan

Corrofin is classified as "other villages" in the Galway County Development Plan 2015-2021. Corrofin does not have a Local Area Plan. There are no zoning objectives for Corrofin. The Flood Zones in the County Development Plan SFRA are based upon the PFRA mapping. The SFRA for the County Development Plan should be updated to consider the CFRAM Flood Zones and impacts of climate change. In the absence of zoning objectives, site specific flood risk assessments for development proposals in Flood Zones should be subject to the justification test to direct development to lower risk locations in accordance with the vulnerability of the proposed land use. Figure 5-2 shows the CFRAM flood zones for the Corrofin AFA.

Figure 5-2: CFRAM Flood Zones for Corrofin



5.2.4 Oughterard

Oughterard Local Area Plan 2006-2012

Oughterard is classified as "other villages" in the Galway County Development Plan 2015-2021. The status of the Oughterard Local Area Plan 2006-2012 is "to be commenced". The LAP for Oughterard pre-dates the publication of the Planning Guidelines on Flood Risk Management, so makes no reference to flooding and does not include an SFRA. In the absence of a current plan, each planning application would have to be assessed on an individual basis by development management and if identified within a flood risk area would have to meet the requirements of the plan policies and its SFRA. The Local Area Plan has two policies relating to flooding, which should both be updated to make reference to relevant SFRA:

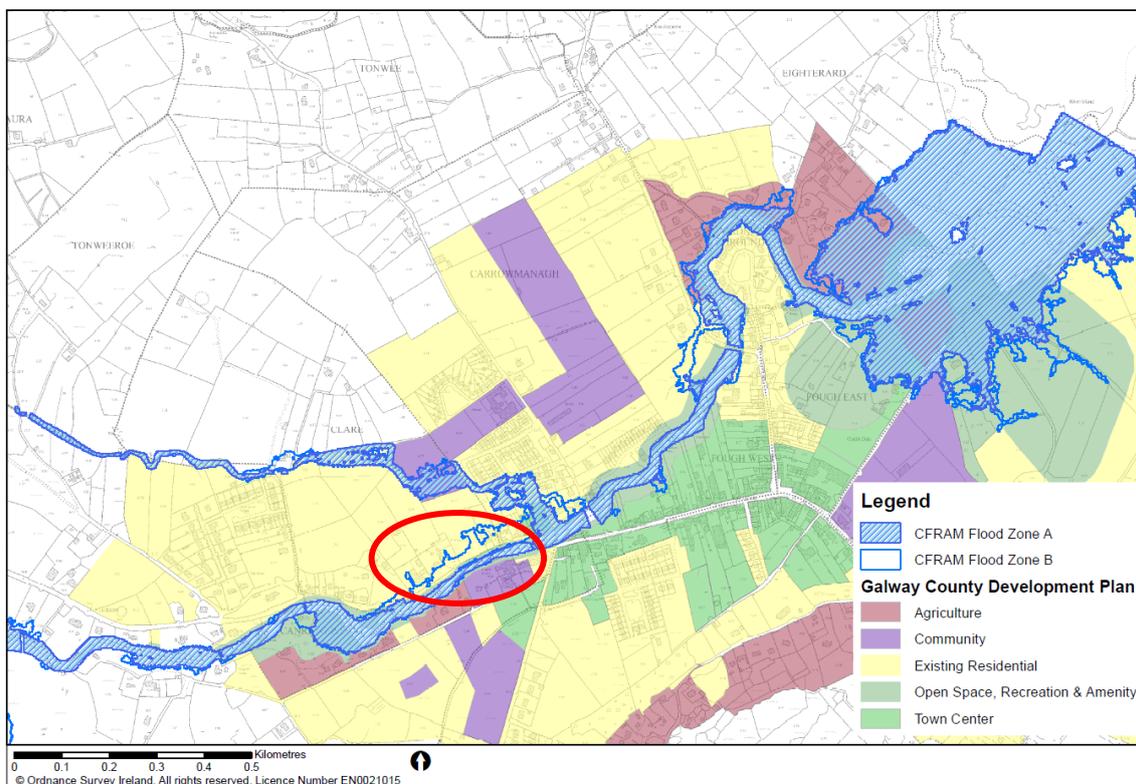
3.6.2 Provide a surface water collection system to improve drainage and alleviate flooding.

3.6.15 Ensure that development is not itself subject to inappropriate risk of flooding and ensure that it would not cause or exacerbate such a risk at other locations.

Current risk

Flood Zones A and B cover land zoned for development to the north of Oughterard (Figure 5-3). An SFRA should assess the level of risk to these sites and recommend changes to land zoning objectives. An area as highlighted below, on the left bank of the main river upstream of Oughterard Bridge is zoned for existing residential and is within Flood Zone B. A portion of the stretch is undeveloped and rezoning should be considered.

Figure 5-3: CFRAM Flood Zones in Oughterard



Future risk

There is negligible change in Flood Zone A in the MRFS future scenario, however an SFRA should consider the impact of climate change on flood depth, velocity and hazards. There are more notable increases in Flood Zone B in the MRFS where the flood extent encroaches further into land zoned for development.

5.2.5 Tuam

Tuam Local Area Plan 2011-2017

Tuam is classified as "hub town" in the Galway County Development Plan 2015-2021. The Tuam Local Area Plan is currently live.

The Tuam Local Area Plan has a specific strategic aim to "avoid development in flood plains and within areas of significant risk of flooding". This includes reference to the strategic philosophy in the Planning Guidelines on Flood Risk Management where development is directed to appropriate locations to avoid, manage or mitigate risk. The sequential and justification tests are referenced and Flood Risk Assessments are to be part of the decision making process for planning applications and appeals. An SFRA should be prepared and updated using the current best available flood risk information as shown in the CFRAM Flood Zones. It is a specific policy objective in the plan to produce an SFRA for Tuam.

Current risk

The CFRAM Flood Zones for Tuam show notable areas of undeveloped land zoned for potentially vulnerable land uses. Some of this undeveloped land is zoned for agricultural use or open space, recreation and amenity. An SFRA should be carried out based on the CFRAM Flood Zones to assess the risk to zoned land and where necessary re-zone land for lower vulnerability land uses. All planning applications within Flood Zones should be subject to a Flood Risk Assessment and the SFRA should recommend specific development management policies to manage surface water runoff from developments throughout the town. There appears to be sufficient zoned land in the town plan boundary for re-zoning not to have a significant impact on available development land.

Figure 5-4: CFRAM Flood Zones for Tuam (North West)

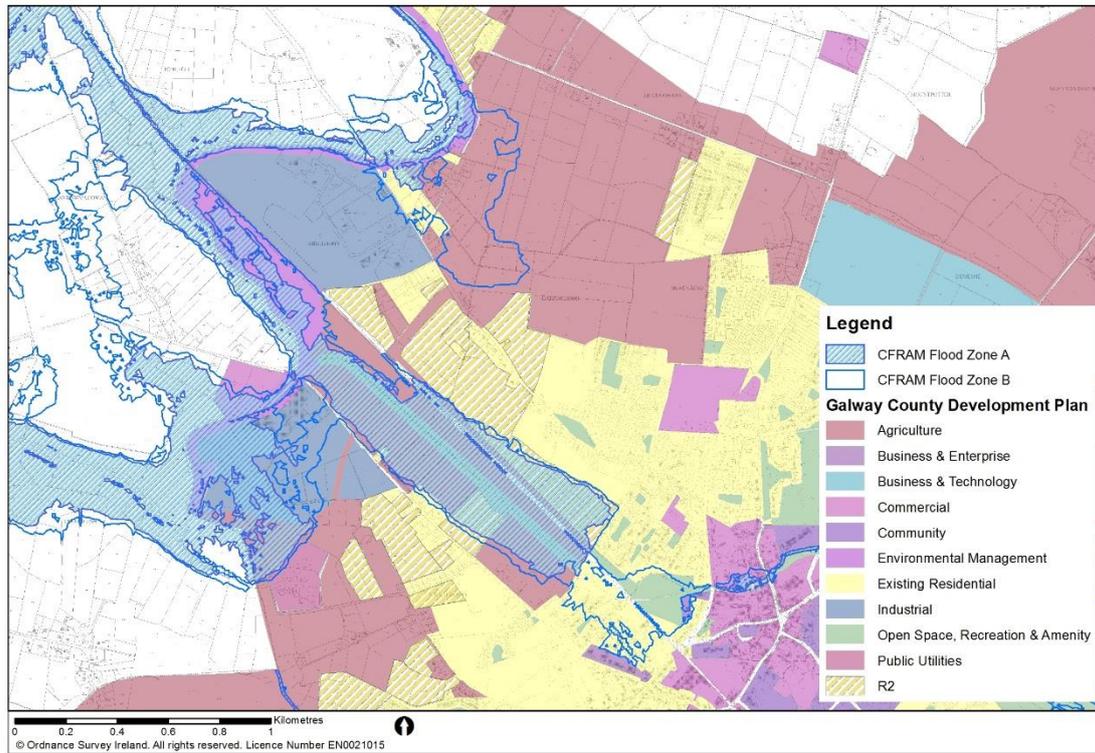


Figure 5-5: CFRAM Flood Zones for Tuam (East)

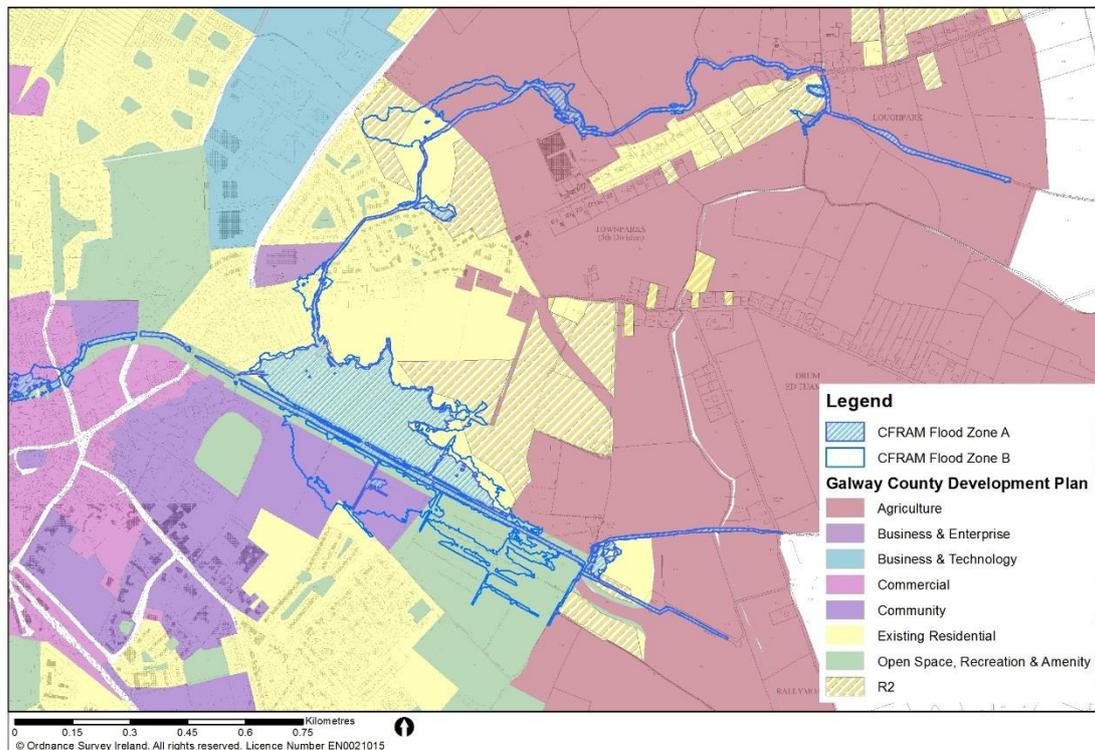
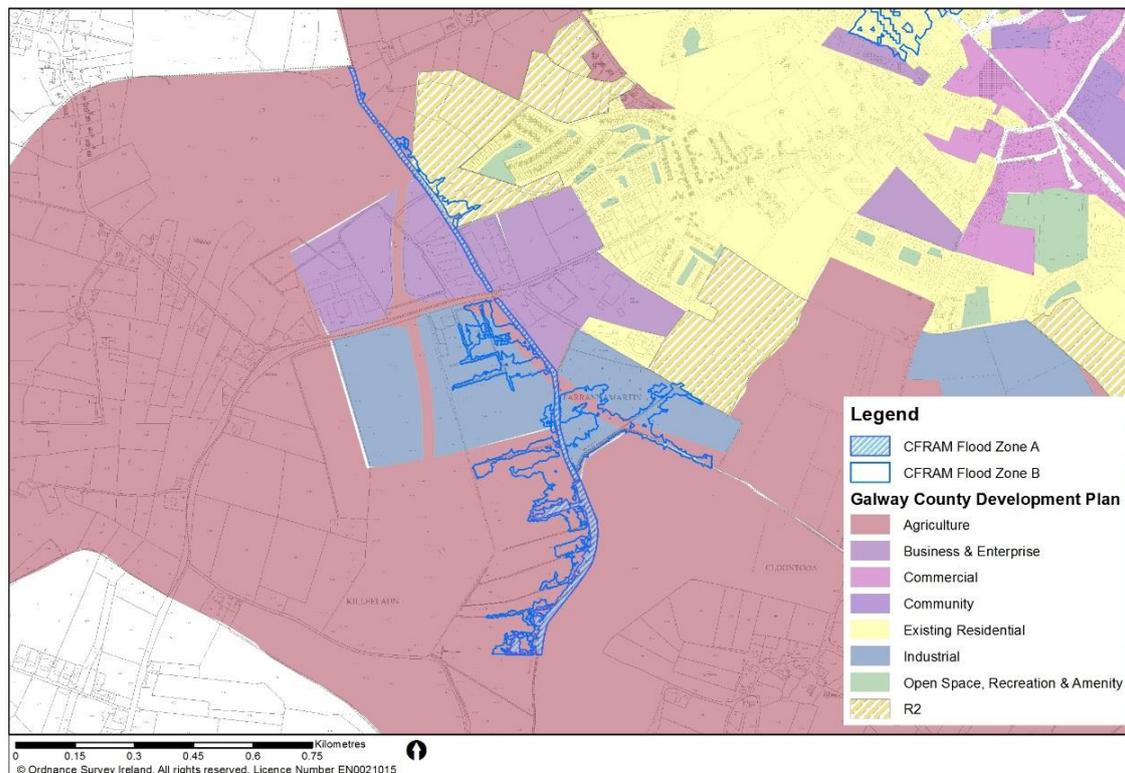


Figure 5-6: CFRAM Flood Zones for Tuam (South)



Future risk

There is negligible change in Flood Zone A or B in the MRFS future scenario, however an SFRA should consider the impact of climate change on flood depth, velocity and hazards.

5.3 Galway City

5.3.1 Galway City Development Plan 2011-2017 (current)

The current plan covers the period 2011-2017 and sets out compliance with National Spatial Strategy and the West Regional Planning Guidelines, including; "To include policies for the protection of areas at risk from flooding." Some of the key flood management policies of Galway City Council, as laid out in the development plan include:

Policy 8.5 Flood Risk:

- Have regard to the findings and relevant identified actions of the future Corrib CFRAM Study when available and incorporate into the Development Plan, where appropriate.
- Review flood risk in the city and carry out detailed site-specific FRA for locations of potential flood risk, where necessary.
- Require development applications in the locations of potential flood risk, to provide flood impact assessment and flood risk minimisation and mitigation methods, to facilitate assessment, in the interest of reducing the risk of flooding.
- Prohibit the location of structures other than structures with essential links to the waterway within 10 metres of the River Corrib in G agricultural zoned lands.
- Ensure flood risk is addressed in any future local area plans, framework plans and masterplans in the city.
- Facilitate sustainable flood defence and coastal protection works in order to prevent flooding and coastal erosion, subject to environmental and visual considerations.
- Ensure the use of Sustainable Urban Drainage Systems (SUDS) wherever practical, in the design of development to reduce the rate and quantity of surface water run-off.

- Ensure new developments, where appropriate, are designed and constructed to meet the flood design standards outlined under Section 11.27 Flood Risk.
- Have regard to the findings and recommendations of the imminent Irish Coastal Protection Strategy Study of the West Coast, when available and incorporate into the Development Plan, where appropriate.
- Continue to protect the coastal area and foreshore and avoid inappropriate development in areas at risk of coastal erosion and/or would cause and escalate coastal erosion in adjoining areas.
- Protect and maintain, where feasible, undeveloped riparian zones and natural floodplains along the River Corrib and its tributaries.

In addition, the Specific Objective for Flood Risk Management requires a detailed site-specific FRA for identified potential flood risk areas, taking into consideration findings of the CFRAM Study when completed.

Within Galway City there are three areas designated for the preparation of Local Area Plans. These are Ardaun, Murrough and the Headford Road south of the Bodkin junction. Stage 1 and 2 Strategic Flood Risk Assessment have been carried out in these LAP areas. The recommendations of the three SFRA's are reproduced below.

Current Risk

Galway City is an established and developed city which is predominantly developed along its coastline and city centre. Ample areas of lands are zoned for residential development and strategic residential reserve within Flood Zone C which provide opportunities for development. Areas within close proximity to the coastline and the River Corrib comprises mainly of existing development with limited scope for future developments. Areas residing within the defined Flood Zones A & B extents are predominantly zoned as Opens space and Conservation areas which are of suitable vulnerability class within these flood zones.

Some development lands situated along the coastline east of the city zoned for mixed/general community services and strategic residential reserve and are currently greenfield sites encroach Flood Zones A & B. Revision of the development boundaries may be modified to ensure future developments are within the appropriate flood zone for their vulnerability class.

Figure 5-7: CFRAM Flood Zones for Galway (West)

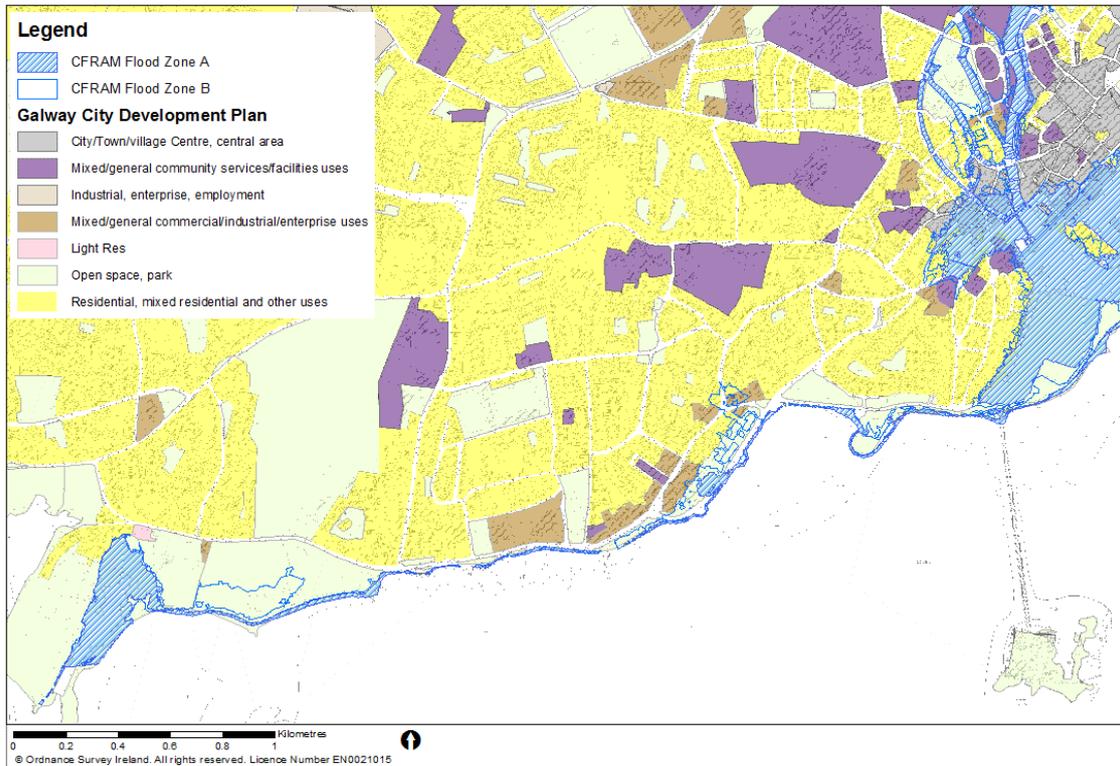


Figure 5-8: CFRAM Flood Zones for Galway (Centre)

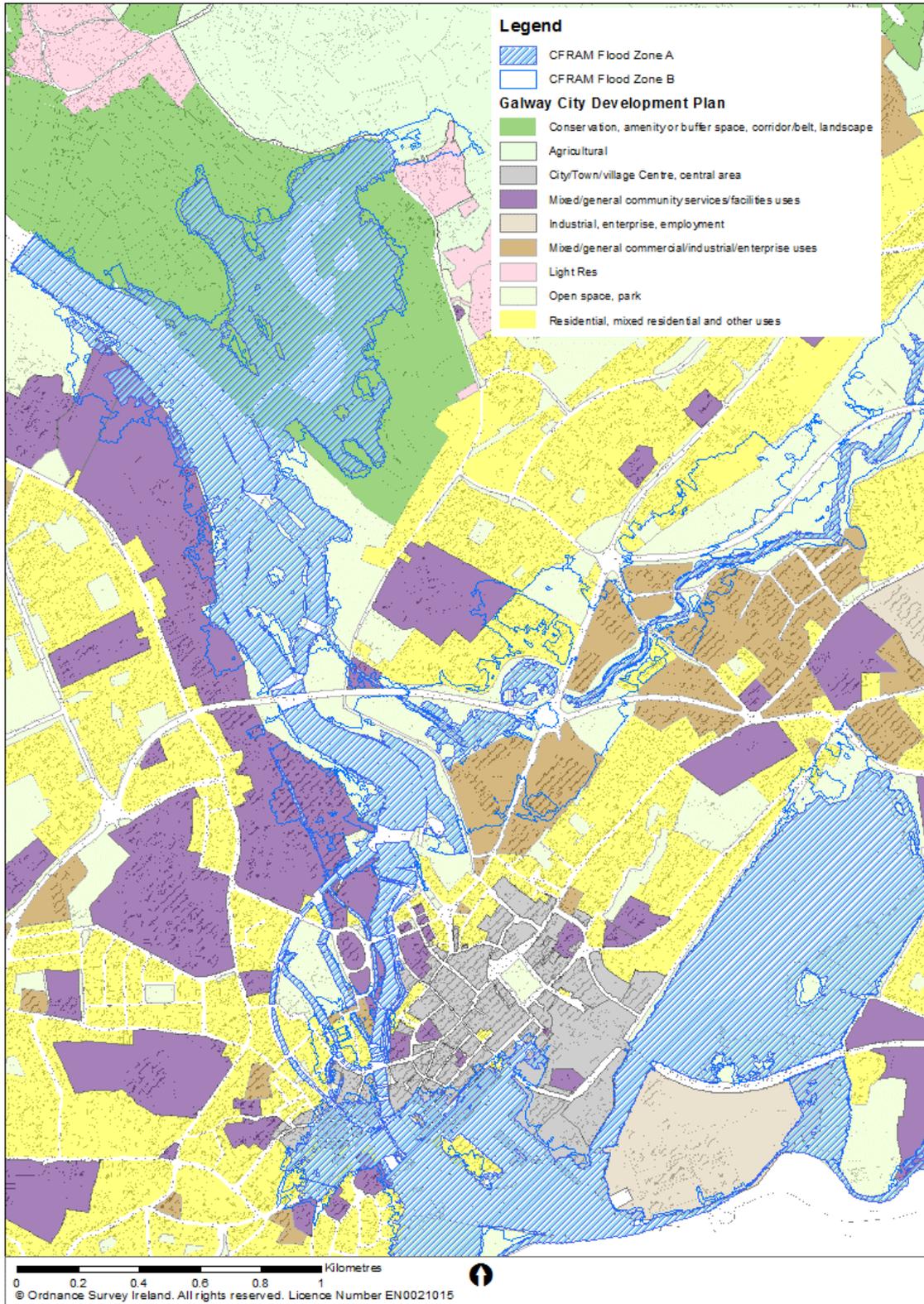
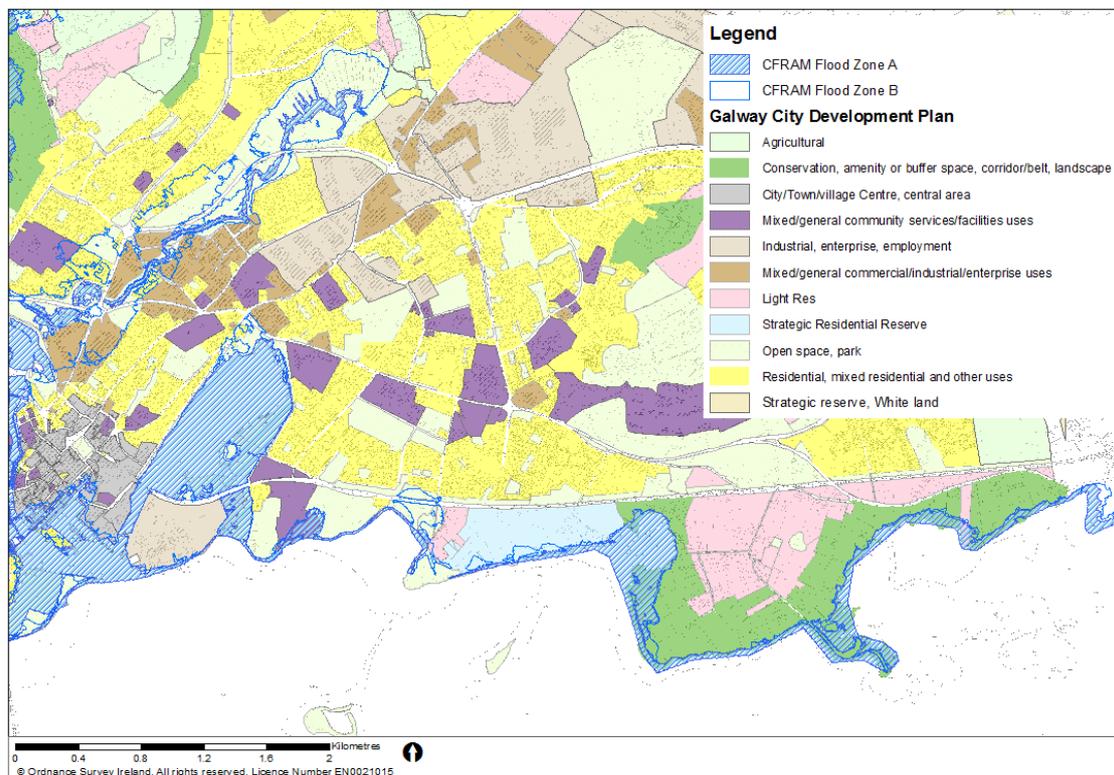


Figure 5-9: CFRAM Flood Zones for Galway (East)



Future risk

There is negligible change in Flood Zone A or B in the MRFS future scenario generally across the city, however exiting residential areas along the coast just west of the city centre are now within Flood Zone B. Some minor encroachment to Flood Zone B is noted in lands zoned for light residential from the River Corrib in the northern section of the city.

5.3.2 Ardaun LAP

In the absence of surface water courses in the vicinity of the Ardaun LAP area, Sustainable Urban Drainage Systems should be implemented to manage the storm runoff. Storm runoff from the developments located in the west and north-western parts of the LAP area (approximate area of 100ha) should be drained westwards to Galway Bay through the Merlin Park Area Drainage System. Surface runoff from the remaining LAP area (58ha) should be discharged to ground via infiltration. Alternatively, where infiltration is not an option, a surface water outfall pipe may be required to discharge this runoff to Galway Bay. Furthermore, it is recommended that no development be allowed in the immediate vicinity of the area identified by the GSI as being the Doughiska turlough. This area should not be used for infiltration.

5.3.3 Headford Road LAP

A further detailed study (Stage 3) should be carried out for the Headford Road LAP area to prepare a reliable flood zone map and to assess any impacts of the proposed development on the existing flood risk and to design the associated mitigation methods. This is vital for finalising the land use zoning process for this LAP area. The Stage 3 study should include:

- Detailed hydrological analysis of River Corrib Flood Flows in the vicinity of the site.
- Detailed hydraulic modelling of the River Corrib and Terryland River channels
- Hydrometric (flow and water level) survey of the River Corrib and associated canal systems (including Terryland River), and
- Cross-sectional survey of the River Corrib and Terryland

5.3.4 Murrough LAP

It is recommended that only water compatible development should be allowed within the flood prone areas along the Murrough LAP area coastline. However, in the absence of any alternative sites, a Justification Test along with a detailed flood risk assessment should be carried out before allowing any development at these locations. Finished floor levels should be set at 500mm above the design tide levels. In the design of any coastal flood protection works, a detailed site specific study along with a wave climate study should be carried out.

5.3.5 Draft Galway City Development Plan 2017-2022

A two stage assessment of flood risk was undertaken for the Draft Galway City Development Plan SFRA. The first stage identifies flood risk and is based primarily on the findings of this study, the Western Catchment Flood Risk Assessment and Management Study (WCFRAM). Historical records and recent events demonstrate that Galway City has a history of flooding and confirms that a proportion of zoned lands are at flood risk. The second stage and the main purpose of the SFRA report appraises the adequacy of existing information, to prepare an indicative flood zone map, based on available data, and to highlight potential development areas that require more detailed assessment on a site specific level. The SFRA also provides guidelines for development within areas at potential risk of flooding, and specifically looks at flood risk and the potential for development within a number of key sites in Galway City, including a stage three assessment of flood risk and management options for the Headford Road site, which has previously been subject to flood risk assessment under the Headford Road Local Area Plan. The SFRA for the draft development plan has taken account of the three Local Area Plan flood risk statements.

The SFRA for the draft development plan sets out specific requirements based upon the vulnerability of proposed development within the different Flood Zones. The SFRA outlines key considerations for developments, climate change impacts and adaptation, and the mitigation of flood risks.

The SFRA addresses current and future flood risks in light of land use objectives within Flood Zones in the following areas where flood risk has been assessed in line with the justification test:

- City centre
- Nuns Island
- Headford Road (three locations)
- Lough Atalia
- Dock Road
- Murrough

The SFRA should be reviewed in light of the final CFRAM flood risk mapping.

5.4 County Mayo

5.4.1 Mayo County Development Plan 2014-2020

The Mayo County Development includes an SFRA, which was carried out in conjunction with the Plan. The SFRA includes a Stage 1 assessment for the whole county, and a Stage 2 assessment for a number of Area Plans, as follows; Ballinrobe, Ballyhaunis, Belmullet, Charlestown Claremorris, Kiltimagh, Killala, Knock, Louisburgh, Newport and Swinford. Foxford and Crossmolina do not have specific areas plans. Of relevance to UoM30 is Ballyhaunis, which has been reviewed in the following section. The SFRAs for non-AFAs have not been reviewed.

The County Plan SFRA is based only on the PFRA mapping and a limited review of historical and anecdotal data. The SFRA highlights areas at potential risk of flooding and provides limited recommendations in relation to proposed development and integrating flood management in the development process.

There is a policy recommendation within the SFRA which requires an FRA for sites:

- In or within 50m of Flood Zone A and Flood Zone B

- In or within 10m of both the Pluvial Indicative and Extreme events
- In of within 25 of Benefitting Land

The Planning Guidelines are clear that an FRA / drainage impact assessment is required for all sites, including those in Flood Zone C, so it is recommended that the above guidance is expanded accordingly.

Volume 2 of the Development Plan includes a brief summary of the recommended content of an FRA, but it is recommended that the SFRA is expanded to provide further guidance on the level of detail required, and the consideration that should be given to freeboard and climate change, amongst other factors. In some locations there may be culverts which are vulnerable to blockage and would result in an increased level of risk and it is advisable that these are either specifically highlighted or general advice is included.

Future iterations of the SFRA / Development Plan should also include the CFRAM data and more detailed historical flood information. Any specific recommendations in relation to the options development process should be carried forward from the CFRAM as well.

There are a number of objectives within the Development Plan which aim to address flooding and flood management. These relate to climate change (CC-01), coastal zone management (CZ-02), flood risk assessment (FS-01) and sustainable drainage systems (FS-02), with a couple of other policies and objectives promoting green infrastructure and sustainable development. With a more robust and comprehensive SFRA, these policies would appear to be reasonably comprehensive, but could benefit from reference to the SFRA itself, the Planning Guidelines and CFRAM outputs amongst other items.

Throughout the Mayo countryside and settlements there are a significant number of vacant units, in most cases more than the number of housing units required from 2011 to 2020¹². With such a high proportion of vacant properties within settlements there less pressure to redevelop buildings in flood risk areas and still retain sufficient activity within a settlement centre.

5.4.2 Ballyhaunis

Ballyhaunis Local Area Plan 2010-2016

The Ballyhaunis Local Area Plan 2010-2016 was made and adopted by Mayo County Council on Monday 8th February 2010 and amended on 9th July 2012.

No SFRA has been produced for the Ballyhaunis Local Area Plan and no Flood Zones are presented. The Local Area Plan does specify that all residentially zoned land located on “Benefitting Lands” and/or flood risk areas will be rezoned as Open Space and Amenity. The plan contains the following policy:

ENV15 Flood Prevention It is an objective of the Council to protect areas prone to flooding within the Plan area from inappropriate development and to ensure that all new development does not result in increased risk of flooding within the site or on other lands. All new development within or close to flood risk areas should be subject to flood risk assessment and should incorporate appropriate flood protection and mitigation methods. It is also an objective of the Council to comply with the EU Floods Directive 2007/60/EC.

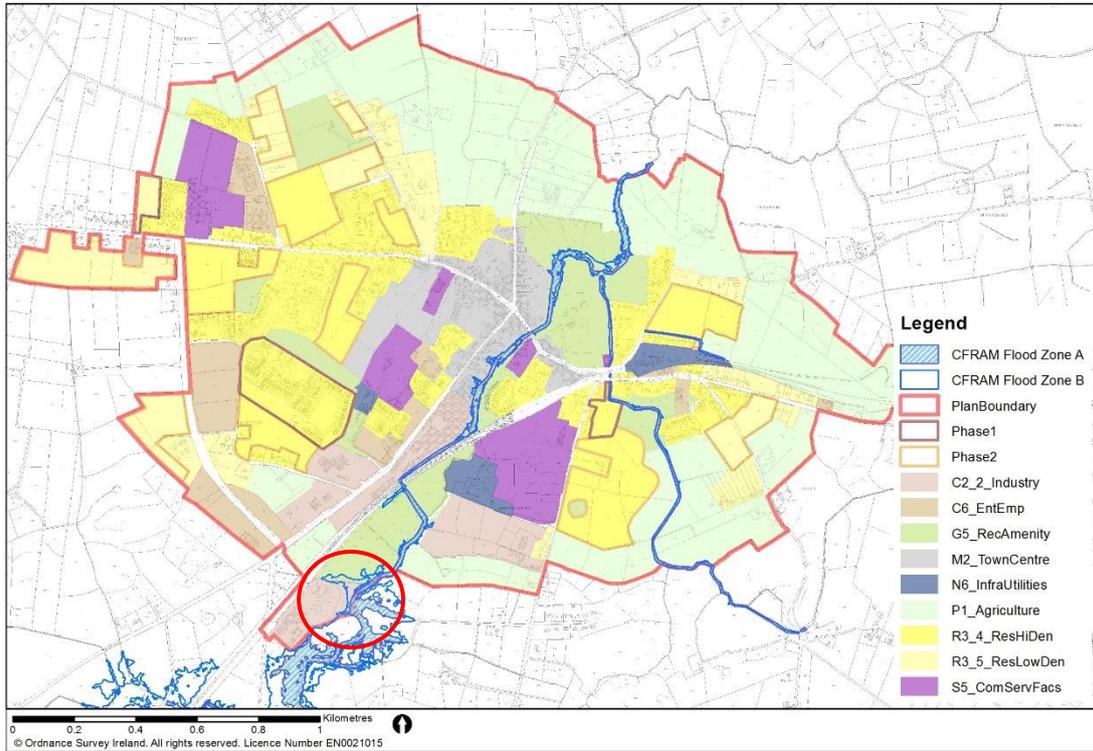
A level 1 SFRA should be produced for the town to take account of the CFRAM Flood Zone maps.

Current risk

There is no zoned land, except for the fringes along watercourses, within the current CFRAM Flood Zone A and some small sections of zoned land in Flood Zone B (Figure 5-10). Planning applications for land parcels which intersect Flood Zones should be subject to the justification test and direct the most vulnerable land uses to lower risk parts of the site. One area to the south, highlighted below shows some risk from the 1% AEP and rezoning should be considered.

¹² Mayo County Development Plan (2014-2020) Tables 1(A-C).

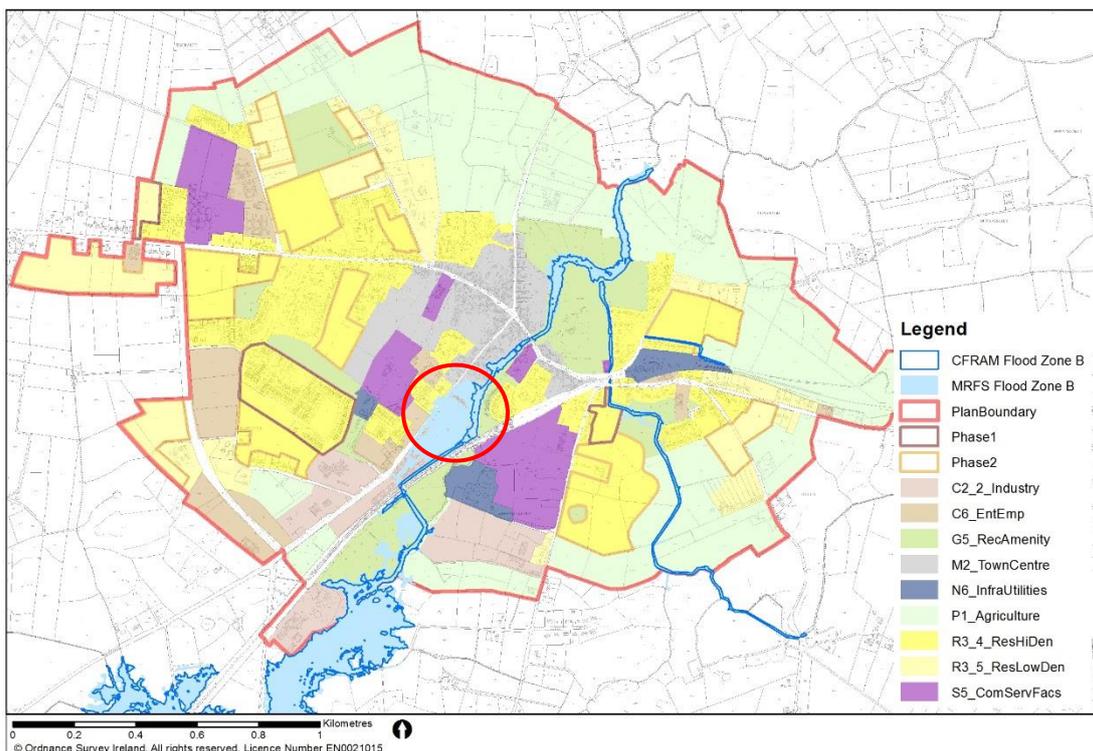
Figure 5-10: CFRAM Flood Zones for Ballyhaunis



Future risk

There is negligible change in Flood Zone A in the MRFS climate change scenario. Flood Zone B does increase in the MRFS (Figure 5-11). It would be appropriate to undertake an SFRA to ensure the development plan zoning objectives are sustainable in the future and consider re-zoning land which is within future Flood Zones.

Figure 5-11: CFRAM MRFS Flood Zone B in Ballyhaunis



6 Surface water drainage strategy

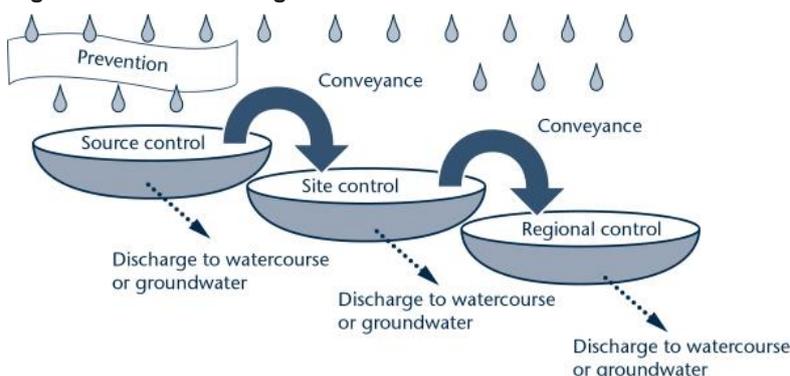
6.1 Overview

The Development Plans reviewed all include some requirement for SUDS, although the specification and threshold for using such a system varies. The usual approach is to adopt some, or all, of the SuDS Management Train approach, illustrated in

Figure 6-1. Preventative, source, site and regional controls can be used to mimic the catchments natural processes as closely as possible. Whilst there are many different SuDS techniques that could be successfully implemented, there is no one single drainage solution for a given site and in most cases a combination of techniques will be required, which could include:

- Prevention - good site design to prevent runoff and pollution i.e. rainwater reuse / harvesting
- Source Control - control runoff as close to the source as possible through soakaways, infiltration trenches, green roofs, pervious pavements and rainwater gardens
- Site Control - management of runoff in a local area or site by routing runoff to swales, detention basins, ponds or wetlands
- Regional Control - management of runoff from site or several sites to a balancing pond or wetland

Figure 6-1: SuDS management train



In addition, it is desirable to maximise the amenity and ecological benefits associated with the drainage system where there are appropriate opportunities. SuDS are green infrastructure components that provide these benefits and provide health benefits, and reduce the vulnerability of developments to the impacts of climate change.

In order to implement SuDS at any given site two aspects in the design need to be considered:

- Provision of treatment volume - to ensure a level of water quality treatment to surface water runoff prior to discharge off site.
- Provision of an attenuation volume - to reduce peak flows and prevent flooding

These two volumes can be combined if source control is applied across a site, but normally a combination of SuDS devices provide these two volumes.

6.2 SuDS and the environment

As detailed in the GSDS, SuDS provide an excellent alternative to traditional systems, and give a means of improving water quality, particularly with the requirements of the Water Framework Directive and other environmental legislation in mind.

The GSDS states that "SuDS minimise the impacts of urban runoff by capturing runoff as close to source as possible and then releasing it slowly. The use of SuDS to control runoff also

provides the additional benefit of reducing pollutants in the surface water by settling out suspended solids, and in some cases providing biological treatment."

Adopting SuDS will provide benefits to water quality, water quantity and amenity and habitat enhancement. By considering all three functions it is possible to provide adequate, well designed systems that:

- offer water quality treatment through natural processes inherent in the system,
- encourage infiltration where appropriate and
- attenuate peak flows
- as well as providing habitat and function for those using the area, including the local community and wildlife.

The European Water Framework Directive requires sustainable management of water resources and protection of water quality. SuDS offer an integrated approach that could play a key part in delivering the Directive's requirements.

6.3 Maintenance and safety considerations

The CFRAM has included a high level review of SuDS systems and their potential applicability in the various AFAs. Where regional systems are possible, and considered desirable, maintenance responsibilities need to be agreed between the local authority and relevant developers. In such instances, ongoing maintenance by the local authority, possibly supported by Development Contributions, as required by Mayo County Council for example, may be the more appropriate solution.

Where the SuDS is localised within a site the responsibility for maintenance needs to be discussed and agreed between the developer, occupier (where relevant) and local authority. At present there is little precedent for local authorities taking SuDS in charge, although as systems become more widespread this may need to be reviewed, particularly where responsibility would otherwise fall to individual homeowners. Where the Local Authority are not going to take charge of a SuDS method, it is advisable that long term maintenance contracts are conditioned as part of the grant of planning and it be obligatory that details are provided to the Local Authority. This should include a long term condition that consecutive maintenance contracts need to stay in place for the lifetime of the development.

In general, maintenance will be more easily managed and monitored where SuDS can be grouped into a single local authority operated, regional treatment system, such as an attenuation basin or wetland, which would be supported by a number of small units, rather than relying on site based storage tanks and outfalls.

Where appropriate, it is also recommended that Local Authorities and/or developers should prepare basic maintenance guidelines that can be provided to home owners and properties owners so they understand what is involved and what is expected of them, including the limitation of the system and a guide to ensuring the system operates effectively.

Under this CFRAM there are no specific proposals presented for SuDS in any AFA, so it is difficult to provide specific health and safety advice, and this should be assessed on a case by case basis. Considerations should include the safety of operators for maintenance activities and the safety of the public who may use the area in and around the system. As with maintenance, it is also worth considering the ease of managing public access and ensuring safe working practices in a regionally based system rather than at a privately operated site scale.

6.4 Drainage policies

6.4.1 Galway City Development Plan

The draft Galway City Development Plan has a specific policy for SuDs.

Policy 9.8 Sustainable Urban Drainage Systems (SUDS)

Ensure the use of Sustainable Urban Drainage Systems (SUDS) and sustainable surface water drainage management, wherever practical in the design of development to enable surface water

run-off to be managed as near to its source as possible and achieve wider benefits such as sustainable development, water quality, biodiversity and local amenity.

Proposals for Sustainable Urban Drainage Systems (SUDS) should include provisions for the long term management, operation and maintenance of these systems.

The policy is reflected in the development management standards:

All proposed development must consider the impact of surface water flood risk in drainage design. Consideration should be given in the design of new development to the incorporation of SUDS. The drainage design should ensure no increase flood risk to the site or downstream catchment.

The SFRA expands upon this and refers to the standards to guidance on the process and design of SUDS provided in the Greater Dublin Strategic Drainage Study (which in the absence of other guidance may be applied in Galway City), and more details and guidance available on the 'Irish SuDS: Guidance and Tools' website.

6.4.2 Galway County Development Plan

The Galway County Development Plan includes policies and objectives relating to the use of SUDS, including Objective FL 2 "Objective FL 2 – Surface Water Drainage and Sustainable Drainage Systems (SuDs)" which states; "*Maintain and enhance, as appropriate, the existing surface water drainage system in the County. Ensure that new developments are adequately serviced with surface water drainage infrastructure and promote the use of Sustainable Drainage Systems in all new developments. Surface water run-off from development sites will be limited to pre-development levels and planning applications for new developments will be required to provide details of surface water drainage and sustainable drainage systems proposals.*"

In particular, the EPA's 'Guidance on Authorisation of Discharges to Groundwater' is referenced. Whilst appropriate in areas where drainage to groundwater is proposed, this does not cover discharges to surface streams or piped networks. There are a number of Development Management Standards which relate to management of surface water, but these do not provide specific guidance for developers.

6.4.3 Mayo County Development Plan

There is an overall objective within the County Development Plan¹³ for any new development to mimic the pre-development situation insofar as possible, which may be in the form of discharge to groundwater within the site or discharge to a surface water drain/stream/ river or to a stormwater sewer. The Development Plan goes on to specify that "*where surface water is discharged in this way, the surface water system shall be designed in accordance with Sustainable Urban Drainage Systems (SUDS) where the discharge shall be kept under the existing Greenfield run-off rate*".

Further, under FS-02 it is an objective of the Council to require certain developments in the settlements identified in the Core Strategy and Settlement Strategy to incorporate "Sustainable Urban Drainage Systems" as part of the development proposals. However, at a glance it is not clear which development might fall into this category.

6.5 Applicability of SuDS

Although providing clear benefits for flood management, particularly during higher frequency events, and for the environment, SuDS are either not permitted or are not appropriate in certain locations and situations.

To assist the application of this process, the soil types and WRAP (Winter Rainfall Acceptance Potential) maps have been reviewed.

Although not directly providing infiltration potential or suitability for SUDS, the recharge map is a surrogate data set which provides an indication of the suitability of the ground conditions for infiltration, and therefore the most common forms of SUDS systems.

¹³ Mayo County Development Plan Volume 2, Section 20.3
WCFRAM UoM 30 Preliminary Options Report - Overarching Report v3.0

The assessment does not consider potential contamination issues associated with infiltration or surface storage adjacent to existing surface water bodies, i.e. watercourses, lakes/ponds or the sea. It is assumed that best practice will be followed (e.g. use of oil separators) so that stored or infiltrated water will not pose a pollution threat to controlled waters.

Discharge to Source Protection Zones is only advised with caution, and with a suitable assessment of the local characteristics of both the discharges and the receiving environment. However, a review of the SPZ in the Western CFRAM area indicates it does not impact on any of the AFA settlements.

The potential for four types of SuDS has broadly been assessed:

- permeable paving (for pavements, car parks, yards, small roads, etc.);
- swales and basins;
- infiltration and filter drains; and
- ponds and wetlands.

Generally, the first three SuDS types all drain to ground (i.e. they involve infiltration); they therefore require relatively high permeability ground, depending upon the system capacity and the volume to be discharged. If the ground is not permeable enough, these types of systems will not function correctly. Where the soil or thin drift layer is not permeable enough for the proposed scheme, but the bedrock is, an engineered solution may be found to allow discharge to bedrock provided that groundwater is adequately protected. This may include removal of the surface layer to replace it with high permeability fill or by locating the infiltration zone beneath the lower permeability surface layer. Permeable paving is often the most sensitive to soil permeability because swales, basins, and infiltration and filter drains often require a degree of excavation and so low permeability soil can be removed in the process.

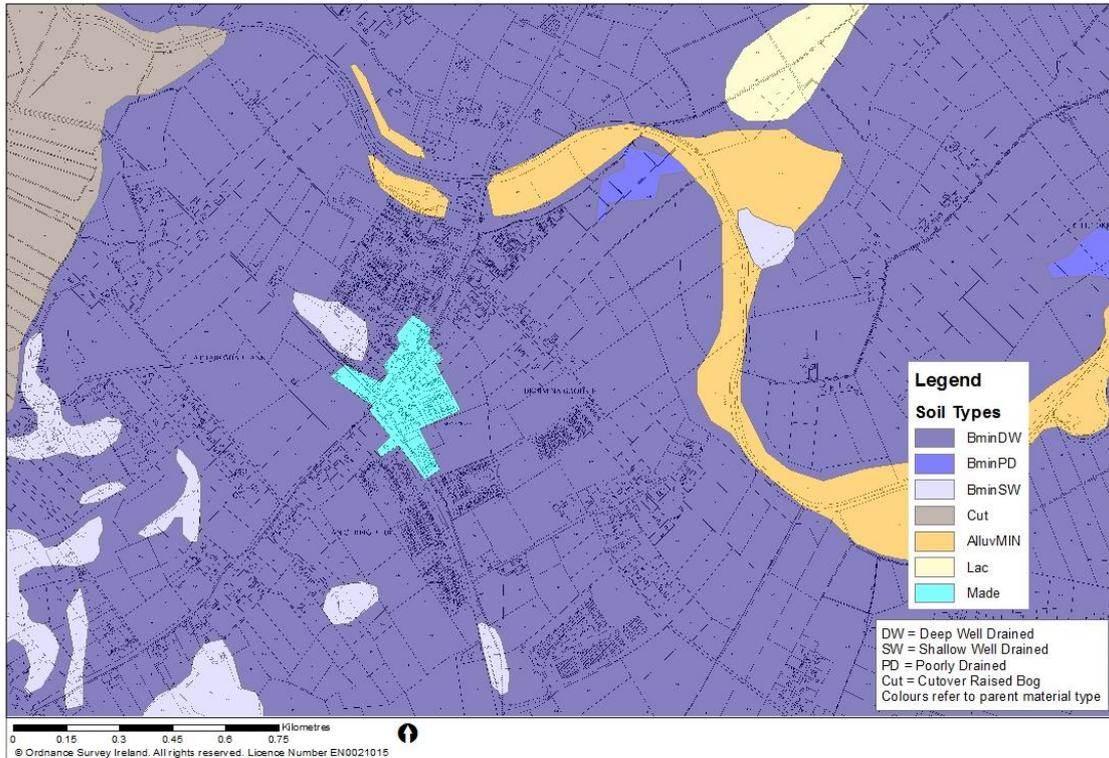
Ponds and wetlands generally require little or no drainage to ground and are therefore better suited to low permeability ground conditions. However, an engineering solution can also be used in high permeability areas by lining the pond with low permeability fill or an artificial liner.

Green roofs and rainwater harvesting have not been included in the process because they do not involve any discharge to ground.

6.5.1 Claregalway

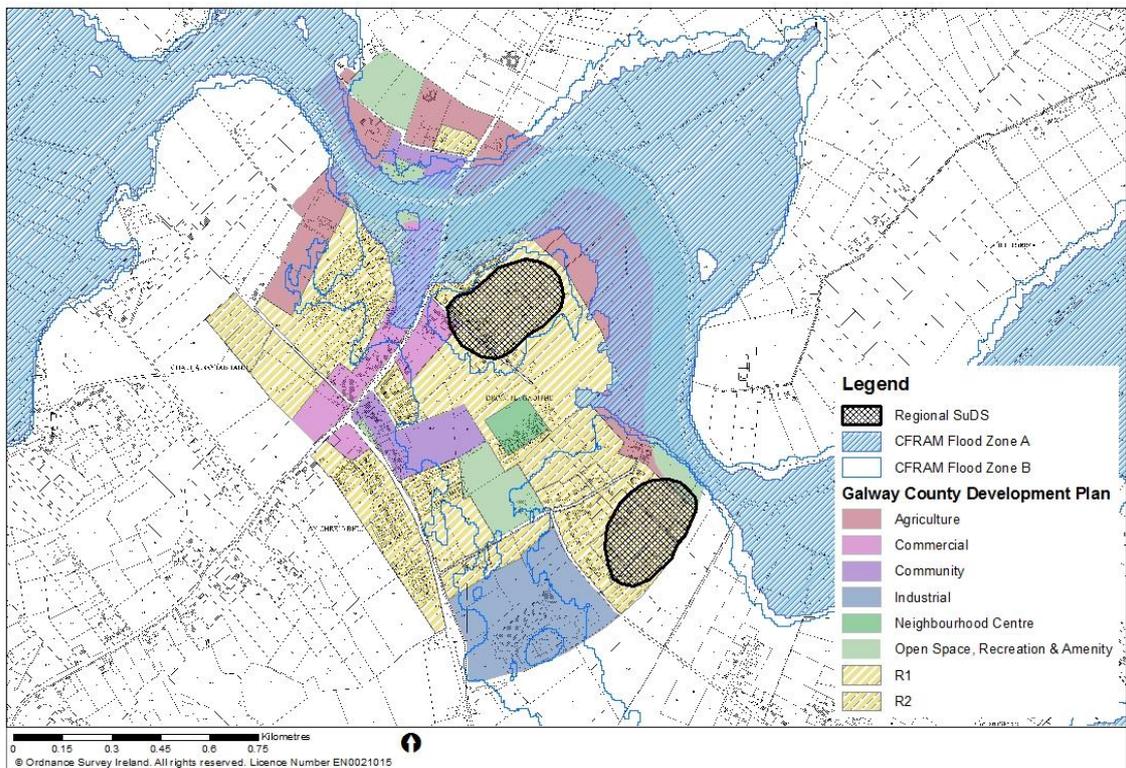
The whole of Claregalway lies within WRAP Class 1, indicating there is a high potential for infiltration to occur. Detailed soil type data shows that Claregalway is underlain by deep well drained soils with a small pocket of shallow well drained soil. The detailed soil map is shown in Figure 6-5. Due to the lack of Lidar data for Claregalway it was not possible to calculate the drainage pathways for the area. One kilometre downstream of the bridge in Claregalway the River Clare flows through cutover raised bog soils down to where it joins Lough Corrib. This indicates that the topography downstream is shallow and that there are potential limitations to the potential for infiltration. There is potential for infiltration based SuDs in Claregalway, subject to site specific assessment including the impact of groundwater discharges to the karst groundwater bodies.

Figure 6-2: Detailed soil types in Claregalway



Development within Claregalway is likely to be of low density and so attenuation of surface water runoff is likely to be able to be achieved within each individual development site boundary. Should large scale development proposals be expected then regional SuDs infiltration and attenuation features should be considered in the locations marked on Figure 6-6 where they can contribute to flood risk management in the village. The areas available for use for SuDs are limited due to the extent of Flood Zone B within Claregalway and available greenfield space. Where SuDs are suitable for development aligning any regional SuDs features with natural drainage paths will help to optimise their benefits.

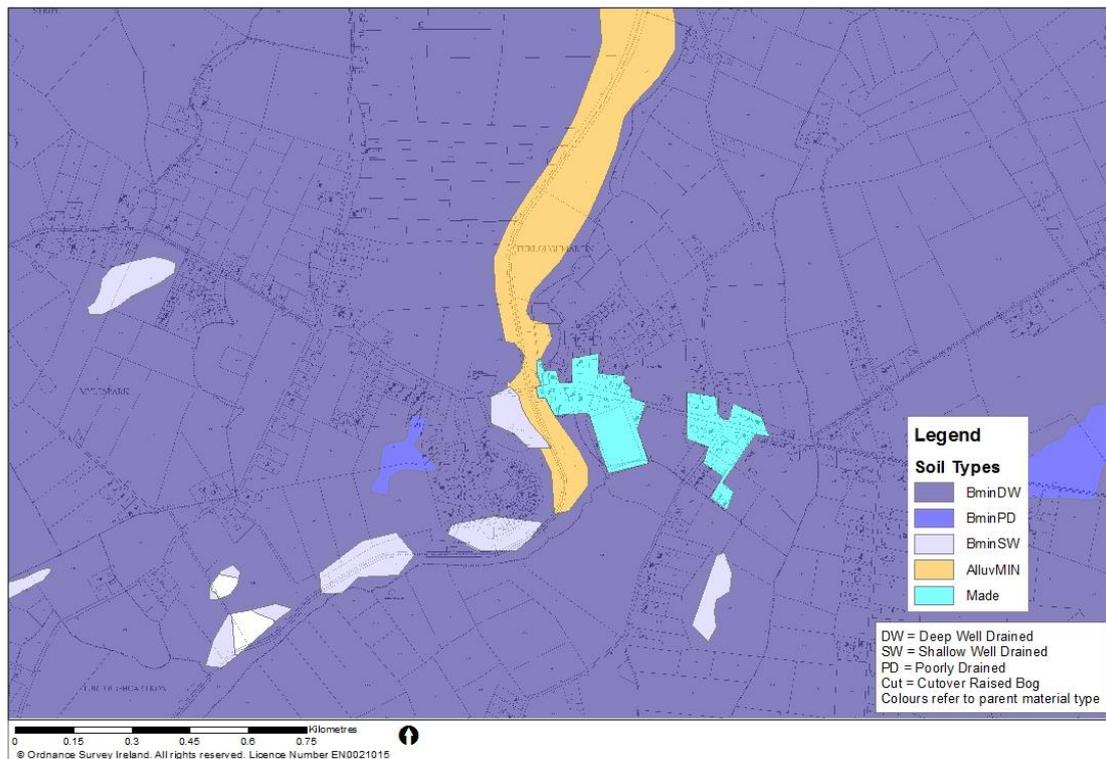
Figure 6-3: Potential for regional SuDs in Claregalway



6.5.2 Corrofin

The whole of Corrofin lies within WRAP Class 1, indicating there is a high potential for infiltration to occur. Detailed soil type data shows that most of Corrofin is underlain by deep well drained soils and the northern part of the village is underlain by poorly drained subsoil with peaty topsoil. This confirms that there is potential for infiltration based SuDs in Corrofin where soils are well drained, subject to site specific assessment including the impact of groundwater discharges to the karst groundwater bodies. The detailed soil map is shown in Figure 6-5

Figure 6-4: Detailed soil types in Corrofin

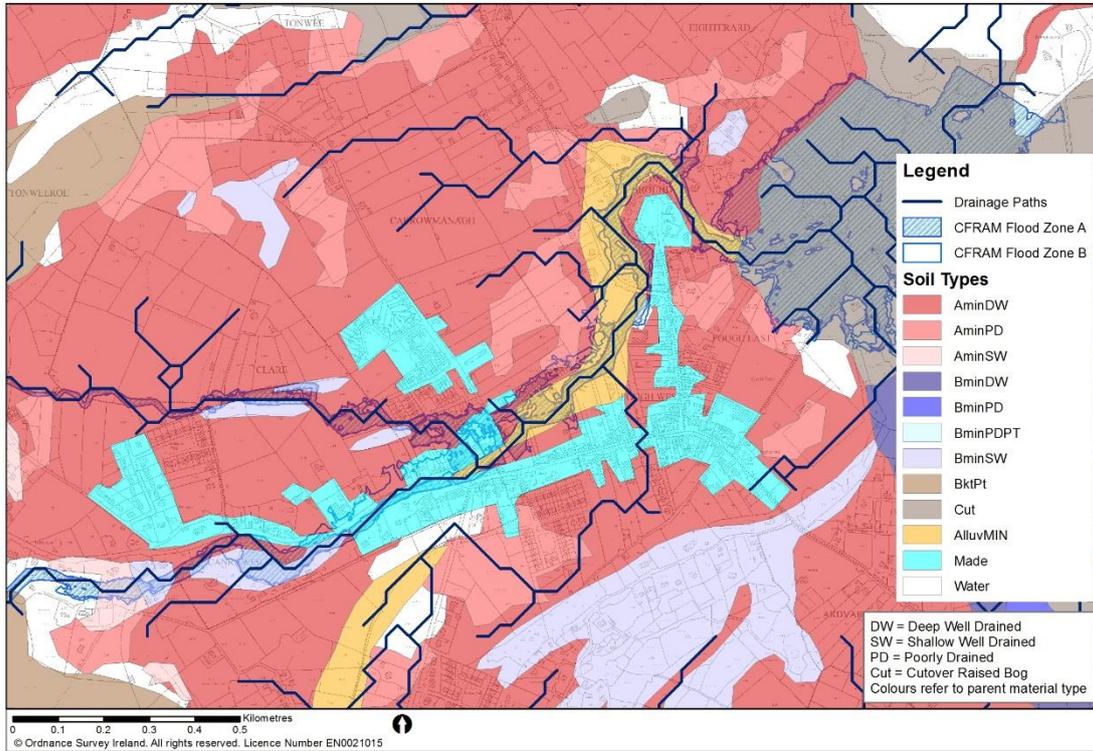


Natural drainage paths in Corrofin are short and join the River Clare in evenly distributed manner. SuDs should be implemented as part of developments in Corrofin, but due to this distribution of drainage paths there is no opportunity for regional attenuation of runoff.

6.5.3 Oughterard

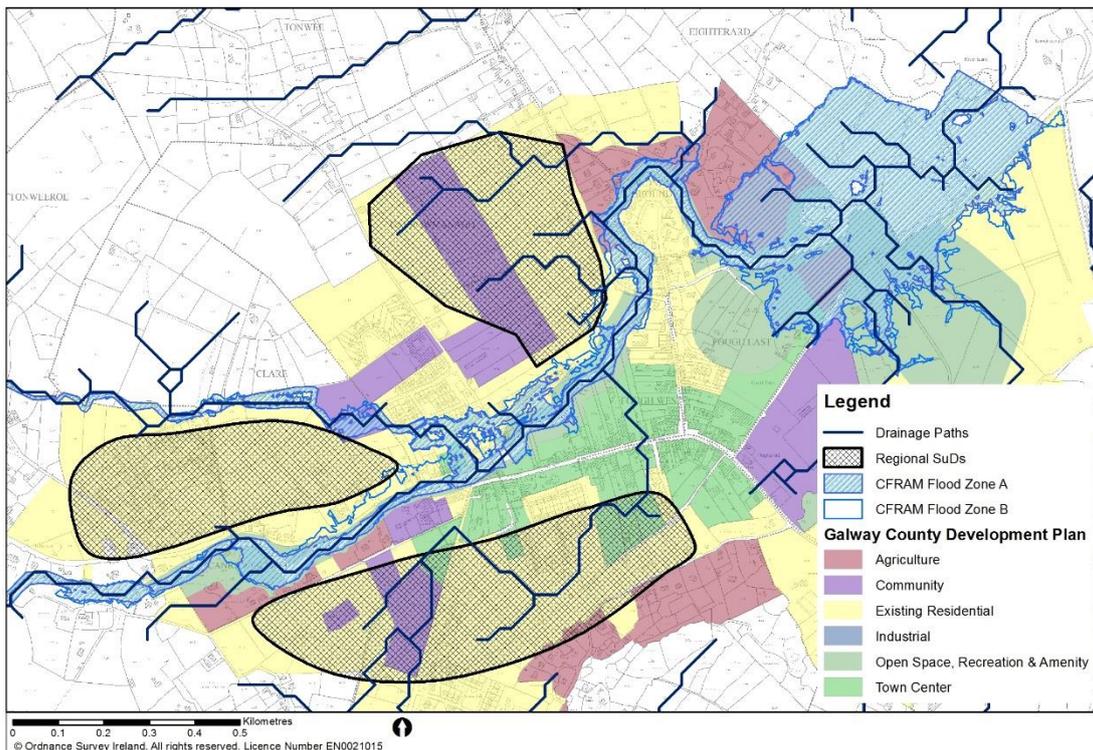
The whole of Oughterard lies within WRAP Class 2, indicating there is a good potential for infiltration to occur. Downstream of Oughterard is WRAP Class 1 with a higher potential for infiltration. The detailed soil map is shown in Figure 6-5. Most of the land in and around Oughterard is underlain by deep well drained soils with some pockets of poorly drained soils. There is an east to west band of shallow well drained soils just to the south of Oughterard. There is a second band from southwest to north east of mineral alluvium, part of which follows the current river channel and part of which underlays what may be a historic watercourse route. Downstream to the east of the village there is a large area of raised bog. This confirms that there is potential for infiltration based SuDs in Oughterard where soils are well drained, subject to site specific assessment including the impact of groundwater discharges to groundwater bodies.

Figure 6-5: Detailed soil types in Oughterard



Development within Oughterard is likely to be of low density and so attenuation of surface water runoff is likely to be able to be achieved within each individual development site boundary. Should large scale development proposals be expected then regional SuDs infiltration and attenuation features should be considered in the locations marked on Figure 6-6 where they can contribute to flood risk management in the village. Aligning any regional SuDs features with natural drainage paths will help to optimise their benefits.

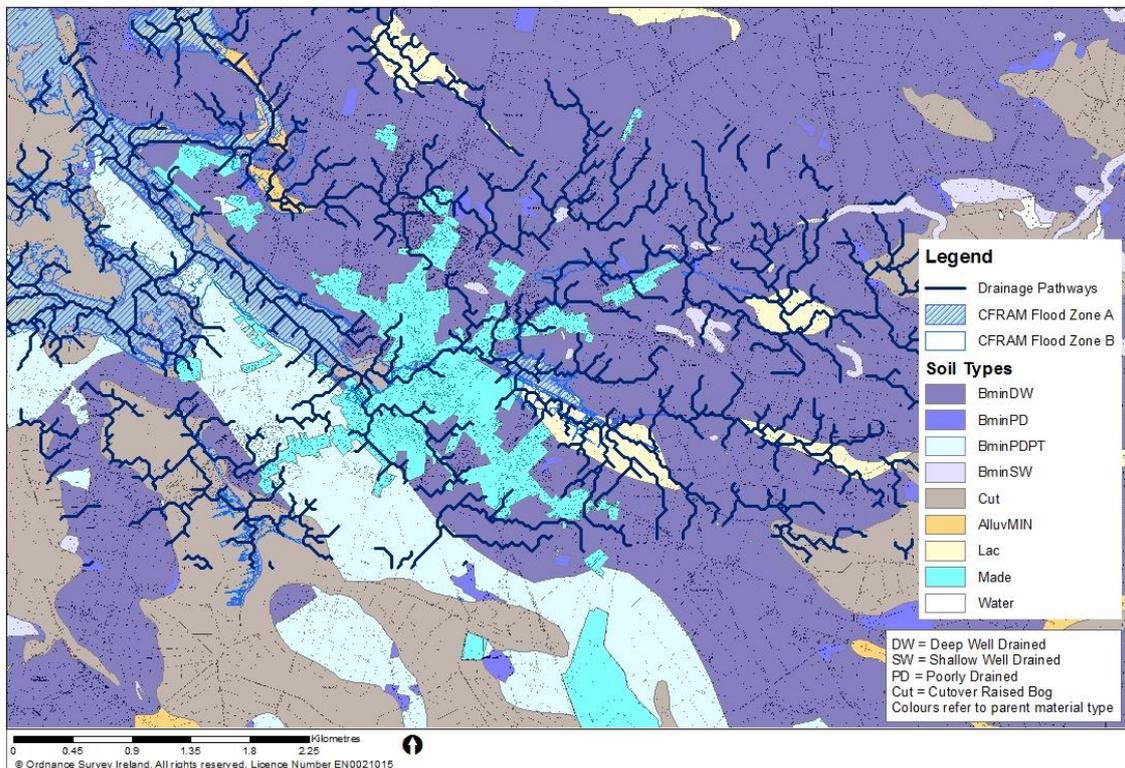
Figure 6-6: Potential for regional SuDs in Oughterard



6.5.4 Tuam

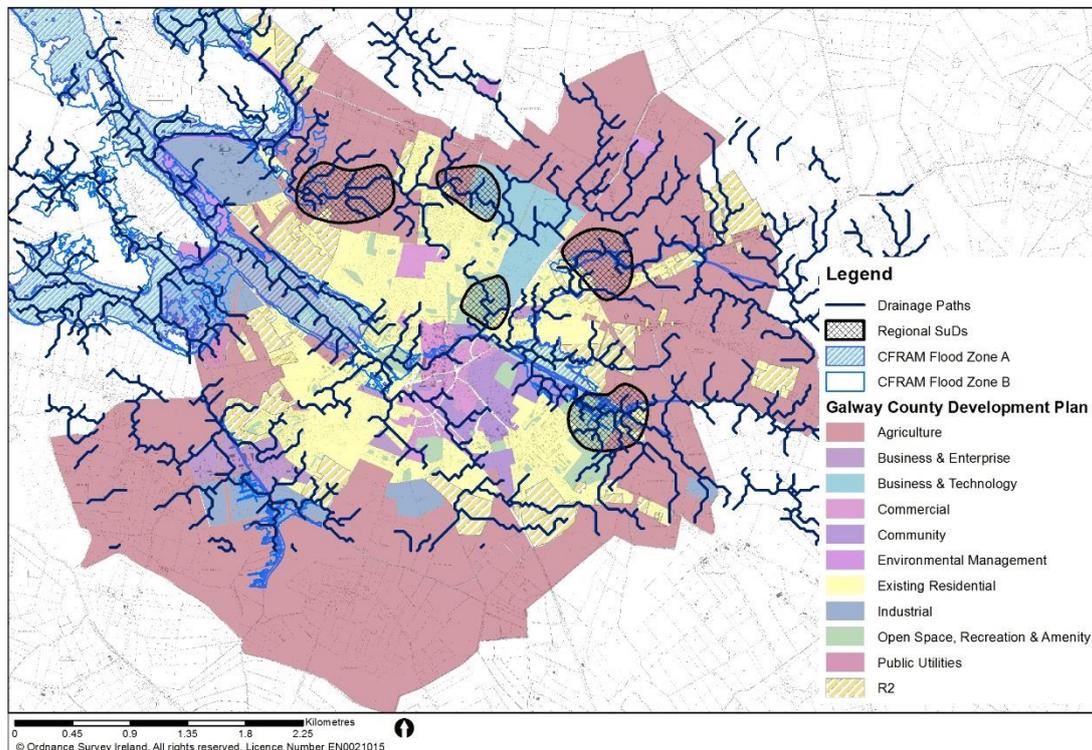
Tuam is split by two WRAP classes. Class 1 to the south west and Class 2 to the north west, but indicating potential for infiltration. Detailed soil maps show most of Tuam is underlain by deep or shallow well drained soils. The detailed soil map is shown in Figure 6-7. There is potential for infiltration based SuDs in the town in these locations, although site specific assessments will need to be carried out, including the impact of groundwater discharges to the karst groundwater bodies. Land in and along the floodplain (Figure 5-4) are underlain by cutover raised bog and lake sediments. These areas are less suitable for infiltration or attenuation based SuDs as are likely to be waterlogged following heavy rainfall.

Figure 6-7: Detailed soil types in Tuam



The best opportunities for regional attenuation and infiltration based SuDs in Tuam are located on land zoned for agriculture and open space as shown in Figure 6-8. This does not remove the necessity for new development to include SuDs features, but presents an opportunity for land management to contribute to flood risk management in Tuam. SuDs methods in Tuam are unlikely to result in a significant reduction in flood flow on the River Clare and so their flood risk benefits will be limited to Tuam only.

Figure 6-8: Regional SuDs opportunities in Tuam



6.5.5 Galway City

The WRAP class in the Galway city area comprises WRAP class 1 and 2 which indicates a high potential of infiltration. Galway city centre and the eastern section are situated within WRAP Class 1 while the western section of the city resides in WRAP Class 2. Review of the detailed soil maps show the presence of deep well draining soils on elevated high ground to the north of the city. Particular attention will need to be given to areas in the western section of Galway City for groundwater ingress where Karst features have been identified. Areas of blanket and cutover peat are located to the northwest of the city which may limit the use of SuDs in these areas of the city. The detailed soil maps for Galway City west are shown in Figure 6-9 and Figure 6-10 while Galway City East are shown in Figure 6-11 and Figure 6-12.

Figure 6-9: Detailed soil types in Galway West

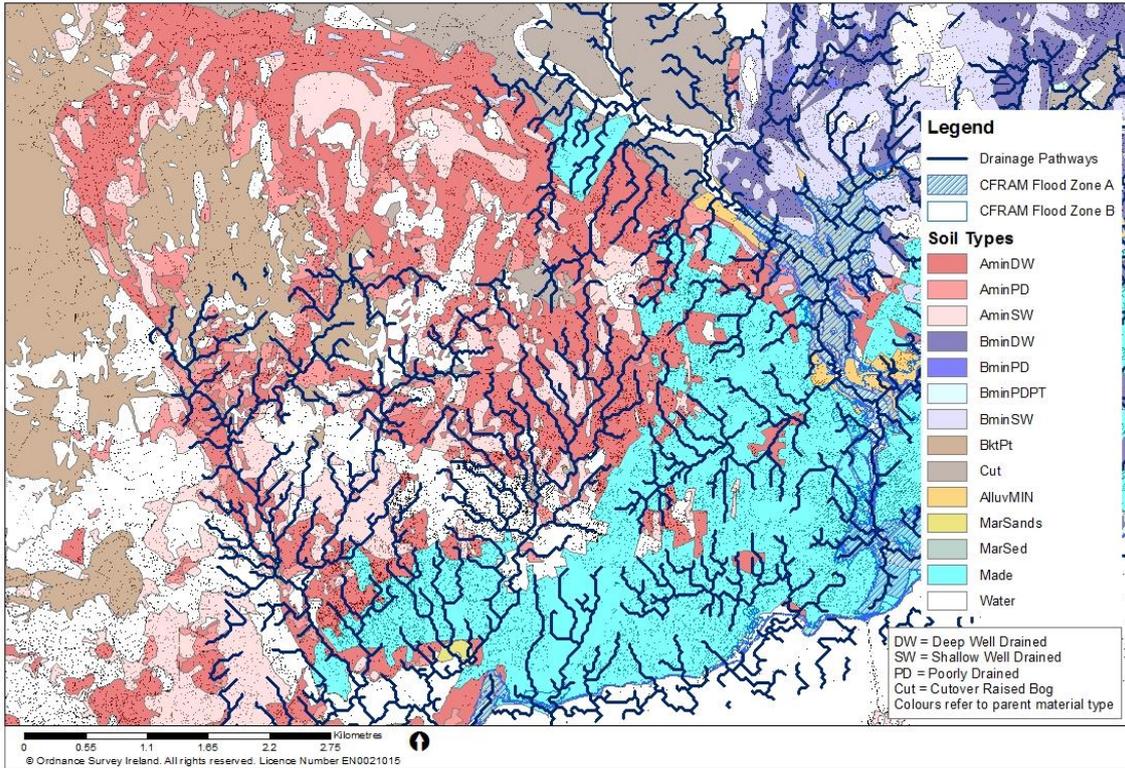


Figure 6-10: Detailed soil types in Galway East

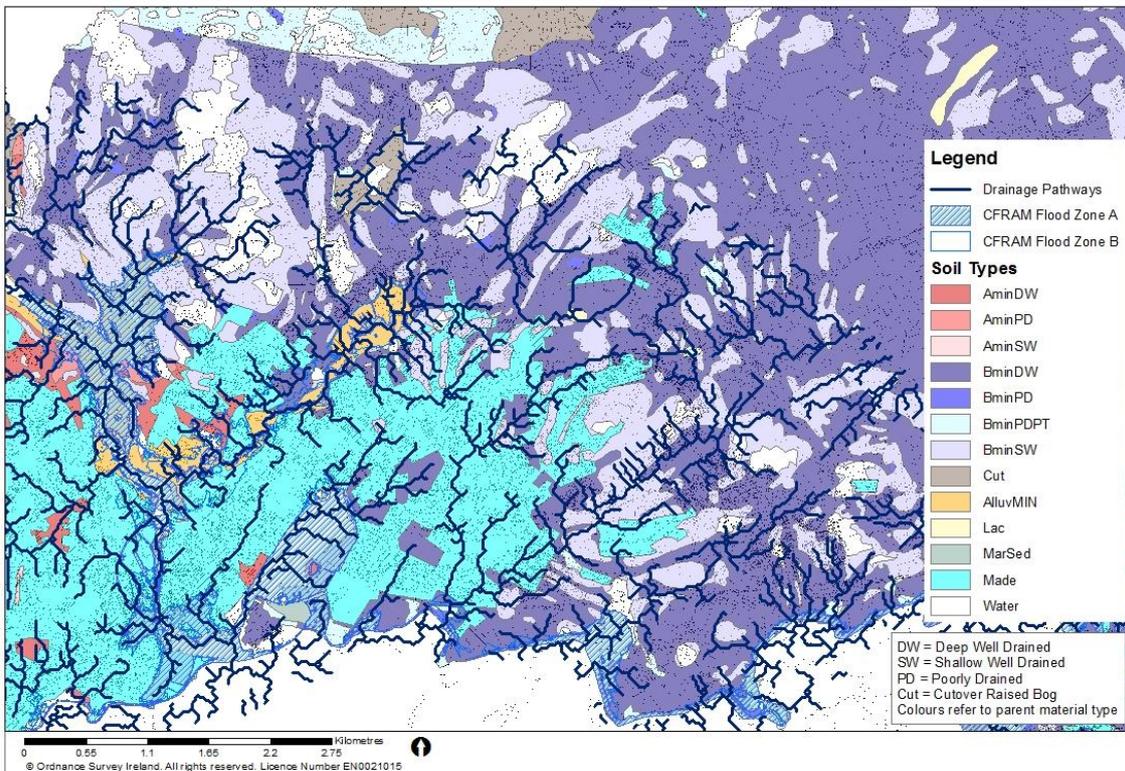


Figure 6-11: Regional SuDs opportunities Galway West

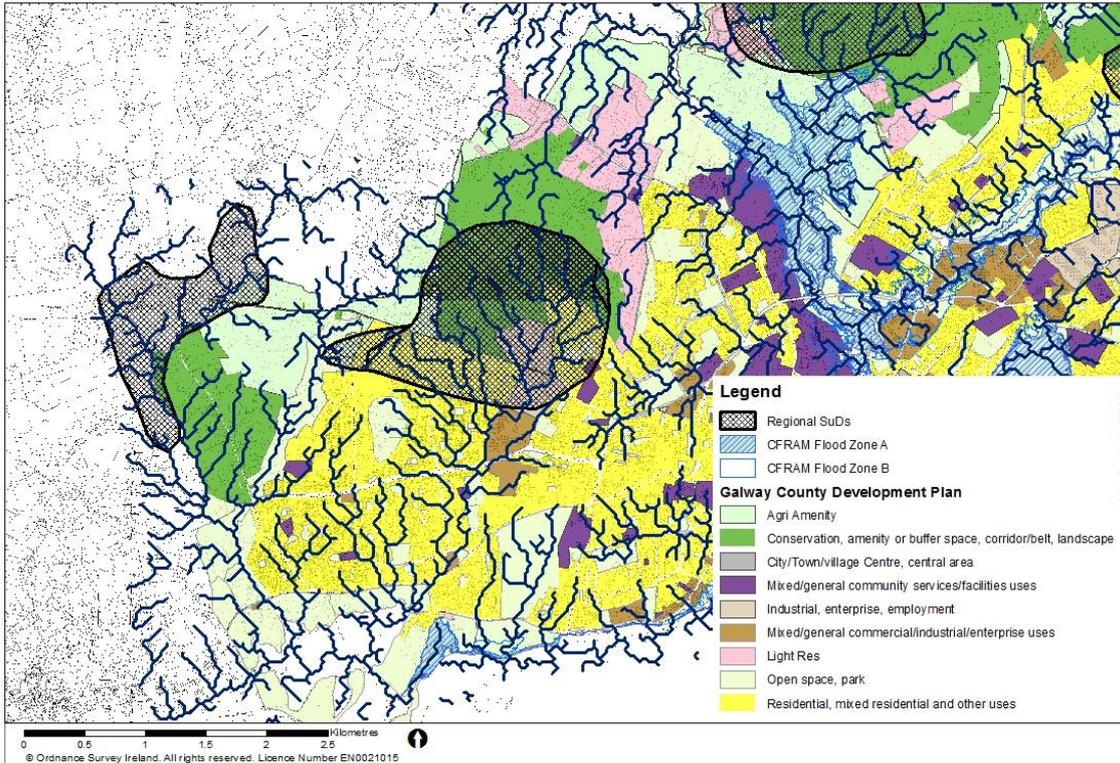
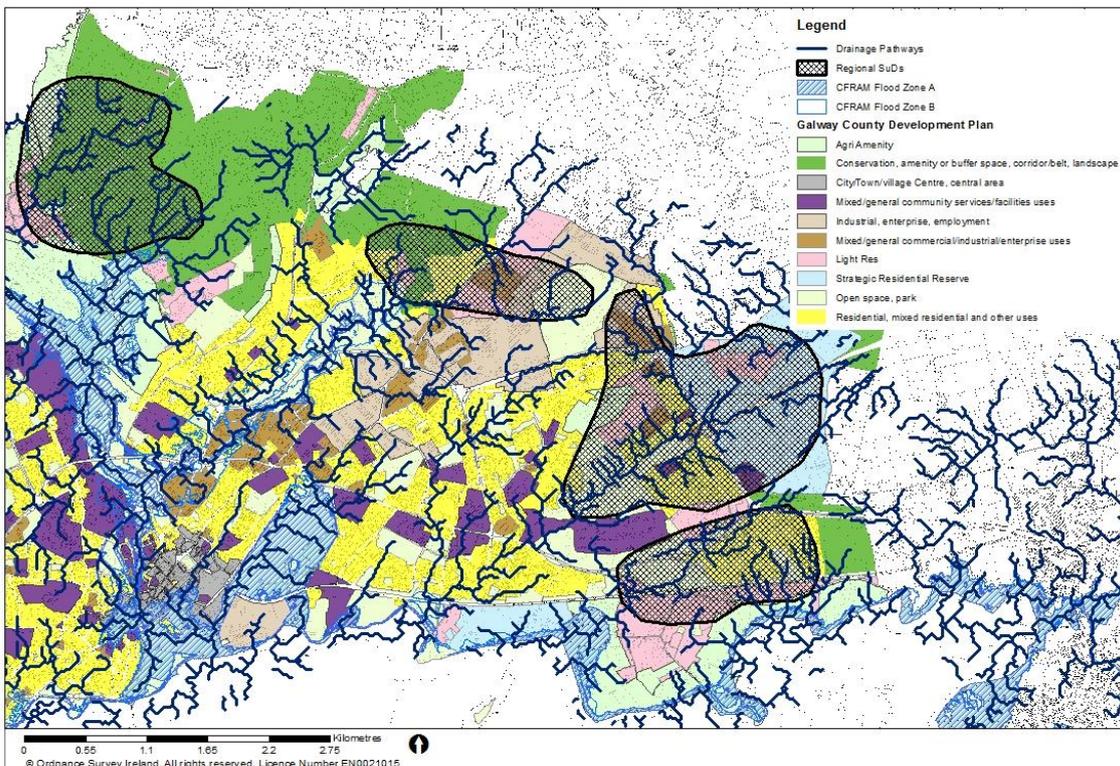


Figure 6-12: Regional SuDs opportunities Galway East



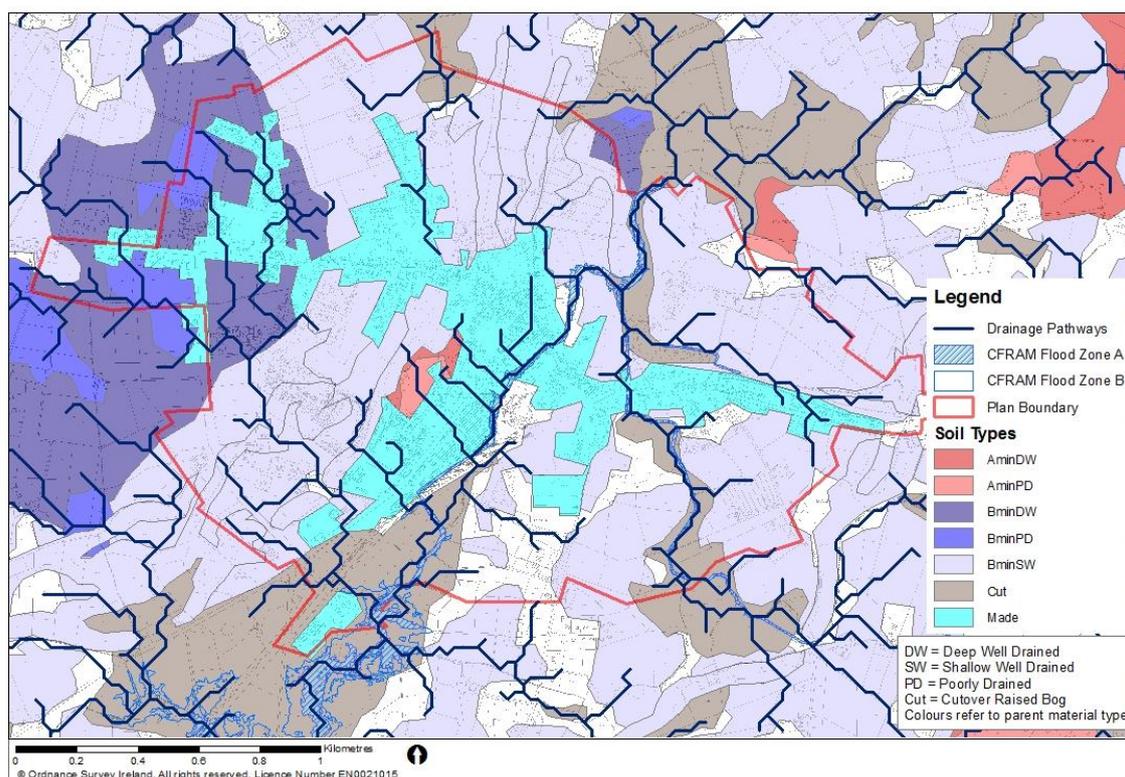
The best opportunities for regional attenuation and infiltration based SuDs in Galway City are located on the outskirts of the city and upper reaches of the drainage pathways. The areas represent the prime development opportunities outside the city centre and comprise areas zoned for residential, industrial and the strategic residential reserve. The scale of the regional SuDs development represents an opportunity to contribute to flood risk management however this does not remove the requirement for the inclusion of SuDs within individual developments.

As a substantial percentage of the drainage network discharges directly to the coastal waterbody coupled with the predominant cause of flooding in the city which is tidal any benefits to flood risk from the deployment of SuDs will likely be at a local level.

6.5.6 Ballyhaunis

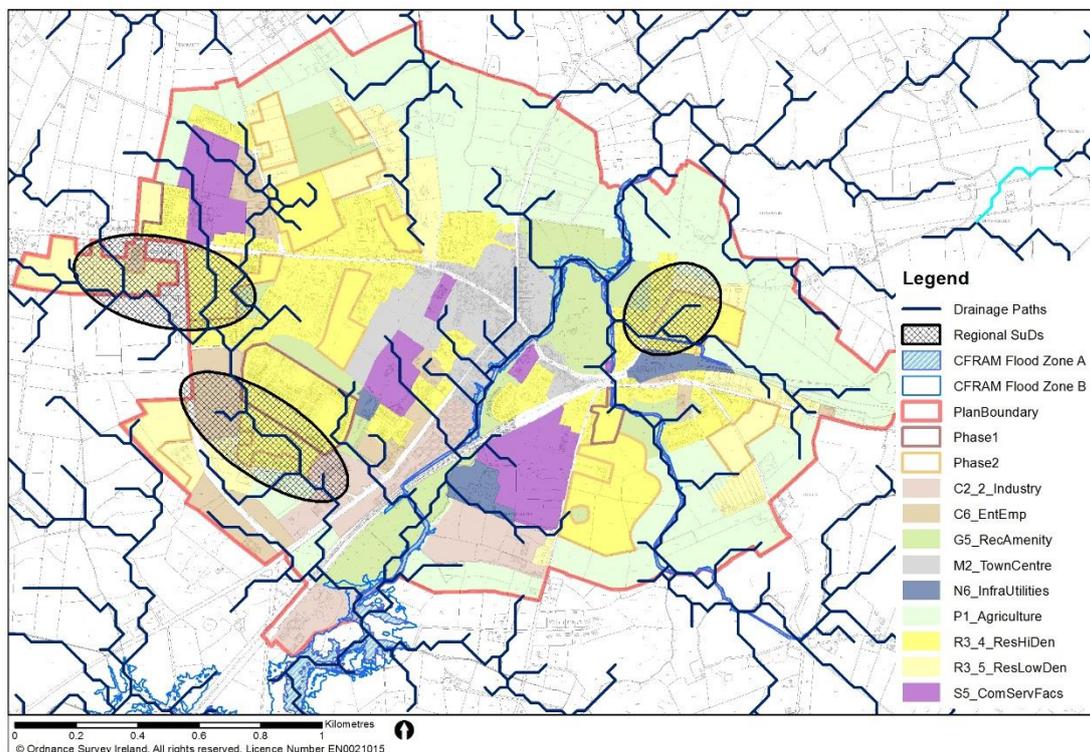
The whole of Ballyhaunis lies within WRAP Class 1, indicating there is a high potential for infiltration to occur. Detailed soil type data shows that soils along the watercourses around Ballyhaunis on low lying land are raised bog. Away from the lower lying land the soil types are predominantly shallow drained with local pockets of poor and well drained soils. To the North West of Ballyhaunis the soil type is mainly deep well-drained. There is potential for infiltration based SuDs in the town, although site specific assessments will need to be carried out, including the impact of groundwater discharges to the karst groundwater bodies. The detailed soil maps for Ballyhaunis are shown in Figure 6-13.

Figure 6-13: Ballyhaunis regional SuDs potential



There are three areas in Ballyhaunis zoned for development with the potential for regional strategic SuDs. These locations are on some of the longer natural drainage paths as shown in Figure 6-14. These development areas which, when taken cumulatively, could benefit from regionally based attenuation basins, both in providing local improvements to drainage but also in limiting increases in flows in the River Clare downstream. Whilst they are not within Flood Zone A or B, the use of SUDS in these areas would provide a positive contribution to reducing flood risk in Ballyhaunis. The potential for regional attenuation features should be considered in light of the phasing of development so that SuDs are considered at the outset of development plans rather than during later phases of development. Some parts of Ballyhaunis drain to the Moy catchment and so SuDs here will benefit Unit of Management 34.

Figure 6-14: Ballyhaunis regional SuDs potential



6.6 Indicative storage volumes

To provide additional guidance to planners and developers an indicative assessment of storage volumes required for SuDS has been developed. The figures shown in Table 6-1 give an indicative surface water attenuation storage volume per hectare for each of the AFAs in UoM30. These figures are based on the most conservative SAAR and WRAP classes for each settlement (i.e. least expected infiltration) and assume the 1% AEP storm is being attenuated to the 1 year greenfield runoff rate, with an allowance of 10% for climate change. MicroDrainage WinDes, the industry standard software for the water industry to detail design fully integrated stormwater and foul water drainage systems, has been used to estimate attenuation volumes. The range given reflects the potential design options for the attenuation system, including construction and outlet control types.

Table 6-1: Indicative storage volumes per AFA

AFA	Indicative storage volume range (m ³ per hectare, based on 100 year + 10% CC assuming control to Q1 year)
Ballyhaunis	515<845
Claregalway	531<815
Corrofin	661<1076
Galway City	226<461
Oughterard	773<1376
Tuam	597<968

It should be noted that the values provided are indicative only and can be used to indicate the area of potential development sites which should be retained for storage purposes; as a guide a storage depth of 1-2m is generally recommended. A site specific assessment will be required for each development, which will take into account local ground conditions, the development type and configuration and the balance of additional SuDS methods, such as permeable paving, swales and soakaways. Whilst a 10% allowance has been included, there may be situations

where it is appropriate to consider a 20% allowance, particularly where the catchment has been highlighted as being particularly vulnerable to surface water runoff in flood generation, or where the proposed development represents a long-term, high value investment.

7 Flood forecasting systems

7.1 Introduction

Flood forecasting and flood warning can be an effective part of the flood risk management response. It can provide an early warning to local residents and response groups in times of emergency allowing residents to move to areas of reduced risk. In conjunction with other flood management methods such as flood gates it allows time for improved flood resilience of properties where more substantial schemes have not been justified or are not feasible. It can usually be implemented in the short-medium term and provides opportunities to raise public awareness of flood risk and so improve community preparedness.

Flood forecasting systems are dependent on an appropriate hydrometric infrastructure. Development of flood forecasting systems need to be done at a catchment level. This ensures that the gauge network is coherent and provides the greatest possible benefit for the minimum number of gauges. Rainfall gauge networks are best developed across multiple catchments. This assessment has been completed for UoM 30 mindful of the proposals in adjacent UoMs 29, 31, 32 and 34.

At present in UoM 30 the only flood forecasting and flood warning services are provided by Met Éireann, who issue general nationwide and regional flood alerts.

The assessment of the viability of a flood forecasting system within UoM 30 have examined the current infrastructure and, focussing on the AFAs, determined the requirements to operate a real-time localised flood forecasting or warning service.

Figure 7-1 details the catchment areas for each of the 5 AFAs within UoM 30 and Table 7-1 details the source(s) of flood risk within each AFA and hence the flood forecasting system(s) required.

Table 7-1: Flood sources per AFA

AFA	Flood Risk Source
Oughterard	Fluvial
Ballyhaunis	Fluvial
Tuam	Fluvial
Corrofin	Fluvial
Galway City	Fluvial, Tidal

Figure 7-1: Catchments within UoM 30



7.2 Fluvial flood forecasting

Forecasting models vary in complexity from simple level-to-level correlations to highly automated integrated catchment flood forecasting systems. The degree of automation and sophistication should be considered based on the needs of a particular location. The type of forecast system will either be based on the enhancement of existing hydrometric data networks or the development of new networks.

7.2.1 Types of fluvial forecasting and warning systems

Flood warning is closely linked to the task of flood forecasting. The distinction between the two is that the outcome of flood forecasting is a set of forecast time-profiles of channel flows or river levels at various locations, while "flood warning" is the task of making use of these forecasts to make decisions about whether warnings of floods should be issued to the general public or whether previous warnings should be rescinded or retracted. Examples of warning and flood forecasting systems include:

- Low-cost community based telemetry and warning
- Level triggers along watercourses
- River Routing Models
- Integrated rainfall runoff and river routing models.

7.2.1.1 Low Cost Community based telemetry and warning

The Environment Agency in the UK has recently trialled low-cost community based telemetry and warning trigger solutions. This uses observed river levels at a single location. When thresholds in rivers levels are exceeded, an alert is sent from telemetry data loggers to servers. Subsequently the server issues a warning (by email and SMS) to the key users who can respond accordingly.

The cost for the provision and installation of a hydrostatic level sensor, staff gauge and telemetry is estimated at €3400. This is an indicative cost estimate for standard telemetry and warning trigger applications where installation is straightforward and there is good access.

The Environment Agency in the UK has also trialled new vehicle activated flood warning signs at flood risk locations where flooding to roads and at fords has caused disruption or fatalities. Driving into water remains one of the main risks when rivers burst their banks. Solar-powered signs, activated by oncoming vehicles and connected to river level telemetry, provide visual warnings once the river levels exceed a predefined threshold. These signs aim to improve safety by providing timely warnings and ensuring that the public take appropriate action.

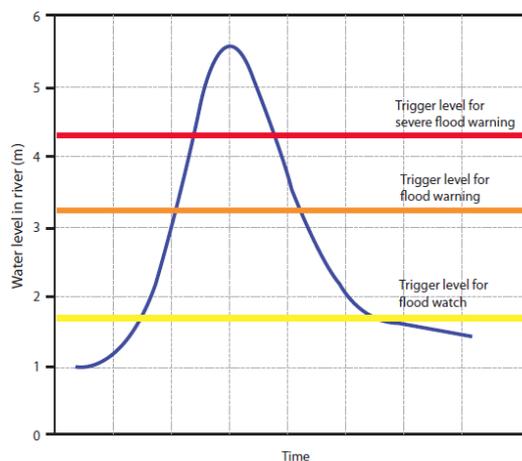
Figure 7-2: Example of interactive road signs (source: Cost estimation for flood warning and forecasting - report - SC080039/R13 - Environment Agency)



7.2.1.2 Level triggers along a watercourse

Providing level triggers along a water course is the more traditional approach to flood forecasting. The system uses hydraulic models to correlate levels at an upstream gauging site with the onset of flooding at downstream sites and so determine an appropriate trigger level for action. This approach could be applied to AFAs relatively easily because the modelling stage has been completed, although a level correlation between the sites at risk and the gauging site would need to be established. Where there is no suitable gauge adjacent to the site at risk of flooding, consideration should be given to the installation of a temporary recording gauge so that the relationship between the upstream gauge and the flood risk site in the hydraulic model can be calibrated.

Figure 7-3: Example of trigger warning system (Source, Flood Forecasting and Early Warning, World Meteorological Organisation)



7.2.1.3 River routing models

Routing models typically forecast flows and/or levels on the basis of observations made further upstream. They provide one of the most reliable forecasting techniques available and are often a good first choice if sufficient warning time can be achieved. Routing models represent the physical processes of a flood event (flow in a river channel) which can in principle be modelled by suitable mass and momentum conservation equations, and usually offer higher performance than rainfall runoff models, although with shorter lead times.

Routing models are appropriate where there is significant uncertainty in a level to level relationship, as discussed in Section 7.2.1.4. This may be because of complicating effects between the site at risk and the upstream gauge (e.g. floodplains, unusual structures or significant tributaries).

The recorded flow at an upstream gauge is routed through a model in real-time and contributing flows from downstream tributaries added to assess the risk to the area downstream. For a routing model to be effective a good understanding of the inflows from these tributaries is required. In some cases inflows may be inferred from observed flows at the upstream gauge but more often than not additional data and analysis will be required determine these flows, either from a gauge directly on larger catchments or through the development of a rainfall runoff model.

7.2.1.4 Rainfall driven forecasting systems

Rainfall runoff models represent the process of conversion of rainfall to flows across a range of soil types, topography and other factors. They can be used independently to forecast flow, or, more commonly, in combination with other model types, e.g. routing or hydrodynamic models to generate model inputs.

Rainfall runoff models may be driven by observed rainfall (by radar or by rain gauge) giving longer lead times than models based on flow alone, with the potential to increase forecast lead times further by using rainfall forecasts as a model input (although with a further reduction in accuracy). Due to these uncertainties, rainfall runoff models are rarely used to issue warnings without the use of a backup trigger at the site and/or real time updating.

7.2.2 Costs of implementing flood warning and forecasting systems

The costs of the implementation of such systems can be calculated using the OPW's Unit Cost Database¹⁴ (UCD) and are dependent on the complexity of the system (i.e. the number of rainfall and hydrometric gauges required). The UCD allows for the following elements of developing the forecasting system and are calculated where required based on the complexity of the proposed system:

- Specification, site survey and administration
- Gauging and telemetry
- Forecast model set-up, calibration, configuration and testing
- Forecasting system development
- Training
- Public awareness campaign
- Operation and maintenance costs.

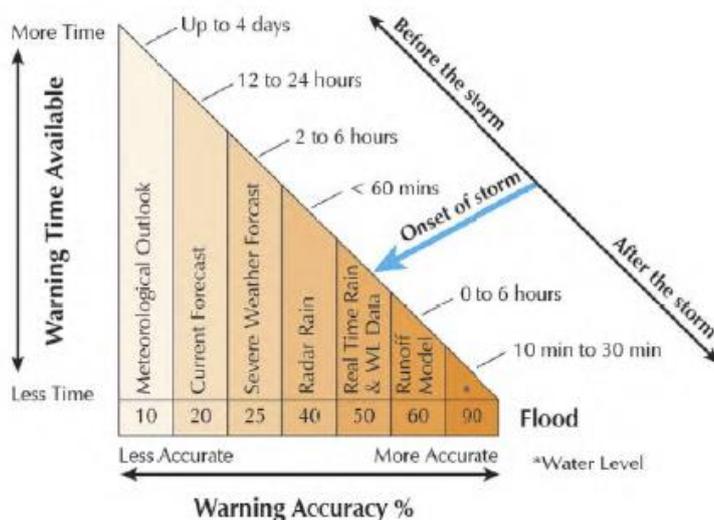
7.2.3 The potential reliability of the forecasts

Usually a flood can only be predicted with high accuracy in the later stages of its development and when more information such as observed flow or rainfall becomes available. Therefore, in order for sufficient warning time to be provided it is often necessary to accept a prediction that is less accurate. There is therefore a trade-off between prediction accuracy and warning time.

Figure 7-4 demonstrates an example of the trade-off between the warning time that can be provided and the level of accuracy.

¹⁴ The Unit Cost Database was developed as part of the CFRAM programme and provides standardised costs for a range of structural and non-structural flood management methods. It forms the basis of cost estimates for the Options Assessment stage of the CFRAM.

Figure 7-4: Warning time vs accuracy (Source, Flood Forecasting and Early Warning, World Meteorological Organisation)



It is not possible to specify a pre-determined accuracy for a forecast and there are real limits to what is possible. A well schematised and calibrated model is designed to minimise uncertainty, but uncertainty still abounds and it is impossible to eliminate errors (such as false warnings, or missed events) entirely.

Hydrological and meteorological forecasts have inherent errors and uncertainties. Uncertainty can arise because:

- A forecast does not occur
- An event is not forecasted
- The magnitude of the event is in exceedance or less than the forecasted event
- The timing of the event is incorrect.
- There are insufficient rain gauges to capture a catchment scale event
- There are errors in the rating curves at gauged locations

Although forecasts can be made at a very broad scale for ungauged locations using remotely sensed rainfall, there is a sensible minimum amount of data required for calibration and real time updating of a flood forecasting system used to warn the general public. This might be one of the following:

- At least one telemetered rain gauge to drive rainfall runoff models. The number of gauges required will depend on several factors, with accuracy generally increasing with coverage. Small, faster responding rivers are particularly sensitive to the magnitude and timing of rainfall inputs.
- A river gauge at, or near to, the risk area. This is required to calibrate forecasting models and correct their predictions in real time.

In large river systems, it is also advantageous to have several rainfall and river gauges upstream of the risk area to allow calibration of a network of sub-catchments and real-time updating of predictions

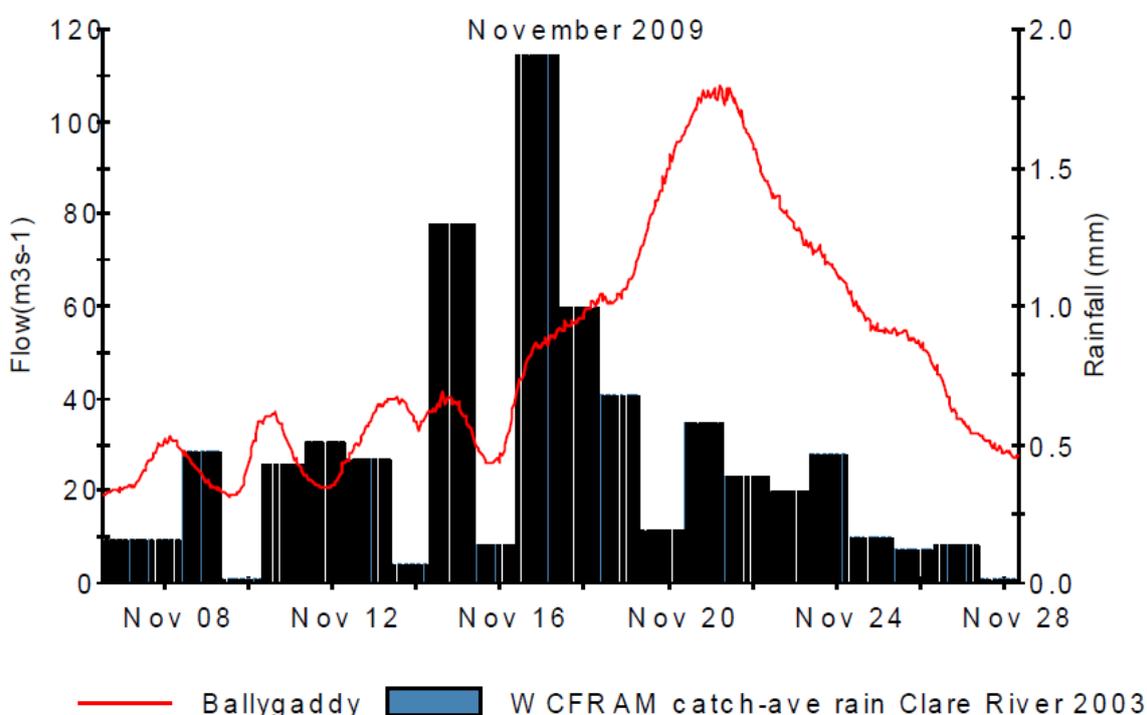
7.2.4 Consideration of lead time

Lead time is a critical concept in forecasting. Forecasts change during a flood event as new data becomes available, tending to become more accurate closer to the event. For example, at 24 hours ahead, river flow predictions which could be based on rainfall forecasts or upstream gauges will be highly uncertain. At six hours ahead, the forecast may be using primarily observed rainfall. At shorter lead times still, the forecast may be based on flows observed upstream, or at the location itself. Each of these data sets is more accurate than the last, directly affecting predictive accuracy. Evolution of forecast accuracy with reducing lead time is a critical concept to understand and communicate to stakeholders. The forecast lead time that is possible

to achieve is related to the type of catchment. However, the principle for assessing lead time requirements is the minimum period of advance warning needed for preparatory action to be taken effectively. This will depend on the community which is at risk. Individual households and businesses may require one to two hours to move items from danger (place items at upper floors, put out sandbags etc.) whilst schemes reliant on demountable defences may take several hours to implement.

To inform the selection of a preferred flood warning approach the potential lead time in the fluvial catchments in UoM 30 has been inferred from the Time to Peak (Tp) and catchment lag both derived from analysis of past flood events. Catchment lag is the time to between the centroid of the total rainfall for the event and the runoff peak (or centroid of peaks for multi-peaked events). Because the rainfall data available in UoM 30 is daily, lag times shorter than 24hrs are highly approximate. Figure 7-5 shows an example for the River Clare at the Ballygaddy gauge, where the lag time for the event is 108.6 hours; full details are provided in Appendix D of the Inception Report. Further discussion on each catchments' expected Time to Peak and Lag Time is provided in Section 7.3 of this report.

Figure 7-5: Example of lag time analysis (Clare River, Ballygaddy)



7.2.5 Flood warning dissemination

In order for Flood Forecasting Systems to be effective flood warning dissemination needs to occur and must:

1. **Reach the right people.** This is a particular challenge if warnings are issued directly to the public. If warnings are communicated directly to individuals or households (e.g. via phone, text, email, sirens, etc.) then it is first necessary to identify with a high level of confidence which properties are at risk of flooding. The results of the CFRAM study mapping stage have highlighted the properties and areas at greatest risk and should be utilised.
2. **Be reliable,** i.e. a high probability of detecting floods and a low rate of false warnings. This is a vital aspect of a successful flood forecasting and warning service, and is a key method of the success of a flood warning service. Reliable warnings generally require an accurate forecast model from which the warnings can be generated. A further aspect of reliability is the ability to warn of flooding from the full range of flood sources (river, tide, heavy rainfall and groundwater).
3. **Provide the information that the recipient needs.** Warnings need to be clear and easy to understand. For some service providers it will be useful to include information on the expected duration of the flood as well as its severity and time of onset.

Information on the uncertainty of the forecast (e.g. probabilistic forecasts) will be useful for some recipients such as local authorities, especially as it can allow the provision of extended warning times.

4. **Allow recipients to appreciate the flood risk** and its potential impacts on their interests. Residents or business owners need to know that they are at risk of flooding, otherwise they are unlikely to take any action. The existing schemes (with the possible exception of the tidal flood forecasting schemes) cover areas that have experienced recent flooding. However, in future, flood warning may be considered for areas that are at risk but have not flooded recently. In these latter cases, raising awareness of the risk will be required. The flood risk management plans and the associated consultation in the CFRAM programme will help in this.
5. **Provide adequate lead time.** For both residential and commercial properties, significant benefits are found from a 2-hour lead time and the rate of increase in benefit reduces once the lead time exceeds 4 hours. However, longer lead times will be required for many service providers, particularly for local authorities needing to erect demountable defences. The required lead time will depend on the capability and capacity of the recipient to respond, for example greater lead times are required out of normal office hours. Some recipients will need advance forecasts, even if their reliability is low, at much longer lead times: for example, dam and reservoir operators.

7.2.6 Damage savings from flood warning

An estimate of the reduction in flood risk damages that can be achieved following the introduction of a flood warning system has been completed by the Flood Hazard Research Centre in the UK. Broadly this is based on the proportion of damages in a flood event that relate to moveable contents within a building, the proportion of people likely to respond to a flood warning and the proportion of the movable contents that will be taken out of flood risk given the warning time. The estimates are a 4.5% reduction in total damage for warning time less than 8 hours and a 5.8% reduction in damages for a warning time of more than 8 hours.

7.3 AFA fluvial forecasting requirements

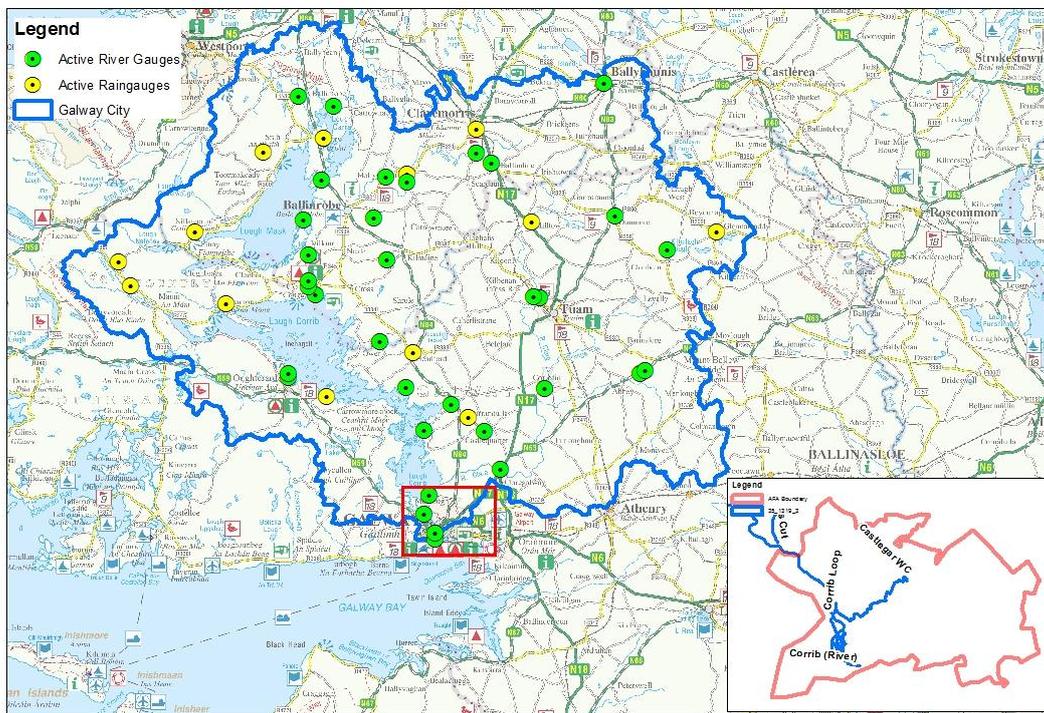
The key components of fluvial forecasting have been introduced in the previous sections. This section will review current data provision and potential forecasting systems at an AFA scale. In UoM 30 the catchments are hydraulically linked so it is necessary to explore flood forecasting at the UoM scale and on an individual AFA scale. Appropriate scales have been identified and are presented below. Currently, there is only fluvial risk in Corrofin, Claregalway and Galway City catchment so the potential to provide flood warning and forecasting systems was analysed.

7.3.1 River Clare / Corrib

Overview

The River Dalgan/Clare flows through Ballyhaunis, Tuam, Corrofin and Claregalway before flowing into the Lough Corrib. The Clare River along with the Corrib River which drains the western side of the catchment are part of the Clare-Corrib Arterial Drainage Scheme. The hydrology and flood response of the River Corrib downstream of the Lough Corrib is significantly different upstream of this point.

The slow response of the River Clare means it is possible to develop a fluvial flood forecasting and warning system for Corrofin, Claregalway and Galway using local level gauges.



Catchment characteristics

The catchment is divided by the Loughs Corrib and Mask into two main sub-catchments, the River Corrib and River Clare each with contrasting catchment characteristics. The bulk of the catchment lies within the River Clare sub-catchment with relative low-lying lands.

The mean annual rainfall is 1422mm throughout the River Clare/ Corrib catchment. There is a contributing catchment of approximately 3,140km² with significant attenuation from Lough Corrib (FARL = 0.66).

Rainfall gauges

There are 13 No. active daily rainfall stations within the River Clare/ Corrib Catchment as shown above. There is one synoptic station within the Catchment located at Claremorris.

River gauges

There are 34 No. active recording flow gauges within the Galway catchment and 11 No. inactive flow gauges. The primary gauges within the system are:

Gauge	Use in study
30020 - Ballyhaunis	Rating Review calibrated to gaugings. Primary Calibration location for Ballyhaunis AFA
30007 - Ballygaddy,	Rating Review calibrated to gaugings.

	Tuam	Primary Calibration location for Tuam AFA, although not in the main AFA centre	
	30004- Corrofin	Rating Review calibrated to gaugings. Primary Calibration location for Corrofin AFA	
	30012 - Claregalway	-	
	30098 - Dangan	Stage compared at location	
	30099 - Salmon Bridge Weir	Stage compared at location	
	30061 - Wolfe Tone Bridge	Rating Review calibrated to gaugings. Primary Calibration location for Galway AFA	
Consideration of lead time	Corrofin		
	<p> $T_p \sim 42.5$ hours </p>	<p> Lag Time = $\sim 3-4$ Days </p>	A lag time of up to 4 days was found which is typical of large shallow catchments.
	Claregalway		
	<p> $T_p \sim 19.3$ hours </p>	<p> Lag Time = $\sim 2- 3$ Days </p>	A lag time of up to 3 days was found which is typical of large shallow catchments.
	Galway		
	<p> $T_p \sim 42.5$ hours </p>	<p> Lag Time = $\sim 6- 10$ Days </p>	The long lag time of 6-10 days reflects the large size of the catchment with extensive lakes and shallow topography. A high percentage runoff was found and this suggests that the soils had high soil water content as well as little available storage of water in Loughs and out bodies following a prolonged rainfall period.
Is there potential for a flood warning system?	<p>Yes - The potential for a level trigger warning system at the gauging site was looked at. All types of flood forecasting are technically viable given the long lead times available. The long lag time between rainfall and flooding from the River Clare/Corrib in Corrofin, Claregalway and Galway City means that medium term flood forecasting is not necessary and existing gauges can be used to set trigger levels for flood warnings.</p> <p>The simplest approach is to use the existing gauge network to issue flood warnings based on trigger levels. The WCFRAM models can be applied here. It is likely that detailed analysis of the existing gauges will be needed, potentially with further rating reviews. Some temporary gauges may be required to improve the calibration of the existing models and level to level relationships. This approach will not allow for any understanding of when flood levels may reach critical levels in the medium to long term.</p> <p>The Medium Priority Watercourse (MPW) models developed for this study could be adapted to produce a calibrated river routing model to inform flood warnings for Corrofin, Claregalway and Galway or used to generate look-up tables of travel time, level to level correlation and flood response. The MPW model is appropriate for determining the peak flow, level and extent of flooding at different flood probabilities. To convert the MPW model to a full flood forecasting model will require more detailed analysis of the timing of inflows and floodplain attenuation. The model outputs can be used to inform level based flood warnings. Further calibration to flood events would refine these estimates.</p> <p>Various triggers at key river, lough or rainfall gauges could inform the need for increased monitoring of water levels and rainfall.</p>		

	Downstream water levels could be taken from tide table predictions at Galway Bay or the Irish Storm Surge model. It will be important to understand lake levels in Lough Corrib. A small uncertainty in gauged lake level could have significant impact on the accuracy of flood forecast model
Justification	<p>The beneficiaries of a fluvial flood forecasting and warning system for the River Clare/ Corrib include the following:</p> <ul style="list-style-type: none"> • Fluvial Damage in Galway City (16 properties) estimated at €261,000 • Damages in Corrofin are estimated at in excess of €360,000 (5 properties) • The Clare River (Claregalway) Flood Relief Scheme was initiated in 2010 following major flooding in 2009. Advance works including the construction of a flood eye on the Claregalway Bridge and replacement of Crusheeny Bridge were carried out in 2011-2012. With scheme construction commencing in 2016 it is expected that the Scheme will be completed in 2018. Though a scheme will be put in place the AFA can benefit from flood forecasting and warning in the catchment in the interim and for exceedence events, or areas that do not benefit from the scheme (e.g. roads, farmland, parks). • Ability to enact a flood response plan. General saving in emergency response costs and reductions in risk to life through the use of warnings to trigger pre-determined national and local road closures and diversions between Corrofin and Galway • The forecasting and warning system could benefit rural populations and businesses outside of the AFAs. The correlation between gauge levels and levels at roads and properties could be inferred to provide local rural warnings. Other flood sources such as surface water and groundwater may also be present in some of these locations
Likely accuracy	<p>The long lead time means that monitoring of water levels and flows can be triggered from weather events and lead to the issue of flood warnings with sufficient lead time.</p> <p>In general, the predictable nature and slow response of the River Clare/ Corrib through Corrofin, Claregalway and Galway should allow for accurate warnings. There is sufficient historic flood data available to calibrate model travel times to between the AFAs.</p> <p>Tidal flood risk also affects Galway and downstream tide levels and times will have a big influence on fluvial flood level prediction. Fortunately, the duration of fluvial flooding will extend over numerous tide cycles to timing of high tides is not critical to the issue of warnings. What is more important is determining the peak tide level with an account for storm surge (see coastal flood forecasting section below).</p>
Hydrometry requirements	<p>The most critical gauges for the proposed forecasting and warning system are outlined above. Continued management of the existing hydrometric network will allow for monitoring of catchment hydrology during high flows. The sharing of real time "live" telemetered data across organisations is essential. Archive data should be readily available to maintain the forecasting system and identify potential errors. General improvements in soil moisture deficit modelling and monitoring and rainfall data</p>
Cost of scheme	<p>The capital costs of the implementation of such a system is estimated to be €51,600. It is assumed the operational costs and Forecast system development cost, which includes purchase and development forecasting platform, computer system and backup software would be carried by proposed national flood forecasting centre currently under consideration. It also assumes the existing gauge and telemetric network is used. A</p>

breakdown of the costs is as follows:

Flood Forecasting Costs		€
Specification, site survey and administration		2,000
Gauging and telemetry		0
Forecast model set-up, calibration, configuration and testing		30,000
Forecast system development		0
Design and plan of training package		2,000
Public awareness campaign		400
Capital Cost		34,400
Optimism Bias	50%	17,200
Total Capital Cost		51,600

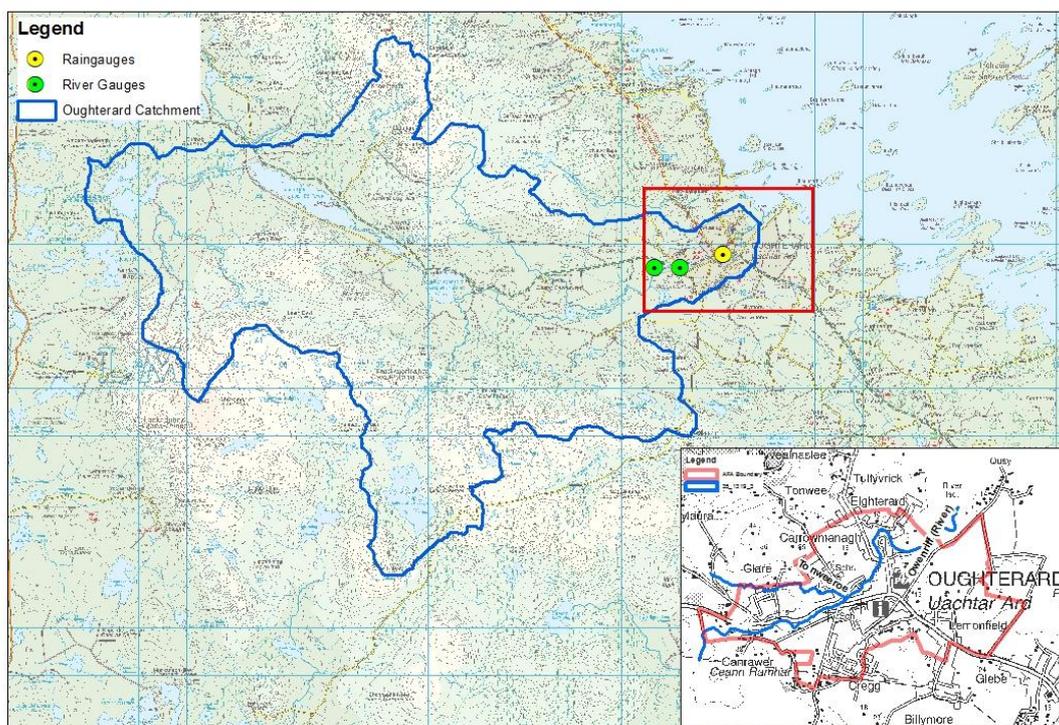
This method is currently not cost beneficial as it would lead to a reduction of 4.5% of the damages (€27,845) giving a BCR of less than 1

7.3.2 Oughterard

Overview

The Owenriff River is the main watercourse passing through Oughterard with a smaller tributary, the Tonweeroe stream, flowing into the Owenriff at the town. The source of flood risk in Oughterard is from the Tonweeroe where a series of culverts at the downstream end of the stream generate out of bank flow during extreme events.

The estimated costs due to property damage for a 1% AEP flood event is €12,263 therefore the costs of developing a dedicated flood warning system will not be cost effective.



Catchment characteristics

The Oughterard catchment covers an area of c.67km². The catchment is hilly with altitudes up to 250-300m and includes areas of high ground with the Lackadunna mountain to the south west and the Knockbrack mountain

	<p>to the north. The Lackadunna drains into the Letterfore River and Bunowen River while the Lackadunna drains into the Glashanasmearany River and Glengawbeg (Tonweeroe) River. A SAAR value of 1900 has been found for the catchment. There is a contributing catchment of approximately 67km² with substantial attenuation from lakes (FARL = 0.75).</p> <p>The Owenriff River is a relatively short watercourse that runs in a predominant westward direction. There are no notable urban areas within the catchment with the exception of Oughterard town therefore is almost entirely rural and 25% is forested.</p> <p>The Tonweeroe watercourse flows to the north of the town and is the primary source of risk. Its catchment is less than 5km².</p>		
Rainfall gauges	There is one daily active rain gauge located within Oughterard town as shown.		
River gauges	There is an active flow site just downstream of Oughterard Bridge (30101). Two stations Claremount (30019) and Oughterard (30044) have been out of operation since 2003 and 2001 respectively.		
Consideration of lead time	Tp = n/a	Lag Time = n/a	Due to the lack of a river gauge it was not possible to estimate Lag time however given the catchment is expected to be flashy with short time to peaks and lag times.
Is there potential for a flood warning system	No - The predominant source of flooding within the Oughterard catchment is from the Tonweeroe sub-catchment which is an ungauged catchment therefore with limited flow information, but due to the size of the catchment the required lead times are not available.		
Description of proposed forecasting system.	There is little potential for flood forecasting. The size of the Tonweeroe catchment is less than 5km ² , so the accuracy required would be unattainable given the nature of the catchment, making forecasting unviable.		

7.4 Coastal flood forecasting

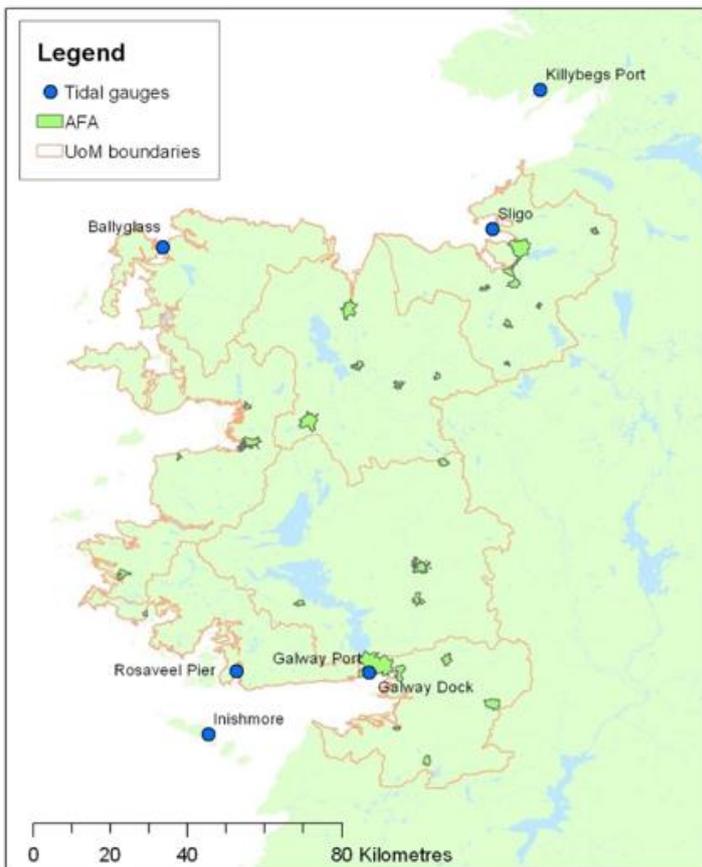
Galway City is affected by coastal flooding. Areas of Salthill are affected by tidal inundation and wave overtopping. The lower reaches of the River Corrib i.e. the canal tail races, Claddagh basin and downstream of Salmon Weir Barrage are mainly exposed to coastal flooding. This flooding is mainly as a result of a surge tide water levels, with wave overtopping been less of an attributing factor. Properties around Spanish Arch, Docklands and Claddagh basin are affected in the tidally influenced reaches. In Salthill the primary flood mechanism is wave overtopping.

7.4.1 Tidal data

Figure 7-6 details the location and available data associated with tidal gauges around the west coast of Ireland. Many of these gauges have been recently installed and are part of an ongoing project by the Marine Institute to develop a centrally controlled Irish national tidal network. The AFAs in UoM 30 are located close to a gauge at Galway Dock, operated by the OPW and Galway Port, which is operated by the Marine Institute.

Currently, the nearest gauges are Rosaveel Pier and Inishmore and the effects of local inlets and bays on tidal levels will not be known and calibrations using this data should be treated with caution. It is imperative that this gauge is reinstated to allow calibration of any flood forecasting system.

Figure 7-6: Tidal gauge network



7.4.2 Galway City

Relative to forecasting rainfall, predicting still-water sea levels (i.e. tide and surge) is generally more straightforward, depending largely on accurate predictions of tide level, atmospheric pressure and wind speed.

Figure 7-7: Components of sea level variation that lead to typical coastal flooding

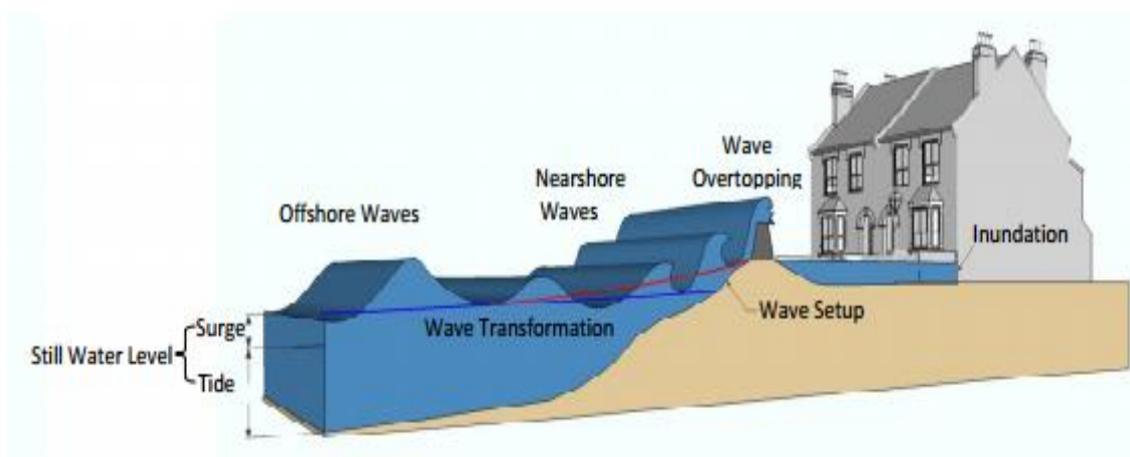


Figure 7-7 illustrates the main components of sea-level variation that contribute to coastal flooding during a storm event. The still water sea-level is comprised of the underlying astronomical tide and any storm surge affects. These two components determine the average sea-level for a particular location at a particular time. Whilst this variable is very important in terms of coastal flooding, still water-induced flooding is normally limited to sheltered locations such as tidal rivers and harbours. These two components are responsible for coastal flood risk in Galway City.

The OPW, as part of the Irish Coastal Protection Strategy Study (ICPSS), has developed a storm surge model for the coast of Ireland. This model is currently being trialled with a view to evaluating and improving its capability.

The OPW uses a national tidal and storm surge forecasting system along with a European Flood Awareness System (EFAS) which provides probabilistic early flood forecasting information. Currently the OPW issues a high tide advisory notice to Local Authorities. Galway City council have erected warning signs in areas of high risk.

The tide and storm surge forecasts are provided twice daily to a project website during the autumn and winter period which is accessible to local authorities. The service provides surge, astronomical tide and total water level time series predictions approximately 65 hours in advance. Low resolution forecasts are available at Galway City and could be used to provide warning to the residents of Galway City. The model is currently only in operation in the autumn / winter months and its operation may need to be extended. As this is a national system its costs would be negligible when broken down by AFA. The system cost €87,000 to put in place with annual running costs of €68,100, which is the cost that is currently incurred by the OPW.

7.4.3 Salthill

Salthill is an exposed location and is affected by wave overtopping. In exposed locations, most flooding occurs through wave action (also illustrated in Figure 7-7), rather than still water flooding. Wave action is a complex process controlled by many contributing factors. The manner in which these factors combine determines the magnitude of any wave-induced flood impacts. Waves are generated in deep water by strong winds and then propagate towards land. As they do so, they enter shallower bathymetry where wave transformation processes occur, including shoaling, diffraction, refraction, depth limitation and breaking. The consequence of these processes is that the properties of the waves, when they reach the base of coastal flood defences, are quite different to the waves in deep water.

It is these nearshore waves that are of most importance in terms of flood forecasting because they interact with beaches and defences and lead to wave overtopping. The magnitude of wave overtopping is controlled by the state of the sea (i.e. depth, nearshore wave properties), the geometry of the beach and local flood defences, and the directional characteristics of the storm (i.e. wave and wind direction). Once wave water overtops a defence, flood inundation commences. The nature of this inundation is related to the magnitude of the overtopping, any additional still water flooding land and its drainage. Coastal flooding can also be exacerbated by fluvial or surface water flooding.

Coastal flood forecasting system development

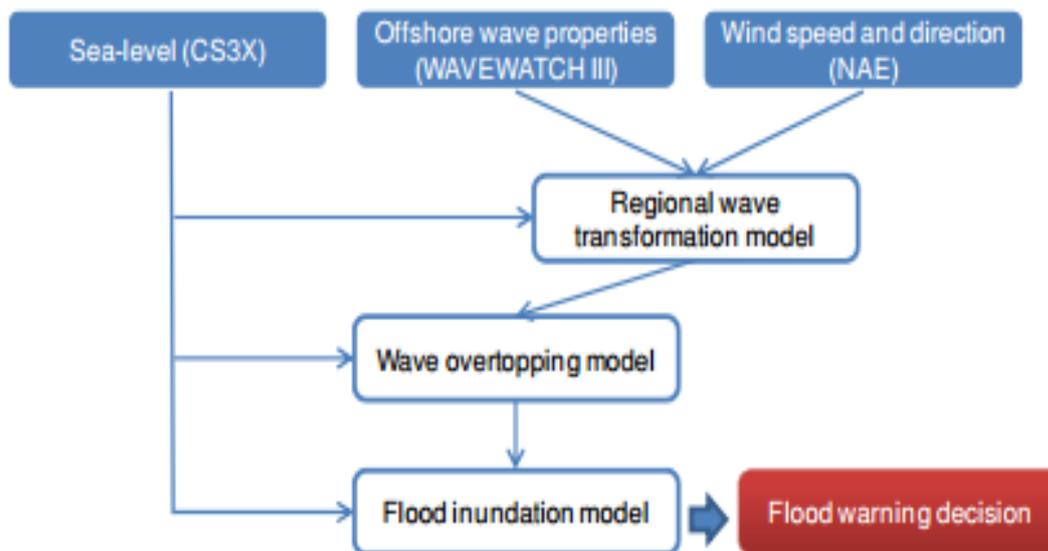
No one numerical model is capable of simulating all of the processes that drive coastal flood risk simultaneously. The development of regional coastal flood forecasting systems therefore normally involves the development and use of a range of models and data inputs. The cumulative results from these components are then drawn together to forecast the expected consequences on land.

The starting point for most coastal flood forecasting systems in Ireland and the UK is 36 hour forecasts of sea-level, offshore wave conditions and wind conditions provided by the Storm Tide Forecasting Service (STFS), run by the UK Met Office. These forecasts comprise of the following components:

- **Sea-level and storm surge** magnitude is currently forecasted 36 hours into the future 4 times a day using the 12km resolution CS3X model developed by the National Oceanographic Centre (NOC) in the UK. This model uses meteorological data provided by the Met Office's 12km grid North Atlantic European (NAE) weather forecast model. Here there is potential to tie into the Storm Surge model developed by the OPW instead of being reliant on NOC data. The OPW Storm surge model currently forecasts 65 hours in advance at low resolution in Clew bay, but only for the winter and autumn months. It would potentially reduce that cost of purchasing data from the Met office as storm and sea level inputs could be obtained from the storm surge model.
- **Offshore wave height**, period and direction are also currently forecasted 36 hours into the future 4 times a day using the 12km resolution WAVEWATCH III model run by the UK Met Office. This model is also forced using weather data from the NAE model.

- **Wind speed and direction** are currently forecasted 36 hours into the future 4 times a day using the NAE model.

Figure 7-8: Schematic of development of a wave overtopping model



Whilst the information provided through the STFS is a critical component of any coastal regional coastal flood forecasting system constructed for Ireland and the UK, this information is only a component part. In particular, the wave information provided is for offshore waves only; no specific information is provided in terms of nearshore wave conditions, wave overtopping or flood inundation. To develop a regional system that accounts for these processes, it is normally the case that three additional model components are required to be constructed, calibrated and validated. These include:

- **A spectral wave transformation model**, used to transform offshore waves from the WAVEWATCH III model to the toe of beaches and flood defences.
- **Wave overtopping models**, used to compute wave overtopping as a function of sea level (from CSX3), nearshore wave height, period and direction (from the WM model) and beach and defence geometry.
- **A flood inundation model**, used to evaluate how flood water originating from still water flooding and/or wave overtopping will spread on the land.

Each of these carries with it a level of uncertainty. Combining the results of these models for forecast therefore suffers from a cumulative uncertainty effect. Rather than running these models live for forecasting purposes, they are used to pre-compute the flooding consequences associated with a wide range of potential combinations of key storm driving variables such as sea-level, offshore wave properties and wind conditions. For instance, recent flood forecasting systems have included the simulation of upwards of 10,000 ensemble combinations of these variables. These pre-computed simulations are then used to develop look-up tables that relate offshore forecasts of sea-level, wind and wave conditions (supplied by the UK Met Office) to the expected flooding consequences on land. This information is then compared to pre-determined thresholds for operational methods, and the issuing of Flood Alerts, Flood Warnings. With this information, a Flood Warning Duty Officer can then decide what action should be taken.

There has been one wave overtopping model developed in Ireland (Tidewatch and Triton system by Dublin County Council) so costs for the development of a wave overtopping model is unknown. Indicative costs have been estimated at between €20,000 and €70,000 capital investment, plus yearly running costs between €14,000-€40,000 depending on the complexity of the system and the data providers. This is equates to between €320,000 - €930,000 net present value.

7.5 Conclusion

The potential for flood forecasting systems have been explored and a summary of results is found in Table 7-2 . It details the proposed system, limitation and the expected benefit to cost ratio of the preferred flood forecasting system.

Table 7-2: Summary of Flood Forecasting Potential

Fluvial forecasting systems		
	Proposed system	Limitations
Ballyhaunis	No system required as currently no risk of fluvial flooding.	-
Tuam	No system required as currently no risk of fluvial flooding.	-
Corrofin	Level triggers along the River Clare system	A flood warning system for the entire Clare catchment can provide warning to residents in Corrofin. This system is currently unviable with a BCR of 0.52
Claregalway	Level triggers along the River Clare system	A flood warning system for the entire Clare catchment can provide warning to residents in Claregalway. This system is currently unviable with a BCR of 0.52
Galway City	Level triggers along the River Clare system	A flood warning system for the entire Clare catchment can provide warning to residents in Galway City. This system is currently unviable with a BCR of 0.52
Oughterard	No system currently feasible due to catchment characteristics.	No - the current flow conditions and flood dynamics indicate that a flood forecast system is not viable. Small ungauged catchment is responsible for flooding in Oughterard. The level of accuracy is not attainable given the size of the catchment. The estimated costs due to property damage for a 1% AEP flood event is €12,263 therefore the costs of developing a dedicated flood warning system will not be cost effective
Coastal forecasting systems		
	Proposed system	Limitations - Benefit to cost ratio
Galway City and Salthill	Tie into the national storm surge model developed by the OPW for Galway City and wave overtopping model is required for Salthill	There are no additional costs associated with this however calibration exercises may be required against the tidal gauge in Galway City. For Salthill it will depend on the available data sources. Estimated cost between €320,000 - €930,000, giving a BCR of less than 0.1.

8 Conclusions

The preliminary options investigations have assessed flood risk management methods at four spatial scales of assessment; the Unit of Management, sub-catchment, AFA and flood cell.

8.1 Unit of Management spatial scale

Methods applicable at the Unit of Management spatial scale are applicable to all AFAs. These methods therefore reflect policy recommendations for spatial planning and future development with respect to flood risk. The general policy objectives are discussed in detail in Section 5 and Section 6. A summary how these objectives should be applied within each AFA is provided in Table 8-1 with regards to spatial planning and Table 8-2 with regards to SUDS suitability

Table 8-1: Spatial planning considerations taking into account current and future risk

	Current flood risk	Future flood risk
Ballyhaunis	One area to the south, currently zones for Industry shows some risk of flooding from a 1% flood event. Generally, all other land at flood risk is zoned for water compatible uses such as agricultural & amenity	Flood Zone B increases considerably in MRFS. It would be appropriate to undertake an SFRA to ensure the development plan zoning objectives are sustainable in the future and consider re-zoning land which is within future Flood Zones
Claregalway	Currently a scheme is under construction for Claregalway. Policies for development in areas protected by the proposed flood alleviation scheme should be put in place to manage the residual risks, should structural flood defences fail or be exceeded (overtopped).	No Future flood mapping available for Claregalway
Corrofin	No development plan available for Corrofin however Flood Zone A & B extents do show inundation of properties in the Ballybanagher area only	A limited increase in the future across Corrofin with slight increases in the extent of Flood Zones A & B.
Galway City	Generally, lands within Flood Zone A & B comprise of existing development or water compatible uses however areas zoned for mixed/general community services and strategic reserve are at risk of flooding and encroach Flood Zones A & B (tidal flooding).	Generally, a limited increase in flood risk in the future is identified however existing residential properties west of the city centre show increased risk of flooding from a 0.1% AEP MRFS tidal flood event. Some light residential zoned lands along the northern section of the city show increased risk of flooding.
Oughterard	Generally, all land at flood risk is zoned for water compatible uses, however there is an area on the left bank of the Owenriff river that is zoned in conflict with Flood Zone B.	A limited increase in the future across Oughterard with slight increases in the extent of Flood Zones A & B.
Tuam	Generally, lands within flood zones are zoned as water compatible however significant areas, to the west and east of the town centre are zoned as residential (R2) and existing residential within Flood Zone A	A limited increase in the future across Tuam with slight increases in the extent of Flood Zones A & B.

Table 8-2: Applicability of SUDS with the AFA

AFA	Applicability of SUDS
Ballyhaunis	Infiltration treatment likely to be appropriate across the AFA. Potential for regionally based attenuation areas has been identified.
Claregalway	Low infiltration capacity indicated, although pockets of well-draining soil are identified. Potential for regionally based attenuation areas has been identified.
Corrofin	Infiltration treatment likely to be appropriate across the AFA. Limited potential for regionally based attenuation.
Galway City	Infiltration treatment likely to be appropriate across the AFA, but probably less successful to the north of the N6. Limited potential for regionally based attenuation, but opportunities for SuDS to be sought on a site by site basis.
Oughterard	Infiltration treatment likely to be appropriate across the AFA. Potential for regionally based attenuation areas has been identified.
Tuam	Infiltration treatment likely to be appropriate across the AFA. Potential for regionally based attenuation areas has been identified.

8.2 Sub-catchment spatial scale

Methods applicable at the sub-catchment spatial scale provide benefit to multiple AFAs, most commonly sitting on the same watercourse and so hydraulically linked. In UoM 35 these methods consist of flood forecasting and warning systems. Full details of the review of viable systems is provided in Section 7 and a summary of the findings are provided in Table 8-3.

Table 8-3: Recommendations for flood forecasting systems

Fluvial forecasting systems	
Ballyhaunis	No system required as currently no risk of fluvial flooding.
Tuam	No system required as currently no risk of fluvial flooding.
Corrofin	A flood warning system for the River Clare / Corrib based on the existing gauged network is technically viable but currently is not economically viable.
Claregalway	A flood warning system for the River Clare / Corrib based on the existing gauged network is technically viable but currently is not economically viable.
Oughterard	The current flood risk is on a small tributary and it is not technically viable to attain the advance warning times.
Galway City	A flood warning system for the River Clare / Corrib based on the existing gauged network is technically viable but currently is not economically viable.
Coastal forecasting system	
Galway City and Salthill	By tying into the national storm surge model developed by the OPW warning can be provided in Galway City. A wave overtopping model is required for Salthill

8.3 AFA and flood cell spatial scales

Methods applicable at either the AFA or flood cell spatial scale provide flood risk mitigation to a single AFA. Structural flood risk management methods have been considered at the AFA spatial scale initially with a flood cell spatial scale considered only where no viable methods are identified at the AFA scale. Structural methods are applicable in those AFAs where there is flood risk to properties in the 1% AEP fluvial or 0.5% AEP tidal events; these are Coolaney, Sligo and Rathbrangan. Full details of these investigations are provided in the AFA specific Preliminary Options Reports (Volume 2). No economically viable methods were identified but the technically viable methods investigated within each AFA are summarised in Table 8-4.

Table 8-4: Technically viable structural flood risk management methods

AFA Name	Options for screening	Conclusion¹⁵
Corrofin (Volume 2b)	Construction of raised embankments This option will construct raised embankments around all 5 properties.	Not economically viable BCR 0.49
Galway City (Volume 2c)	Flood Containment This option involves the placement of quay defence walls in order to protect against the 0.5% AEP design event with an average wall height of 1.2m required. This includes a freeboard allowance of 0.3m. The quay walls would extend from the dock continuing along Long Walk and Spanish Arch. The properties in the Claddagh area, along Grattan road and Father Griffin would be provided protection also by placing a quay wall along the Claddagh basin and Nimmo's pier. Property defence line protection and localised raising in Salthill.	Economically Viable (BCR 1.0)
Oughterard (Volume 2d)	Upstream Storage This option would involve creating an upstream storage area by the construction of a storage embankment and hydrobrake.	Not economically viable - BCR 0.08
	Flow Diversion Channel This option will create a 200m bypass channel from the Tonweeroe to the Owenriff	Not economically viable - BCR 0.03

¹⁵ BCR - Benefit Cost Ratio. A ratio greater than 1 was needed to allow an option to be developed further.
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	Embankment / Walls A 320m embankment and 30m (1.2high) wall to cut off the flow routes to the properties	Not economically viable - BCR 0.05
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Non-structural methods are applicable at both the AFA and flood cell spatial scales. Full details of the suite of non-structural methods considered are provided in Section 4. Table 8-5 presents recommendations for individual property protection and Table 8-6 details considerations for maintenance regimes within each AFA.

Table 8-5: Recommendations for individual property protection

AFA Name	No. of properties with depths:		Recommendations
	< 600mm	> 600mm	
Corrofin (Volume 2b)	2	1	The costs of a community scale option are prohibitive for Corrofin given the current level of flood risk. Individual property methods should be considered.
Galway City (Volume 2c)	301	11	The number of properties at risk of flooding means a community scale option will be more cost effective in Galway City
Oughterard (Volume 2i)	4	0	The costs of a community scale option are prohibitive for Oughterard given the current level of flood risk. Individual property methods should be considered.

Table 8-6: Maintenance Considerations within each AFA

AFA Name	Recommendations
Ballyhaunis	This AFA is covered by Corrib-Clare Arterial drainage scheme and should be subject to regular maintenance under the requirements of the Arterial Drainage Act. Consideration should be given to the key structures that have been identified as susceptible to blockage.
Tuam	This AFA is covered by Corrib-Clare Arterial drainage scheme and should be subject to regular maintenance under the requirements of the Arterial Drainage Act. Consideration should be given to the key structures that have been identified as susceptible to blockage.
Corrofin	This AFA is covered by Corrib-Clare Arterial drainage scheme and should be subject to regular maintenance under the requirements of the Arterial Drainage Act. Currently a scheme built under the same act.
Claregalway	This AFA is covered by Corrib-Clare Arterial drainage scheme and should be subject to regular maintenance under the requirements of the Arterial Drainage Act.
Oughterard	This AFA is covered by Corrib-Clare Arterial drainage scheme and should be subject to regular maintenance under the requirements of the Arterial Drainage Act.
Galway City	The OPW, Lough Corrib Trustees, Galway Port and Galway City Council have all responsibility in some part of Galway City. Engagement between these groups is important for maintenance regimes to be effective. Consideration should be given by all parties to incorporating the key structures identified into a priority monitoring schedule ahead of the formalisation of maintenance responsibilities for these watercourses.

A Breakdown of risk receptors

Table A-1: Flood risk to receptors in Ballyhaunis

Risk Type	Receptor	Ballyhaunis				
		10% AEP	1% / 0.5% AEP	0.1% AEP	1% AEP MRFS	1% AEP HEFS
Social	Residential property	0	0	0	0	0
	School	0	0	0	0	0
	Health centre	0	0	0	0	0
	Nursing home	0	0	0	0	0
	Public residential care home	0	0	0	0	0
	Social infrastructure	0	0	0	0	0
	Hospital	0	0	0	0	0
	Gardai station	0	0	0	0	0
	Fire station	0	0	0	0	0
	Civil defence HQ	0	0	0	0	0
Social amenity sites	Not at Risk	Not at Risk	Not at Risk	Not at Risk	Not at Risk	
Environment	IED / IPPC sites	0	0	0	0	0
	WFD Annex IV sites	At Risk	At Risk	At Risk	At Risk	At Risk
	NHAs	Not at Risk	Not at Risk	Not at Risk	Not at Risk	Not at Risk
	pNHAs	Not at Risk	Not at Risk	Not at Risk	Not at Risk	Not at Risk
	SACs	Not at Risk	Not at Risk	Not at Risk	Not at Risk	Not at Risk
	SPAs	Not at Risk	Not at Risk	Not at Risk	Not at Risk	Not at Risk
Cultural heritage	National monument	0	0	0	0	0
	UNESCO heritage site	0	0	0	0	0
	Museum/ gallery	0	0	0	0	0
	NIAH building	0	0	0	0	0
Economy	Airport	0	0	0	0	0
	Train station	0	0	0	0	0
	Railway line (km)	0.00	0.00	0.00	0.00	0.00
	National roads (km)	0.00	0.00	0.00	0.00	0.00
	Water treatment plant	0	0	0	0	0
	Utilities	0	0	0	0	0
	Commercial building	0	0	0	0	0

Table A-2: Flood risk to receptors in Tuam

Risk Type	Receptor	Tuam				
		10% AEP	1% / 0.5% AEP	0.1% AEP	1% AEP MRFS	1% AEP HEFS
Social	Residential property	0	0	92	4	38
	School	0	0	0	0	0
	Health centre	0	0	0	0	0
	Nursing home	0	0	0	0	0
	Public residential care home	0	0	0	0	0
	Social infrastructure	0	0	0	0	0
	Hospital	0	0	0	0	0
	Gardai station	0	0	0	0	0
	Fire station	0	0	0	0	0
	Civil defence HQ	0	0	0	0	0
Social amenity sites	Not at Risk	Not at Risk	Not at Risk	Not at Risk	Not at Risk	
Environment	IED / IPPC sites	0	0	0	0	0
	WFD Annex IV sites	At Risk	At Risk	At Risk	At Risk	At Risk
	NHAs	Not at Risk	Not at Risk	Not at Risk	Not at Risk	Not at Risk
	pNHAs	Not at Risk	Not at Risk	Not at Risk	Not at Risk	Not at Risk
	SACs	Not at Risk	Not at Risk	Not at Risk	Not at Risk	Not at Risk
	SPAs	Not at Risk	Not at Risk	Not at Risk	Not at Risk	Not at Risk
Cultural heritage	National monument	1	1	1	1	1
	UNESCO heritage site	0	0	0	0	0
	Museum/ gallery	0	0	0	0	0
	NIAH building	0	0	0	0	0
Economy	Airport	0	0	0	0	0
	Train station	0	0	0	0	0
	Railway line (km)	0.00	0.69	1.61	1.03	1.19
	National roads (km)	0.00	0.00	0.00	0.00	0.00
	Water treatment plant	0	0	0	0	0
	Utilities	0	0	1	1	1
	Commercial building	0	1	9	3	3

Table A-3: Flood risk to receptors in Corrofin

Risk Type	Receptor	Corrofin				
		10% AEP	1% / 0.5% AEP	0.1% AEP	1% AEP MRFS	1% AEP HEFS
Social	Residential property	2	3	9	5	6
	School	0	0	0	0	0
	Health centre	0	0	0	0	0
	Nursing home	0	0	0	0	0
	Public residential care home	0	0	0	0	0
	Social infrastructure	0	0	0	0	0
	Hospital	0	0	0	0	0
	Gardai station	0	0	0	0	0
	Fire station	0	0	0	0	0
	Civil defence HQ	0	0	0	0	0
Social amenity sites	Not at Risk	Not at Risk	Not at Risk	Not at Risk	Not at Risk	
Environment	IED / IPPC sites	0	0	0	0	0
	WFD Annex IV sites	At Risk	At Risk	At Risk	At Risk	At Risk
	NHAs	Not at Risk	Not at Risk	Not at Risk	Not at Risk	Not at Risk
	pNHAs	Not at Risk	Not at Risk	Not at Risk	Not at Risk	Not at Risk
	SACs	Not at Risk	Not at Risk	Not at Risk	Not at Risk	Not at Risk
	SPAs	Not at Risk	Not at Risk	Not at Risk	Not at Risk	Not at Risk
Cultural heritage	National monument	0	0	0	0	0
	UNESCO heritage site	0	0	0	0	0
	Museum/ gallery	0	0	0	0	0
	NIAH building	0	0	0	0	0
Economy	Airport	0	0	0	0	0
	Train station	0	0	0	0	0
	Railway line (km)	0.00	0.00	0.00	0.00	0.00
	National roads (km)	0.00	0.00	0.00	0.00	0.00
	Water treatment plant	0	0	0	0	0
	Utilities	0	0	0	0	0
	Commercial building	0	0	0	0	0

Table A-4: Flood risk to receptors in Oughterard

Risk Type	Receptor	Oughterard				
		10% AEP	1% / 0.5% AEP	0.1% AEP	1% AEP MRFS	1% AEP HEFS
Social	0	0	4	21	4	7
	0	0	0	0	0	0
	0	0	0	0	0	0
	0	0	0	0	0	0
	0	0	0	0	0	0
	0	0	0	0	0	0
	0	0	0	0	0	0
	0	0	0	0	0	0
	0	0	0	0	0	0
	0	0	0	0	0	0
	Not at Risk	Not at Risk	Not at Risk	At Risk	Not at Risk	At Risk
Environment	0	0	0	0	0	0
	At Risk	At Risk	At Risk	At Risk	At Risk	At Risk
	Not at Risk	Not at Risk	Not at Risk	Not at Risk	Not at Risk	Not at Risk
	Not at Risk	Not at Risk	Not at Risk	Not at Risk	Not at Risk	Not at Risk
	Not at Risk	Not at Risk	Not at Risk	Not at Risk	Not at Risk	Not at Risk
	Not at Risk	Not at Risk	Not at Risk	Not at Risk	Not at Risk	Not at Risk
Cultural heritage	0	0	0	0	0	0
	0	0	0	0	0	0
	0	0	0	0	0	0
	0	0	0	0	0	0
Economy	0	0	0	0	0	0
	0	0	0	0	0	0
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0	0	0	0	0	0
	0	0	0	0	0	0
	0	0	0	2	0	1

Table A-5: Flood risk to receptors in Galway City (Coastal)

Risk Type	Receptor	Galway city				
		10% AEP	1% / 0.5% AEP	0.1% AEP	1% AEP MRFS	1% AEP HEFS
Social	Residential property	99	678	934	1266	2525
	School	0	0	0	0	0
	Health centre	0	0	0	0	0
	Nursing home	0	0	0	0	0
	Public residential care home	0	0	0	0	0
	Social infrastructure	0	2	2	2	2
	Hospital	0	0	0	0	0
	Gardai station	0	0	0	0	0
	Fire station	0	1	1	1	1
	Civil defence HQ	0	1	1	1	1
	Social amenity sites	At Risk	At Risk	At Risk	At Risk	At Risk
Environment	IED / IPPC sites	0	0	0	0	0
	WFD Annex IV sites	At Risk	At Risk	At Risk	At Risk	At Risk
	NHAs	Not at Risk	Not at Risk	Not at Risk	Not at Risk	Not at Risk
	pNHAs	Not at Risk	Not at Risk	Not at Risk	Not at Risk	Not at Risk
	SACs	At Risk	At Risk	At Risk	At Risk	At Risk
	SPAs	At Risk	At Risk	At Risk	At Risk	At Risk
Cultural heritage	National monument	3	4	6	10	13
	UNESCO heritage site	0	0	0	0	0
	Museum/ gallery	0	0	0	0	0
	NIAH building	0	0	0	0	0
Economy	Airport	0	0	0	0	0
	Train station	0	0	0	0	0
	Railway line (km)	0.08	0.08	0.09	0.09	0.10
	National roads (km)	0.00	0.00	0.00	0.00	0.00
	Water treatment plant	0	0	0	0	0
	Utilities	0	0	0	1	1
	Commercial building	70	508	626	724	1051

Table A-6: Flood risk to receptors in Galway City (Fluvial)

Risk Type	Receptor	Galway city				
		10% AEP	1% / 0.5% AEP	0.1% AEP	1% AEP MRFS	1% AEP HEFS
Social	Residential property	16	99	895	504	648
	School	0	0	2	0	1
	Health centre	0	0	0	0	0
	Nursing home	0	0	0	0	0
	Public residential care home	0	0	0	0	0
	Social infrastructure	0	0	2	2	2
	Hospital	0	0	0	0	0
	Gardai station	0	0	0	0	0
	Fire station	0	0	1	1	1
	Civil defence HQ	0	0	1	1	1
	Social amenity sites	At Risk	At Risk	At Risk	At Risk	At Risk
Environment	IED / IPPC sites	0	0	0	0	0
	WFD Annex IV sites	At Risk	At Risk	At Risk	At Risk	At Risk
	NHAs	Not at Risk	Not at Risk	Not at Risk	Not at Risk	Not at Risk
	pNHAs	Not at Risk	Not at Risk	Not at Risk	Not at Risk	Not at Risk
	SACs	At Risk	At Risk	At Risk	At Risk	At Risk
	SPAs	Not at Risk	Not at Risk	Not at Risk	Not at Risk	Not at Risk
Cultural heritage	National monument	1	1	5	3	7
	UNESCO heritage site	0	0	0	0	0
	Museum/ gallery	0	0	0	0	0
	NIAH building	0	0	0	0	0
Economy	Airport	0	0	0	0	0
	Train station	0	0	0	0	0
	Railway line (km)	0.00	0.00	0.00	0.00	0.00
	National roads (km)	0.00	0.00	3.91	0.00	0.26
	Water treatment plant	0	0	0	0	0
	Utilities	0	0	0	0	0
	Commercial building	16	81	627	350	489



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**Corrofin Preliminary Options
Report
Volume 2a (1 of 3)**

**UoM 30 - Corrib-
Western CFRAM**

Final
September 2016



Office of Public Works
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**WESTERN
CFRAM
STUDY**
CATCHMENT FLOOD RISK
ASSESSMENT AND MANAGEMENT

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This report describes work commissioned by The Office of Public Works, by a letter dated (28/07/11). The Office of Public Works' representative for the contract was Rosemarie Lawlor. Joanne Flanagan of JBA Consulting carried out this work.

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Glossary

AAD.....	Average annual damages
AEP.....	Annual exceedence probability
AFA.....	Area for further assessment
BCR	Benefit cost ratio
CC.....	Climate change
CFRAM	Catchment-based flood risk assessment and management study
CPI.....	Consumer price index
DEM	Digital elevation model (Includes surfaces of structures, vegetation, etc)
DTM	Digital terrain model ('bare earth' model; does not include surfaces of structures, vegetation, etc
FHRC	Flood Hazard Research Centre
FRISM.....	Flood risk metric tool
FRM	Flood risk management
FRMP.....	Flood risk management plan
FRR.....	Flood risk review
GIS.....	Geographical information system
HEFS	High-end future scenario
HPW.....	High priority watercourse
IROPI	Imperative Reasons of Overriding Public Interest
LA.....	Local authority
LAP	Local area plan
LIDAR	Light detection and ranging
MCA	Multi-criteria analysis
MCM	Multi-coloured manual
MPW	Medium priority watercourse

MRFS.....	Mid-range future scenario
NDHM	National digital height model
OPW	Office of Public Works
OSi.....	Ordnance Survey Ireland
PCD	Public consultation day
POR	Preliminary options report
PPP.....	Purchase price parity
PVd.....	Present value damages
SAC.....	Special area of conservation
SEA.....	Strategic environmental assessment
SPA.....	Special protection area
SSA.....	Spatial scale of assessment
STP	Social time preference
STPDR.....	Social time preference discount rate
SUDS.....	Sustainable Urban Drainage Systems
UK	United Kingdom
UoM	Unit of management
WCFRAM.....	Western catchment-based flood risk assessment and management study
WTP	Water treatment plant
WWTW.....	Wastewater treatment works

1 Introduction

1.1 Scope of report

This report details the preliminary options investigation for addressing flood risk in Corrofin. The report should be read in conjunction with the Preliminary Options Investigation General Methods Report.

The Preliminary Options Investigations represent the next phase of the Western CFRAM study. The work already completed has identified the scale and extent of flood risk within Corrofin. Reports which are relevant to this AFA are:

- Western CFRAM Flood Risk Review Report
- Western CFRAM UoM 30 Inception Report
- Western CFRAM UoM 30 Hydrology Report
- Western CFRAM UoM 30 Hydraulic Modelling Report
- Western CFRAM UoM 30 - Corrib Hydraulic Modelling Report: Volume 2b - Corrofin
- Western CFRAM UoM 30 Hydraulic Modelling Report: Volume 3 - Flood Risk maps

Using the work already completed, the OPW have identified a requirement to develop methods to manage flood risk, both now and into the future, within Corrofin. The scope of this study is to identify a preferred flood risk management option for Corrofin.

The work completed includes the screening of possible methods to identify technically feasible and economically viable structural and non-structural methods to manage flood risk sustainably. From these, preferred options have been identified, consulted on, and appraised against societal, environmental and cost criteria to identify a single recommended option. The final recommendations from this study will feed into the overarching Flood Risk Management Plan for Corrofin.

1.2 Flood risk overview

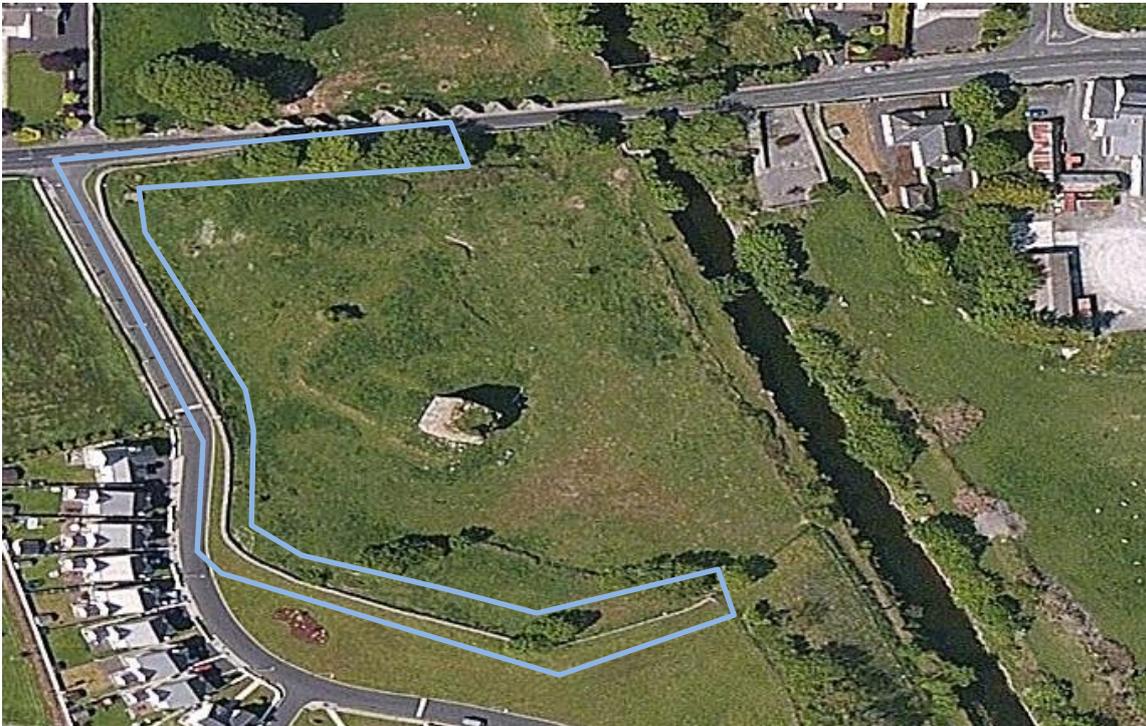
The River Clare, through the village of Corrofin, has been deepened by the OPW Arterial Drainage works and is defended by earthen embankments, shown in Figure 1-1 below. These embankments have been classified as informal ineffective defences as they have large gaps and do not tie in with high ground at all relevant locations. There is approximately 5km of earthen embankments on the right bank and 4km on the left bank, where there is a large gap in embankment to allow for the Grange River to join the River Clare. These embankments protect farm land rather than properties in the case of a flood event.

There is also a substantial wall located some distance from the River Clare channel in the village of Corrofin, which has the potential to be bypassed. This informal ineffective defence is shown in Figure 1-2 below.

Figure 1-1: Earthen embankments along River Clare



Figure 1-2: Informal ineffective wall at Castlegrounds, Corrofin (Source: Bingmaps.com)



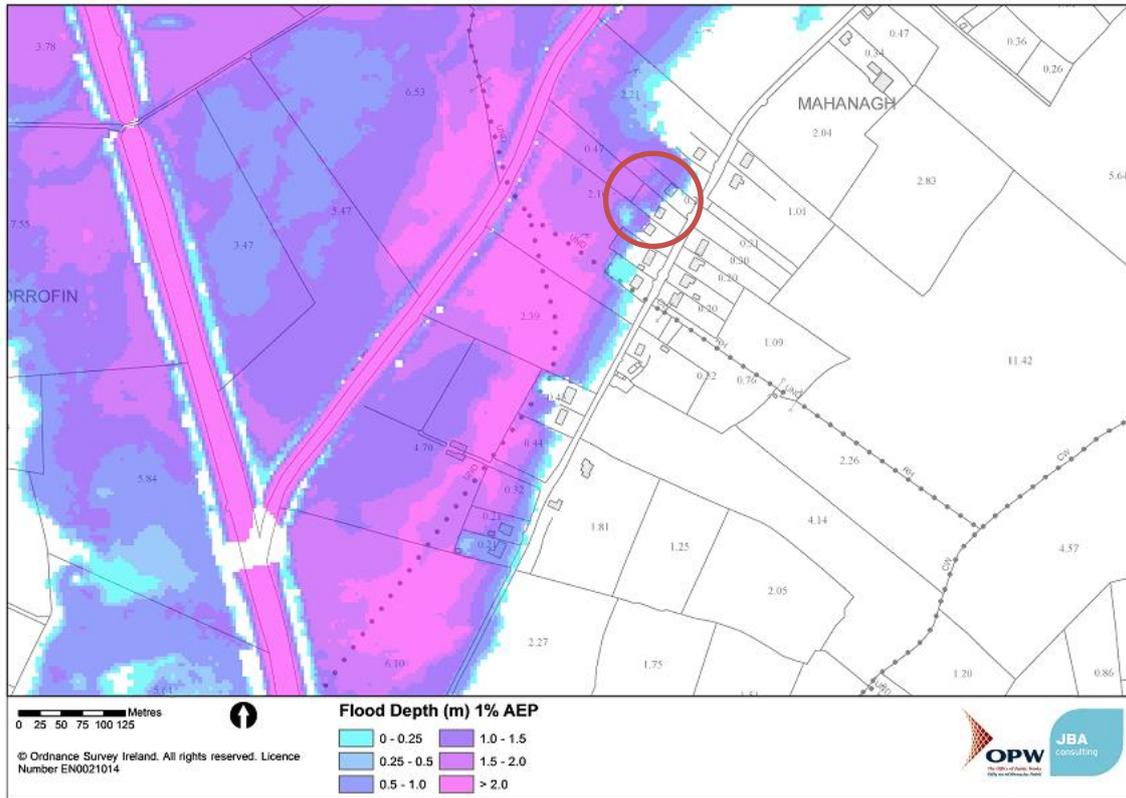
1.2.1 Current flood risk

There is one area within Corrofin where flooding in the current 1% AEP fluvial event is predicted to affect properties from the Grange River, due the Clare River backing up; these are located on an un-named road in the Ballybanagher area of Corrofin. Figure 1-3 illustrates flood risk in the

Ballybanagher area. Deepening works have been completed on the River Clare in recent years, however the River Clare overtops its left bank and flood waters flow into the Grange River, adding to the flooding from this source.

The flood risk mechanism in this area is simply the large floodplain filling up to a level to cause flooding to the property. Flood water on the left bank floodplain of the Clare River flows into the River Grange channel and the combined flow comes out of that channel into the area of the properties.

Figure 1-3: Overview of flood risk



The frequency of flooding is high in Corrofin, with the onset of flooding the 10% AEP event. Five properties are impacted. Of the five properties, the three properties highlighted in the circle above have basements. Only one of the three properties highlighted floods to finish floor level (the most northern property) and is shown to be inside in the flood extent. The basement of all three properties flood regularly.

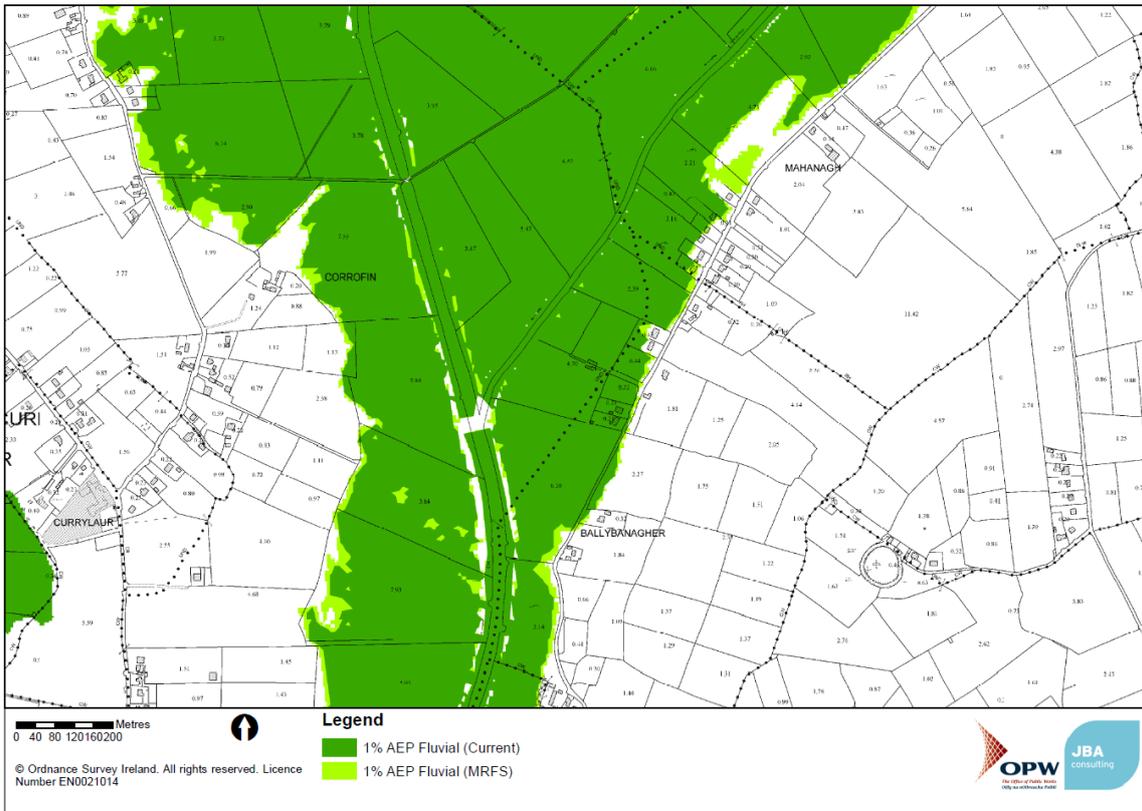
1.2.2 Future flood risk

The future scenarios, based upon the CFRAM specification climate change projections alter the profile of flood risk in Corrofin.

Figure 1-4 below shows the current and medium range future extents for the 1% AEP fluvial design events. The increase in flows of 20% over the course of the next 100 years under the medium range forecast is the main driver of change in flood risk.

There is no introduction of new separate flood risk areas from the 1% AEP MRFS flood event. In the town, mapping indicates that extents increase 5 properties flood in the 1% AEP MRFS event. An increase of flood water depth occurs within the affected properties from the 1% AEP current event.

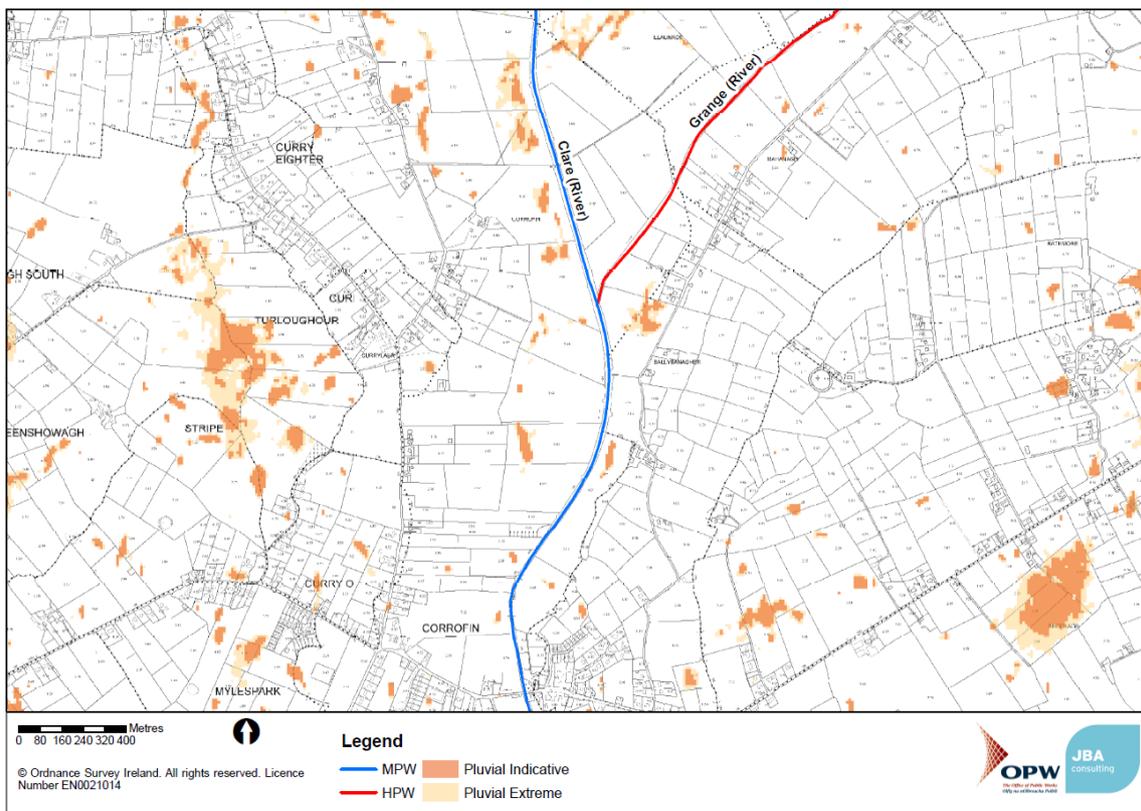
Figure 1-4: Current and future (MRFS) 1% AEP fluvial flood extent - Corrofin



1.2.3 Pluvial, groundwater and sewer flood risk

There is a risk of pluvial flooding in Corrofin. The pluvial risk from the Preliminary Flood Risk Assessment (PFRA) maps is indicated in Figure 1-5 below. This map indicates flooding in the Curry Eighter area of Corrofin. This area is not affected by fluvial flood risk and is a considerable distance from areas affected by fluvial risk as discussed above. The areas of pluvial flooding shown in Figure 1-5 below should be considered as part of any flood management methods.

Figure 1-5: Pluvial flood risk map - Corrofin



There are turloughs in the vicinity of Corrofin village, which could be contributing to elevated river levels within the catchment. Groundwater flooding has been recorded on Floodmaps.ie¹, where four properties in Ardskeaghmore were flooded in 2009. Ardskeaghmore is south east of the village of Corrofin and outside of the AFA boundary. Groundwater flooding is outside the scope of the CFRAM study.

1.3 Economic Benefit

To provide an understanding of the likely scale of a cost beneficial scheme within Corrofin a preliminary assessment of the benefits associated with the protection of properties to the 1% AEP event has been completed. This assumes any scheme will remove all properties from the 1% AEP extents. Full details of the methodology used to determine these benefits is set out in Appendix A.

Damages are based on a short duration flood event and properties are assumed to have a threshold of mean LIDAR based on local observations. Benefits are €360,310 and €1,657,614 in the 1% AEP event for the current and MRFS respectively. Capping reduces damages to €1,087,774 in the MRFS.

Figure 1-1 and Table 1-1 show the number of properties flooding during the different design events for the current and MRFS excluding basement damages. They also show the cumulative damages for each of the return periods which can be presumed to give a rough indication of likely scheme benefits associated with a given standard of protection. Figure 1-8 details the distribution of the damages across the AFA

¹ www.Floodmaps.ie

Figure 1-6: Current and MRFS - Property damages without inclusion of Basements

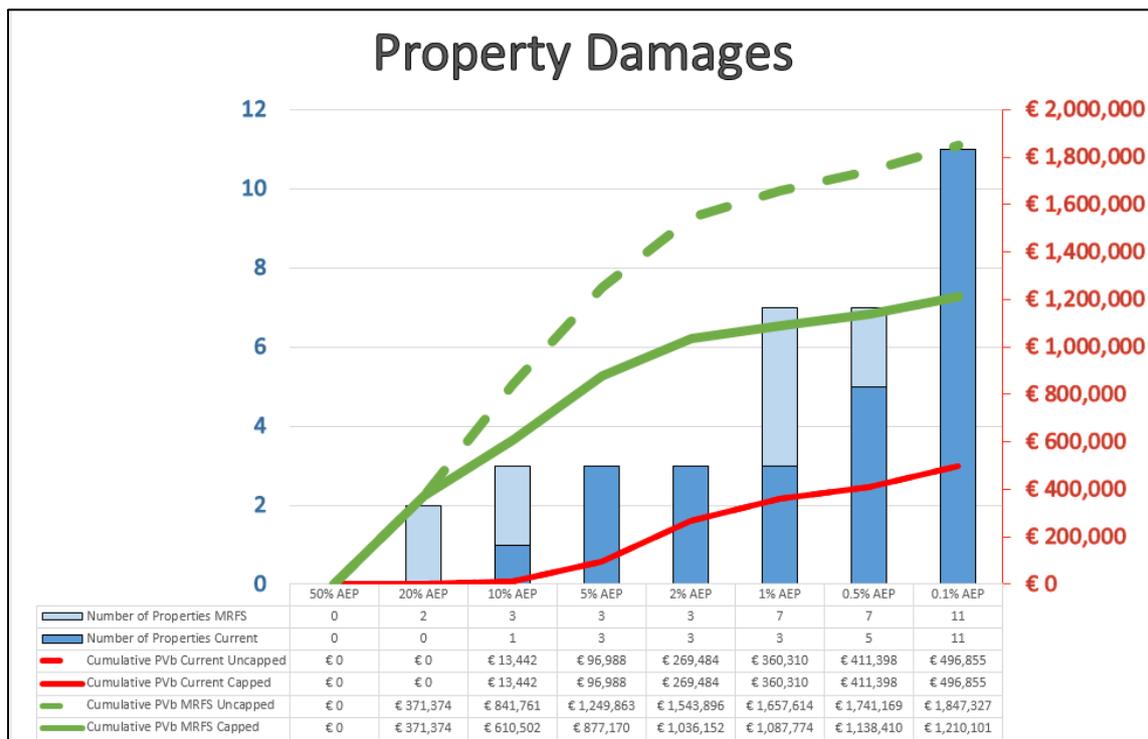


Table 1-1: Flood cell property damages (current and MRFS)

	Return Period (% AEP)							
	50%	20%	10%	5%	2%	1%	0.5%	0.1%
Current								
No. of properties	0	0	1	3	3	3	5	11
PV Damages (€)	0	0	13,442	96,988	269,484	360,310	411,398	496,855
MRFS								
No. of properties	0	2	3	3	3	7	7	11
PV Damages (€)	0	371,374	610,502	877,170	1,036,152	1,087,774	1,138,410	1,210,101

1.3.1 Allowance for basement damages

The FHRC does not give any allowance for basements for residential properties. Three properties to the north have basements. A site visit was carried out and one basement has a gym and heating pumps that they estimate to worth in the region of €30,000 if flooded and a replacement was required. These basements have flooded a number of times in recent years. In order to carry a sensitivity, the threshold level was set to the level of the basements. This would overestimate the damages as the basements are unlikely to give damages to the scale of residential properties however allows the cost of any viable options to be compared against. The damages incorporating these basements is shown in Figure 1-9. This gives damages of €574,933 in the current scenario. In reality damages will sit between €360,310 and €574,933.

Figure 1-7: Property damages allowing for basements

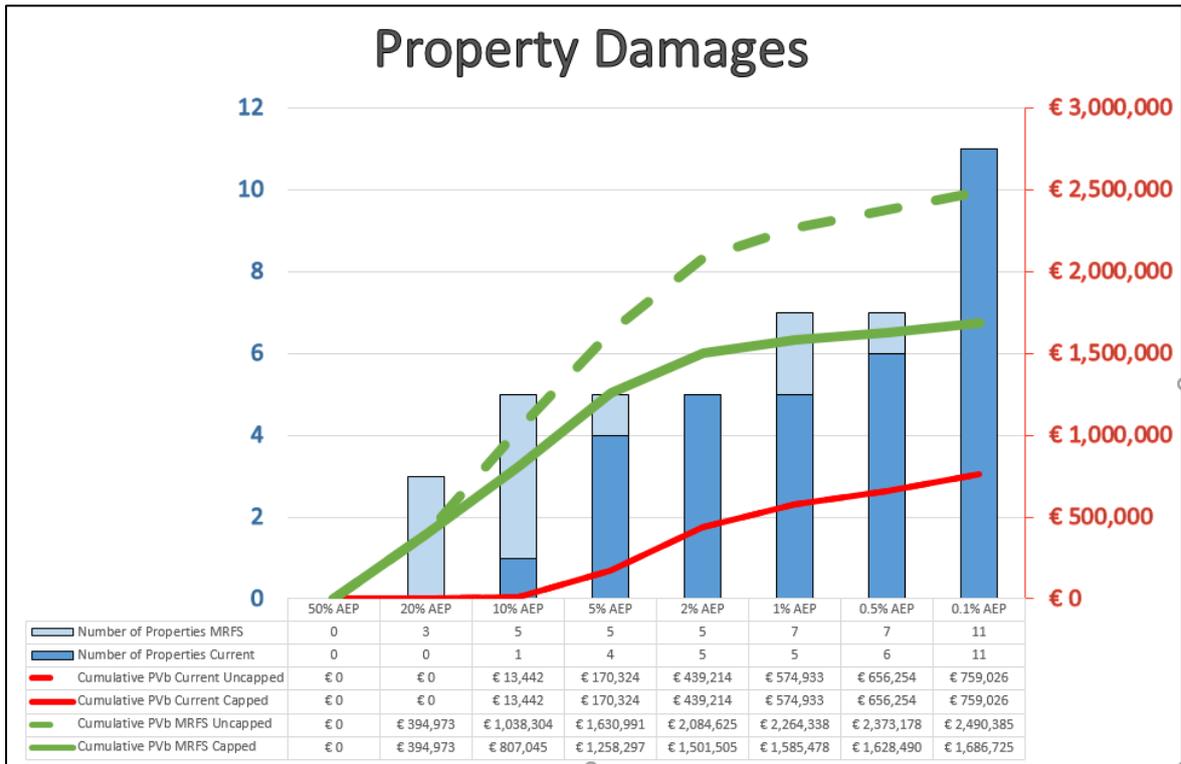


Table 1-2: Flood cell property damages (Current and MRFS) including basement damage

	Return Period (% AEP)							
	50%	20%	10%	5%	2%	1%	0.5%	0.1%
Current								
No. of properties	0	0	1	4	5	5	6	11
PV Damages (€)	0	0	13,442	170,324	439,214	574,933	656,254	759,026
MRFS								
No. of properties	0	3	5	5	5	7	7	11
PV Damages (€)	0	394,973	807,045	1,258,297	1,501,505	1,585,478	1,628,490	1,686,725

Figure 1-8: Distribution of property damages (including basement damages)

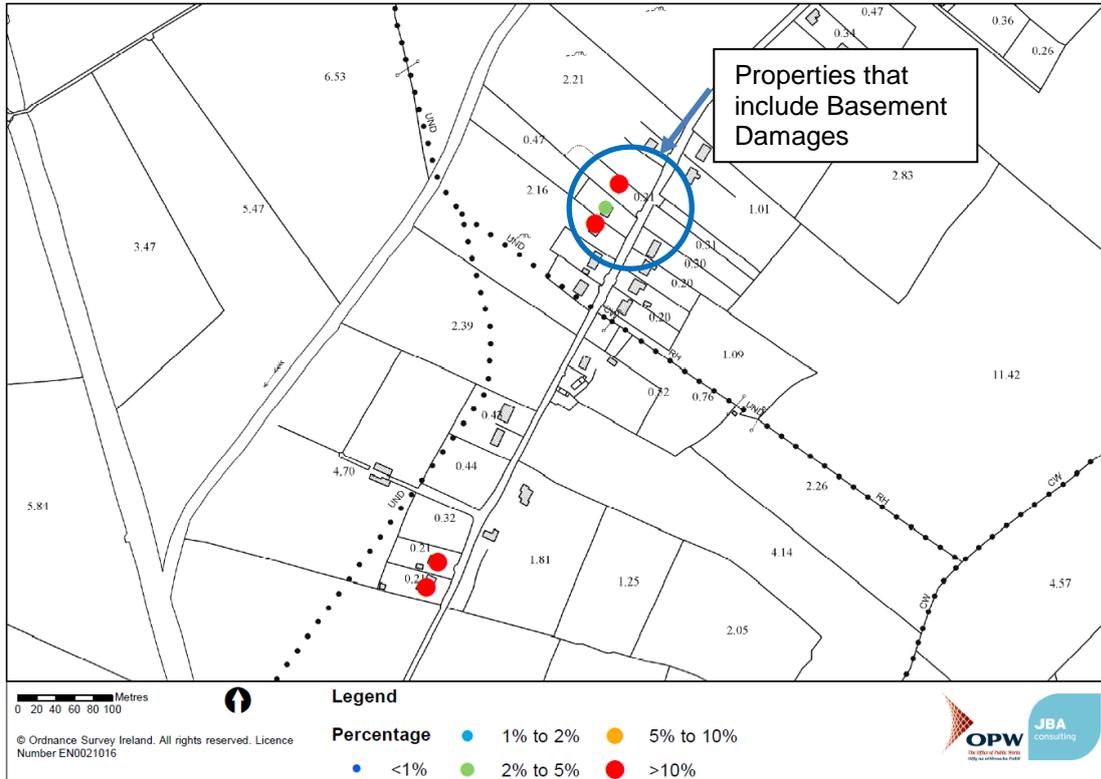
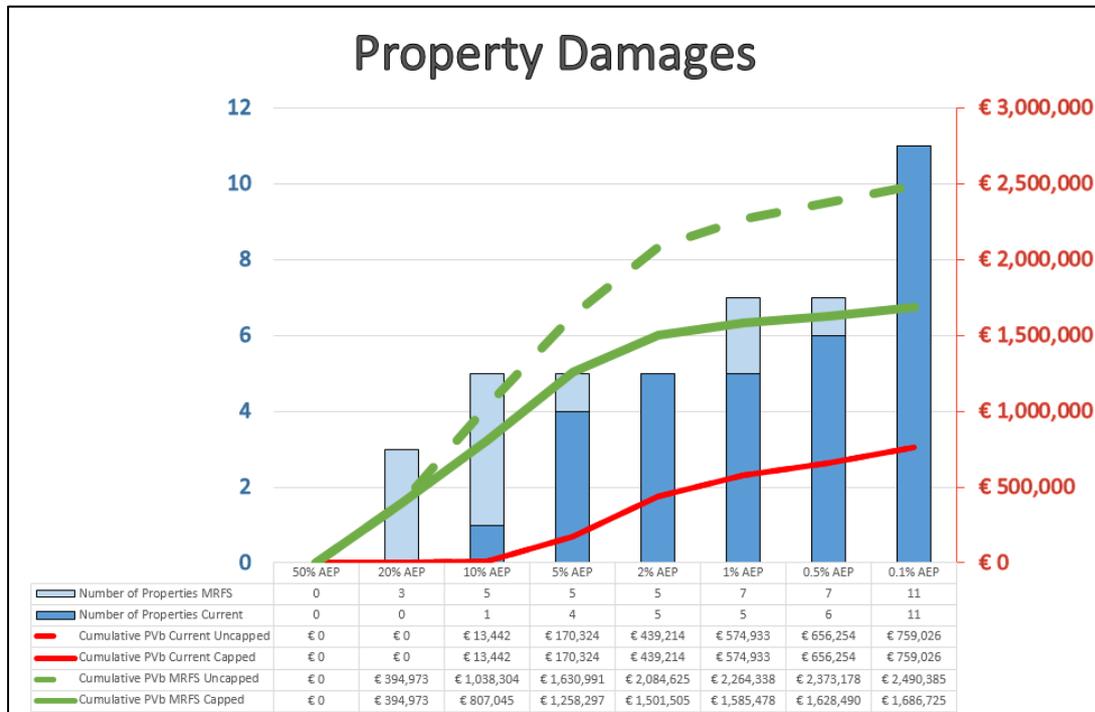


Figure 1-9: Property Damages (Basement Sensitivity)

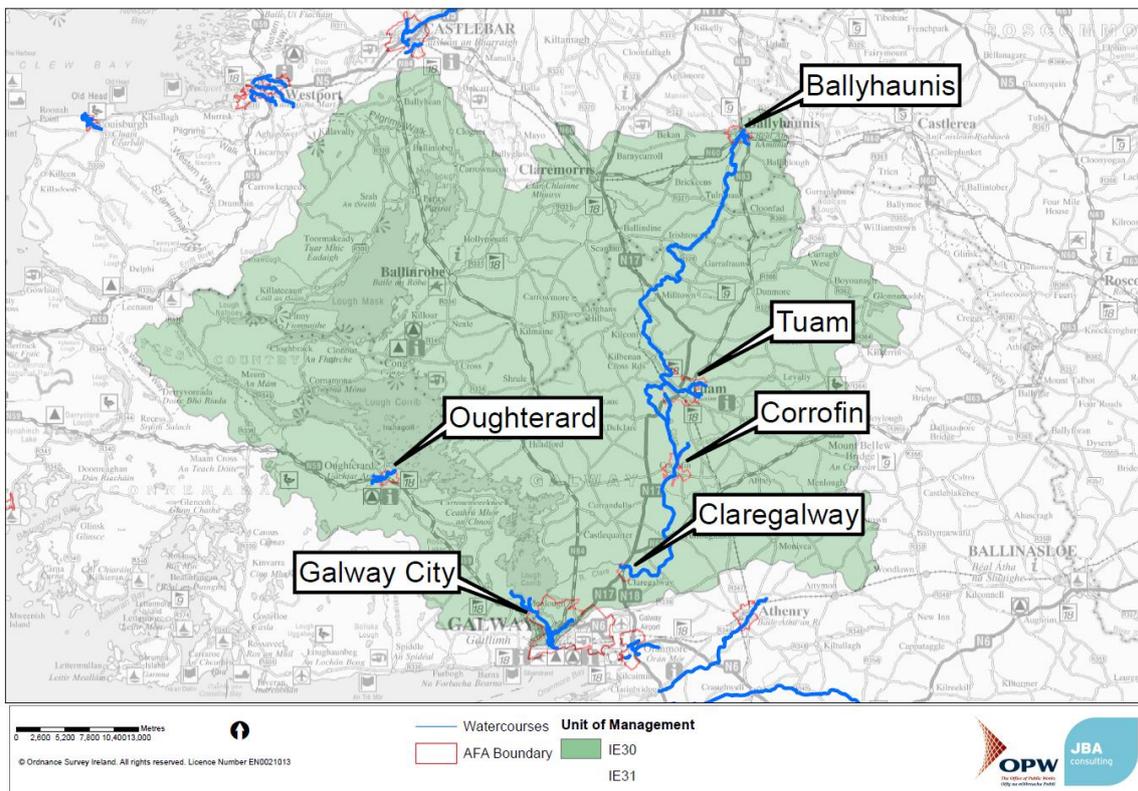


2 Scheme Spatial Scales of Assessment (SSE)

2.1 Overview

This section documents the analysis of spatial scales of assessment and the identification of flood cells for the Corrofin options appraisal. The interactions between flood risk, hydrology, hydraulic, economic, social, cultural and environmental aspects of Corrofin have been considered. Figure 2-1 shows the location of Corrofin in relation to other AFAs within the Corrib Unit of Management (UoM). This section will discuss the hydraulic connectivity of the site with other AFAs and in particular justify where there is no such interconnectivity.

Figure 2-1: AFA's within UoM 30



2.2 Spatial Scales of Methods

2.2.1 Unit of Management Spatial Scale

There are multiple AFAs within the Corrib UoM - namely Galway City, Tuam, Corrofin, Ballyhaunis and Oughterard. Non-structural methods such as planning and development control, SUDs, targeted public awareness campaigns and development of emergency plans will be assessed at the UoM scale in cooperation with the relevant authorities.

2.2.2 Lough Corrib Catchment

Corrofin is located on the Clare River, of which the River Grange joins upstream of the village. There is sufficient land available upstream of Corrofin to effectively store fluvial flood water, however, the local area is prone to groundwater flooding, thus this measure may not be appropriate for Corrofin AFA.

The network of river and lake gauges on the River Clare catchment could be used to form an effective flood forecasting and warning system. A flood forecasting system for Corrofin would need to be incorporated into the Corrib catchment as a whole to be cost beneficial. It would provide the residents with a warning with considerable lead time, due to the nature of the catchment.

2.2.3 AFA Spatial Scale - Corrofin

Localised structural methods will be assessed on an AFA scale. This will include analysing the suitability of flood containment methods, individual property protection etc. Any containment methods in Corrofin will not have an effect on water levels in other AFAs due to the distance of other AFAs away from Corrofin. Corrofin AFA is located on the River Clare, which flows from the River Dargan at Ballyhaunis AFA (55km upstream) to Tuam AFA (13km upstream) and as far as Lough Corrib (27km downstream). The change in water levels at Corrofin will not affect levels in the other AFAs.

The Ballybanagher flood cell of the Corrofin AFA is the only area where properties are currently at risk of fluvial flooding. There are 5 properties at risk of flooding for the current 1% AEP fluvial event at Ballybanagher, while this increases to 7 properties for the MRFS 1% AEP fluvial event.

2.3 Key environmental, social and cultural constraints

This section summarises the social, cultural and environmental issues relating to flood risk in Corrofin and the spatial scales they relate to.

2.3.1 West of Ireland

Corrofin is a village located in County Galway, situated on the N17 road between Galway City and Tuam. Corrofin is approximately 25km north east of Galway City and 14km south of Tuam. The village is just off the N17 Galway to Sligo Road and the N63 Galway to Roscommon road, as a network of secondary roads linking the area with neighbouring towns and villages.

The River Clare, designated as part of the Lough Corrib Special Area of Conservation (SAC), passes through the AFA. This SAC is a large site designated for a number of contrasting habitats and species, however, not all are likely to be located in close proximity to Corrofin AFA. The Clare River may contain watercourses of plain to montane levels with the *Ranunculus fluitantis* and *Callitriche-Batrachion* vegetation, which could be adversely impacted upon by flooding and flood risk management activities. Other downstream SAC habitats could also be adversely impacted upon by flooding or flood risk management within the Corrofin AFA. The species for which Lough Corrib is designated an SAC are generally riverine/wetland species such as Freshwater Pearl Mussel (FWPM), White-clawed Crayfish, lamprey, Otter, Salmon, Slender Naiad and Shining Sickle Moss. These species may be adversely affected by flooding through siltation, disturbance to spawning gravels, changes in nutrient conditions or flooding of holts. The site is also an SAC for Lesser Horseshoe Bat, which are likely to be tolerant of flooding, unless the entrances to cave hibernation sites are blocked.

2.3.2 Galway County

Corrofin village in County Galway is a historic and cultural centre of regional importance. Served by established road links, Corrofin exerts a significant influence on its hinterland.

The N17 Galway to Sligo road and N63 Galway to Roscommon road bypass the village of Corrofin. These are major transport links for the area.

The future vision and zoning in riparian areas as set out in development plan and policy documents needs to be reflected in, or revised in response to, the flood management plan. The uncertainty in future flood risk needs to be considered in these plans.

2.3.3 Corrofin

On a local scale, Corrofin is a village with a population of approximately 1000 and serving its rural hinterland. The local businesses and shops are reliant on the passing trade from the N17 and N63. Flooding is likely to affect this trade as will traffic disruption during construction of any structural methods.

3 Screening of possible methods and options

3.1 Introduction

A flood risk management option consists of one or more combinations of flood risk management methods; a measure being one distinct approach to flood risk management in a specific location such as a flood wall or flood warning system. Flood risk management options consist of all methods required to deliver mitigation at the relevant spatial scale.

This section provides an overview of the screening of all possible flood methods to arrive at a suite of viable methods that have then been carried forward to detailed modelling and the identification of feasible options. The purpose of the screening process is to filter out Flood Risk Management (FRM) methods that are not acceptable or viable, either alone or in combination with other methods, for the Spatial Scales of Assessment (SSA) under consideration.

3.2 Existing Scenario

To analyse the impact of flood management methods, it is first necessary to access the existing scenario. Currently in Corrofin there is no flood forecasting or warning system. There are informal ineffective earthen embankments with gaps on the left and right bank of the River Clare, upstream of the Grange River confluence, as well as earthen embankments within Corrofin village. There is also a substantial wall some distance from the River Clare channel which could potentially be bypassed by the river flow.

Flood hazard maps have been produced that show the 'risk to life'. These indicate the level of risk to human life based on depth and velocity. Figure 3-1 and Figure 3-2 indicate the risk levels in the Ballybanagher area of Corrofin for the 1% AEP current and MRFS events. These show significant to extreme danger for the 1% AEP events. An economically, environmentally and socially acceptable solution to alleviate flooding is sought to protect the town.

Figure 3-1: Risk to life - River Clare and Grange River (Current)

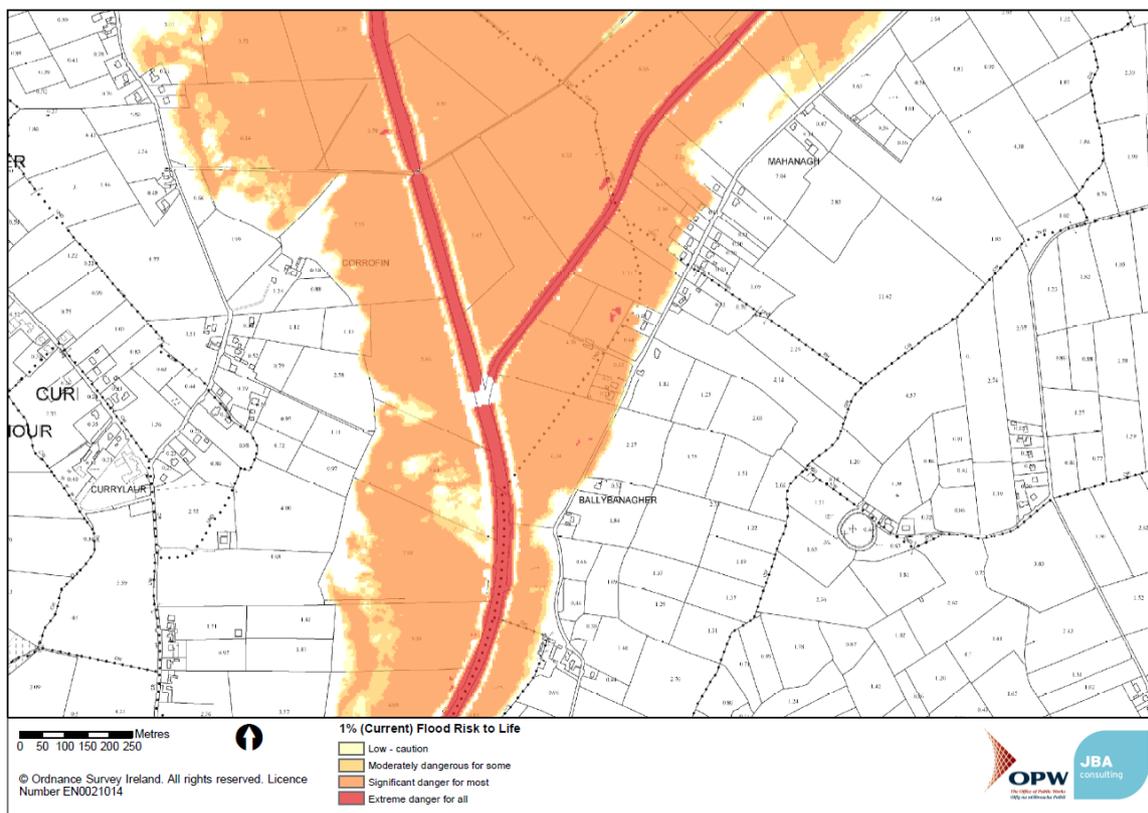
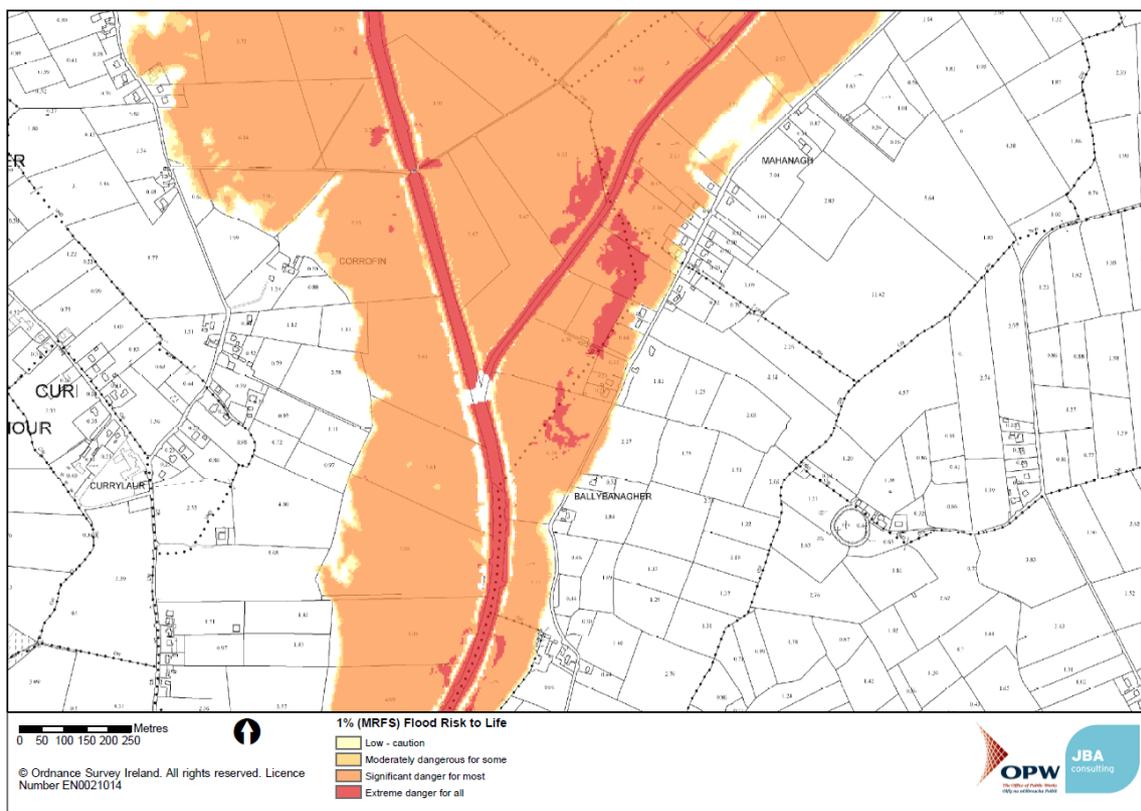


Figure 3-2: Risk to life - River Clare and Grange River (MRFS)



3.3 Screening of possible Flood Risk Management methods

The objective of the screening process is to develop a long list of technically feasible and economically viable methods to feed into the option identification stage. Options have only been discounted at this stage on technical or economic grounds, however the process has also required social and environmental constraints identified as part of the work to be recorded to support the further development of options and the SEA process at a later stage.

Details of the cost estimates are provided in Appendix B and an overview of the screening considerations for environmental and social constraints is provided in Appendix C

Information was recorded under the following criteria as follows:

- **Technical** - Methods were screened on feasibility only, requiring a high level description of what the likely method would entail. Where methods were not considered to be technically feasible or not relevant to the site no further consideration has been given
- **Economic** - Technically feasible methods have been reviewed for economic viability. As noted previously, approximate benefits associated with the 1% AEP fluvial event is €360,310, so any standalone methods or combination of methods will be required to cost less than this, assuming a benefit cost ratio of 1:1.
- **Health and Safety** - The degree of health and safety risk during construction and operation was assessed at a level appropriate to the screening stage. Risks have been recorded for future reference, however if the risk could not be managed or mitigated then the measure was screened out.
- **Environmental** - The environmental screening has made use of the SEA scoping report and has taken into account the key environmental constraints noted in Section 2.2. Methods may be rejected on the basis that a measure may have a detrimental impact on an environmentally or culturally valuable or protected site, and may need to complete the costly IROPI process to proceed.

Table 3-1 shows the results of the screening process for each method considered. A method can Pass (P) or Fail (F) the above criteria. A method must pass all four criteria to be considered viable. The below criteria were also considered at the screening stage however methods were not rejected based on these criteria but the key constraints were noted.

- **Social and Cultural** - Again, methods are not rejected based on social and cultural constraints at the screening stage however the constraints are noted.
- **Adaptability to Climate Change** - Corrofin is significantly affected by the effects of Climate Change with damages increasing from €360,310 in the fluvial current scenario to €1,087,774 in fluvial MRFS scenario. Any methods for the area will have to be sustainable and adaptable in the face of potential future changes, including the potential impacts of climate change.

Only structural methods have been screened. Non-structural methods such as planning and development control, SuDs, targeted public awareness campaigns and development of emergency plans will be assessed at the UoM scale and are detailed in the overarching UoM Report with issues relevant to this AFA discussed in Section 4.

Table 3-1: FRM method screening - Ballybanagher area, Corrofin

Possible Flood Risk Management Measure	Technical	Economic	Health and Safety	Initial Screening Result	Comment
Non - Structural Method					
Do Existing	Pass	Pass	Fail	Not Viable	There is a high risk to society and where feasible this risk should be reduced by the implementation of methods be that structural or non-structural methods.
Structural					
Fluvial Methods					
Storage Options	Fail	-	-	Not Viable	The size of the River Clare in this location means that any storage area would need to be unrealistically large. Flooding occurs to some of the properties in the 10% AEP event and the storage volume required to attenuate flows to the 1% AEP event would be of the order of 14 million m ³ .
Flow Diversion	Fail	-	-	Not Viable	The properties at risk are situated at the confluence of the Clare and Grange Rivers. There is therefore no obvious diversion route as both watercourses would need to be diverted independently.
Increased Conveyance - Dredging/ Widening and Straightening	Fail	-	-	Not Viable	The floodplain at the confluence of the Clare and Grange Rivers is up to 1 km wide in locations. The gradient through this reach is relatively shallow with a slope of approximately 1 in 1000, so increasing the capacity of the channel will not provide a significant increase in pass forward flow. It will also provide negligible additional storage in comparison to the floodplain and so have little or no impact on flood levels.
Increased Conveyance - Removal of local obstructions	-	-	-	Not Applicable	Not applicable to the River Clare and the Grange River as there are no known obstructions. The floodplain narrows at the Corrofin Bridge significantly but there is no significant headloss across this structure or change in water level gradient upstream and downstream of the structure.
Upgrade Culvert Capacity	-	-	-	Not Applicable	There are no culverts that require upgrading.
Flood Containment Methods					
Rehabilitation of Existing Walls	F	-	-	Not Viable	There are existing ineffective embankments along the banks of the Clare, but these are not situated suitably to be of use to prevent flooding to the properties affected. Using these would result in the removal of significant sections of the River Clare natural floodplain.
Walls	Pass	Fail	-	Not Viable	This method would install a wall between the Grange River and the affected properties, however there is sufficient space for embankments in the area,. A wall would require sheetpiling and of a similar extent and heights to the embankments discussed below. The cost of such a wall would not be economically viable.

Embankments	Pass	Fail	-	Viable	There is sufficient space along the property boundary to install an embankment instead of a wall. This method would involve 2 embankments around the perimeter of the properties. An embankment to protect the southern properties would consist of a 200m long embankment of an average height of 2m. The gardens of the properties in question slope considerably so the height of the embankment would be little over finish floor height and should not have a large visual impact. Due to ground conditions sheet piling would be required. For the northern properties a 140m long embankment is required. Approximately 100m is required to be 2m high and the remaining 40m would be an average of 1m high. Again, due to ground conditions sheet piling is required. A total cost of the embankment has been estimated to be €721,791 (Appendix B.1) and this excludes pumping costs. As elevated flood levels are likely to affect the properties for a considerable duration pumping would be required and this would be an additional cost.
Demountable Walls	-	-	-	Not Applicable	There is no requirement for demountables in this location.
Road Raising	-	-	-	Not Applicable	There is no road between the affected properties and the watercourse.
Individual Property Protection Methods					
Relocation of Properties	-	-	-	Not Applicable	Relocation of properties will result in significant stress for property owners. It will not be proposed where there are viable alternatives, as is the case in Corrofin.

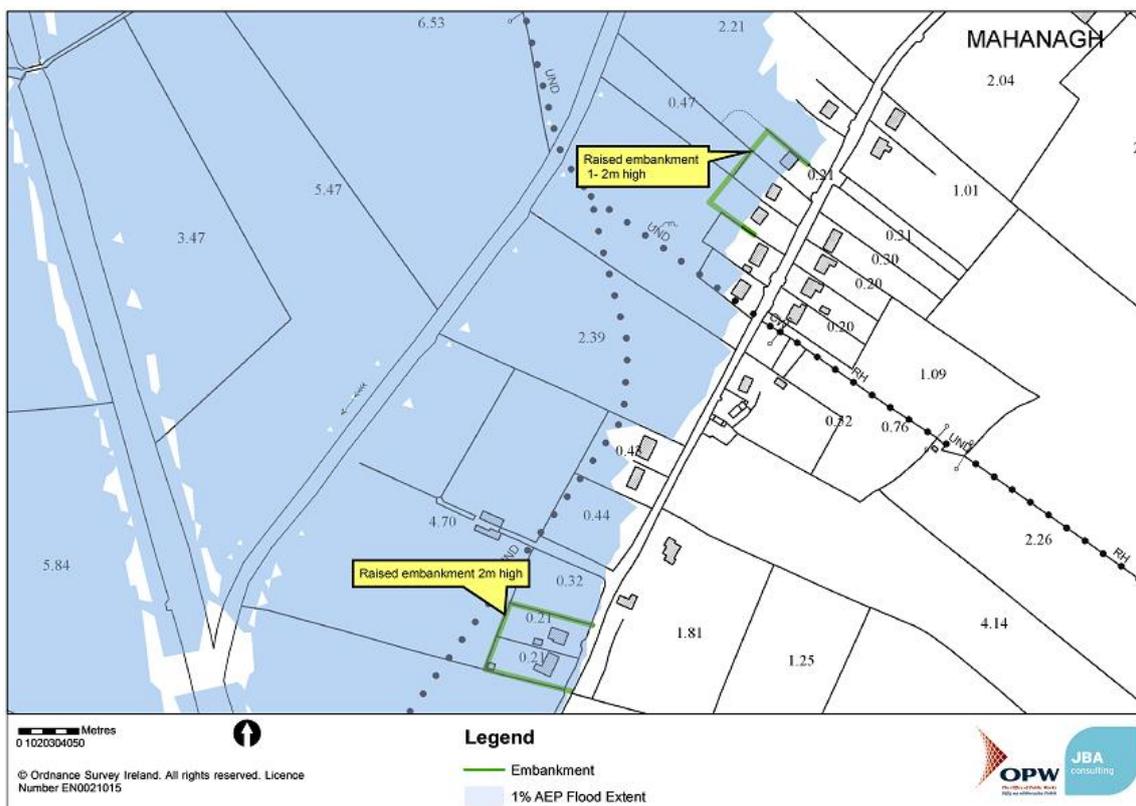
3.4 Findings of the screening assessment

Pulling together the individual methods discussed above, Table 3-2 details the management options for Corrofin. The preferred option is raised embankments around the properties. The screening assessment has found no economically viable structural methods for Corrofin. The options assessed are presented in Table 3-2 and Figure 3-3.

Table 3-2: Flood management options for Corrofin

	Option 1	Option 2
Present day	Flood forecasting and property resilience This option would install a flood warning system and provide simple resilience methods such as awareness raising.	Construction of raised embankments This option will construct raised embankments around all 5 properties.
In the future	This option would not negatively impact on potential future methods. Depths and increased frequency of flooding in future scenario will reduce the effectiveness of such methods.	The defence heights could be extended to accommodate climate change flows but the height may have a visual impact on the properties.
Conclusions	Flood warning will not provide a standard of protection but will improve the readiness of local residents. Such methods are very applicable to the basement of the three northern properties, where resilient use should be employed.	This option provides protection to the 1% design standard. The situation of the embankments within the boundary of the properties will need agreement with the owners. It is easily adaptable to climate change.
Cost Benefit Ratio	n/a	0.49 - 0.79

Figure 3-3: Locations of flood mitigation methods



A breakdown of the estimated costs for the options for Corrofin is presented in Table 3-3. It is noted that for the screening stage, the additional cost allowances only included optimism bias, maintenance and preliminaries to reduce the risk of omitting potentially cost beneficial options at this stage. Full details of the assumptions made in the cost estimates are provided in Appendix 0. Individual measure costs are detailed in Appendix B.

Table 3-3: Indicative screening costs

Option 1- Do Existing		€
Do Existing - No Costs Involved		
Option 2- Embankment		€
Construction costs		
Rural Clay Embankment (with 5m sheet pile) 200m @2m high		224,180
Rural Clay Embankment (with 5m sheet pile) 100m @2m high		37,549
Rural Clay Embankment (with 5m sheet pile) 40m @1m high		115,873
Construction costs - Subtotal		377,601
Preliminaries	17%	64,192
Capital costs - Subtotal		441,794
Optimism Bias	50%	220,897
Capital costs - Total		662,690
Operation and maintenance net present value		
Embankment O&M Cost; higher estimates		39,401
Operation and maintenance - Subtotal		39,401
Optimism Bias	50%	19,701
Operation and maintenance costs - Total		59,102
Option cost for cost benefit analysis		721,792

None of the identified methods qualify for funding as part of the national CFRAM programme as they have a benefit cost ratio of less than 1.

In the interim non-structural methods can provide a reduction to risk and damages for the area. These are discussed in detail in Section 4.

3.5 Stakeholder engagement

Throughout this process, the OPW regional engineers and local authority engineers have been consulted in the form of steering group, progress group and engineer meetings and their input has feed into the preliminary option stage.

Public Consultation Day (PCD)

On 30th of June 2015, a public consultation was held at Dr. Duggan Hall in Corrofin, to outline possible methods for the town. It should be noted that the length of the embankment presented at the PCD has changed to take in account flood data collected following the December 2015 events.

This PCD was attended by 16 people. At the PCD, attendees were invited to provide feedback, in the form of a questionnaire. The questionnaire sought opinion on the public's attitude to some of the types of methods being explored for the town. A detailed report on the PCD has been prepared. This report details all responses received on the day. Table 3-4 outlines the main concerns and how they have been incorporated into the POR stage by the study team. Positive feedback in general, a number of residents concerned about maintenance of the channels, in general there was good agreement with flood maps and extent of flood risk shown.

The diversion channel appeared to be the preferred measure.

Table 3-4: PCD feedback

Comments received	Study response
Considerable number of residents were concerned over the lack of maintenance on the Abbert River. The Ardskea More area has flooded previously and this has led to three houses being demolished and one house being abandoned. In November 2009 the bridge downstream of the area backed up and the village was marooned by flooding. No maintenance has been seen in the area since the 1960s when the scheme was constructed. Residents would like to see further embankments in the area.	This has been highlighted to the OPW. It is currently outside the scope of the study
The new N17/N18 Gort to Tuam bypass is currently been constructed in the area with a considerable length of embankment and a bridge over the Grange River. It will not cross the Clare River. There is concern over the reduced storage area due to the construction of the road will have on the area.	The blockage of the downstream culverts has been highlighted in this study and a rigorous maintenance regime for same has been proposed.
It was confirmed that a basement flooded in the past in the Ballybangher area in the November 2009 by a local councillor however, there was no representation at the PCD from residents in the area.	A site visit was conducted following the December 2015 event and discussions were held with the residents. Calculation of damages to these basements has been considered in the study.
A resident on the right bank of the River Clare was concerned with the backing up of Daly's Bridge and the lack of maintenance of the main Clare river. He was also concerned about the effect the silt build up at the mouth of the Corrib was having on the flow regime of the river.	The Clare River is part of the Corrib -Clare and maintenance is conducted in line with this.

4 Non-structural methods

Non-structural flood risk management methods are proven methods and techniques for reducing flood risk and flood damages incurred within towns. Besides being very effective for both short and long term flood risk and flood damage reduction, non-structural methods can be very cost effective when compared to structural methods. A particular advantage of non-structural measure when compared to structural methods is the ability of non-structural methods to be sustainable over the long term with minimal costs for operation, maintenance, repair, rehabilitation, and replacement.

Full discussions on non-structural methods has been discussed in overarching UoM preliminary options report. The section provides a bit more detail on these methods and how they could be implemented, either as standalone or in conjunction with a structural flood relief scheme in Corrofin.

Non-structural methods
Planning development and control
<p>Spatial planning and impacts on development</p> <p>Corrofin falls within the Galway County Development Plan. The Galway County Development Plan included a Screening SFRA which identifies and plots a series of flood risk indicators.</p> <p>The Flood Zones in the Country Development Plan SFRA are based upon the PFRA mapping. The SFRA for the County Development Plan should be updated to consider the CFRAM Flood Zones and impacts of climate change. There are currently non land zoning objectives for Corrofin. In the absence of zoning objectives, site specific flood risk assessments for development proposals in Flood Zones should be subject to the justification test to direct development to lower risk locations in accordance with the vulnerability of the proposed land use.</p> <p>Further detail on flood risk and land zoning objectives under both current and future scenarios is provided in Section 5 of the UoM 30 Overarching Report.</p>
<p>Sustainable Drainage Systems</p> <p>Having reviewed the potential for various types of SuDS it indicates there is a high potential for infiltration to occur.</p> <p>Natural drainage paths in Corrofin are short and join the River Clare in evenly distributed manner. SuDs should be implemented as part of developments in Corrofin, but due to this distribution of drainage paths there is no opportunity for regional attenuation of runoff.</p> <p>More detail on the applicability of SuDS in Corrofin, and indicative storage volumes, are provided in Section 6 of the UoM 30 Overarching Report</p>
Flood preparedness methods
<p>Flood forecasting and warning systems</p> <p>A flood warning based on a trigger alone is feasible as it gives adequate warning time. Potentially the gauging station at Tuam located upstream of Corrofin could be utilised to provide a flood warning system. Minor works will need to be undertaken to install telemetry capabilities, warning system and calibration. A flood warning system for the entire catchment can provide warning to residents in Claregalway. However, this system is currently unviable with a BCR of 0.52.</p> <p>More detail of the potential for flood forecasting in Corrofin is provided in Section 7 of the UoM 30 Overarching Report.</p>
<p>Emergency response planning</p> <p>Until such time as a scheme is built in Corrofin, the existing risk to life will remain unless a flood response plan can ensure necessary actions are taken and all vulnerable residents can be safely evacuated and accommodated, if necessary. Well prepared and executed emergency plans can significantly reduce the impact of flood events. Galway County Council has produced a Major Emergency Plan, which incorporates a "Flooding Sub Plan and should be implemented by Galway County Council it times of flood emergency.</p>
<p>Targeted public awareness</p> <p>Individuals and communities that are aware of any prevalent flood risk are able to prepare for flood events such that is and when such events occur, people are able to take appropriate actions in advance of, during and after a flood to reduce the harm and damages a flood can cause. There has been limited attendance to both the flood mapping and POR Public Consultation Days (PCD) in the town, with 17 and 16 people in attendance respectively. Public awareness through education schemes or increased awareness by the relevant authorities is needed to ensure that the residents of the area are aware of the risk.</p>

Individual property resilience

Resilience measure may be suitable for properties vulnerable to repeated flooding where the depth of flooding exceeds 600 mm (CIRIA 2007). When floodwater exceeds this level it may be more appropriate to allow water into a property, preventing possible structural damage to walls in a way that limits the potential damage, cost, disruption and ultimately the time that a property is uninhabitable. In Corrofin one property flood to the depth of approximately 800mm and there are also three basements effected by flooding. These basements should be made resilient to flood risk with only moveable items stored. The River Clare is a slow responding system giving the residents time to remove the items to less the impact of any event.

Individual property protection

Flood resistance, or dry proofing, techniques prevent floodwater from entering a building. This approach includes, for example, using flood barriers across doorways, airbricks and raised floor levels. Household flood resistance methods aim to prevent floodwaters from entering a building structure. Individual Property Protection methods may be appropriate in areas that frequently flood to shallow depths, and where community-scale defences are unlikely to be a viable option. In Corrofin, individual property protection to the 2 residential within the 1% AEP extent have estimated depths of less than 600mm. Individual property protection to this site should be considered in conjunction with the resilience measures described above.

Maintenance

The Clare and Grange watercourses are part of the Corrib-Clare arterial drainage scheme. Under the 1945 the OPW has responsibility to maintain the scheme. At the PCD there was a number of concerns over the lack of maintenance of the rivers.

The hydromorphic audit has not identified any reaches susceptible to sedimentation processes or blockage risk and no formal or informal effective defences or walls were identified in Corrofin.

5 Conclusion

The hydraulic modelling demonstrated that there is flood risk to properties in Corrofin due to the water backing up from the River Clare. All identified methods have a benefit cost ratio of less than 1 meaning they will not qualify for funding as part of the national CFRAM programme. For this reason, no further work has been undertaken investigating a preferred option.

The justification for the proposed scheme in Corrofin is marginal. To progress the flood scheme in Corrofin it is recommended a scheme cost review be undertaken to see if there are potential savings that can be achieved by progressing elements of the proposal under direct labour by either the local authority or by the OPW. The proposed methods are technically viable and if funding is identified from alternative sources then it is recommended further consideration be given to the methods discussed to mitigate flood risk.

Possible non-structural methods have been discussed which are proven methods and techniques for reducing flood risk and flood damages incurred and should be utilised as viable methods to reduce risk and should be used in conjunction with any scheme that is built in the future.

A Economic appraisal of methods and options

A.1 Overview

The economic appraisal of a method or option is based on the assumption that the cost of implementing a method should not exceed the benefit associated with the reduction in flood risk following the implementation of that method. The cost of implementing a method reflects the costs of construction and whole life costs arising from maintenance. The benefits associated with the reduction in flood risk as a result of a method are discussed in detail in this Section.

For each AFA with a technically viable method or set of methods, the following economic appraisal has been carried out. Where there are no technically viable methods, economic appraisal has not been undertaken.

The starting point for determining the benefits of a flood relief scheme is to identify the tangible costs associated with a flood event, or those costs which would be removed if a flood relief scheme were put in place. The tangible costs are those factors for which there is a clear monetary cost resulting from a flood. These costs can be split in to direct and indirect costs. Direct costs are the damages incurred to property as a result of a flood. Indirect costs are costs incurred as a result of a flood other than direct damages, for example the rental costs of temporary accommodation or the costs associated with a flood event response by the emergency services.

There are also intangible costs associated with a flood event. These represent the human impacts on an event such as anxiety, stress and ill health.

The total economic costs associated with a flood event are assumed to equal the total of the tangible and intangible costs. The methodology for calculating these costs is set out in the following sections.

Having established the potential benefits of a method or option, the viability of selected methods is dependent on the likely costs of construction and long term maintenance compared to the benefits.

Indicative costs have been calculated as part of the screening assessment where the screening assessment confirmed an economically viable option was available, the costs have been refined as part of the full scheme development costings. In both cases, costs have been determined using the unit cost database.

The unit cost database has been used to maintain consistency in estimated costs of construction and maintenance of methods nationwide under the CFRAM project.

The screening cost estimate consists of construction costs, associated preliminaries, operation and maintenance costs and an allowance for optimism bias. The final option costs also include additional allowances detailed design, archaeology, land compensation and art.

The following section step through the process of calculating benefits (Sections A.2 to A.5) and costs (Section A.6). The costing summary sheet for all technically viable options is provided in Appendix B.

A.2 Direct flood damages

A.2.1 Source data

Economic flood damages have been estimated using the data and general methodologies outlined in 'The Benefits of Flood and Coastal Risk Management: A Handbook of Assessment Techniques 2010), which is often referred to as the 'Multi-Coloured Manual' (MCM). This manual provides depth damage curves for different types of residential and commercial properties compiled from historical data of damages incurred in past flood events. By extracting the flood depths for affected properties from WCFRAM hydraulic modelling outputs the total damages in a given flood event can be determined.

Property types have been derived from the An Post geodirectory. The An Post directory assigns one of four codes to each of the property points to indicate the property type. These are R – residential, C – commercial, B – both and U – Unknown. A review of property points assigned a

B code confirms it is generally the commercial property on the ground floor and so, subject to flood risk, residential costs in these instances have been removed.

Residential properties are further categorised in the geodirectory into detached, semi-detached, terraced, duplex and bungalow. Unknown (U code) properties were found to include a description of the property type (detached, semi-detached etc.) and so were assumed to be residential.

Commercial properties in the geodirectory have a NACE code assigned; this is a European equivalent to the MCM codes but not directly comparable. To facilitate the analysis, each NACE code has been attributed an equivalent MCM code and so each commercial property attributed an appropriate MCM code. Where a NACE code was not available an appropriate MCM code has been determined based on knowledge of the town.

Property floor areas were extracted from OSi data and geographically linked to the An Post data. Where multiple An Post points existed within the same building polygon it was assumed the building footprint was divided equally between points. Where An Post data did not coincide with a building polygon a footprint area of zero was applied and hence no damages will be calculated for these points.

Property threshold levels are assumed to be equivalent to the mean LiDAR level over the buildings' footprint polygon plus a typical observed threshold level for the area.

A.2.2 Methodology

The depth damage curves used in the analysis for residential properties are based on the type of property described above only, i.e. detached, semi-detached etc. Where this data was not available a residential average was applied. Damage curves have been further selected based on local conditions such as whether the event had a short or long duration, defined as less than or greater than 12 hours, or whether salt water damage should be considered, as would be the case for tidal flooding. For residential properties damages begin at -0.3m to allow for damage to foundations.

In some AFAs, properties are affected by both fluvial and coastal flooding. However, hydraulic modelling has demonstrated that there is no joint probability risk from the two sources, so damages from each source can be treated independently. Once calculated for each individual source the total direct damage to an individual property is the sum of the damages from the two sources.

Prices (damage costs) in the data provided by FHRC 2010 have been converted to euro rates applicable to Ireland in 2013 (the reference date set by the OPW to allow a consistent comparison of findings across all CFRAMs) by:

- Applying a 'PPP' multiplication factor of 1.279. This is derived from the relative OECD Purchasing Price Parity values for the UK and for Ireland for 2010. The 'PPP' factor is net of currency conversion (i.e., already includes for exchange rates as well as price differences, and so no currency conversion rate should be applied in addition to this factor)
- Applying an inflation multiplication factor of 1.051. This is derived from inflation rates based on the CPI in Ireland for the period 2010 - 2013

Economic damages to infrastructural utility assets (e.g. electrical sub-stations, gas installations and pipe-work, telecommunications assets, etc.) are assumed to be 20% of total direct damages to properties for the AFA.

A.3 Intangible and indirect damages

Flood events can cause significant stress, anxiety and ill health to potentially affected people, during and then after a flood. Individuals generally also incur some costs due to their properties flooding that are not directly related to damage, such as evacuation, temporary accommodation, loss of earnings, increased travel and shopping costs, etc.

For residential the intangible and indirect flood damages shall together be set equal to the total direct property damages as calculated above.

Costs attributable to emergency services (which includes evacuation costs) are assumed to be equivalent to 8.1% of the total direct property damages. This value was derived as an average of the measured emergency services costs for the 2000 and 2007 floods in the UK.

Traffic disruption has not been included in the assessment of damages. Traffic disruption historically makes up a small percentage of damages and was not included at this strategic level.

A.4 Calculation of Annual Average Damage (AAD) and Present Value of damages (PVd)

A.4.3 Discount rate and project horizon

Given a choice between receiving a specific sum now and the same amount sometime later, most people will express a preference for the present sum. The tangible benefits accruing from a flood alleviation scheme will not provide cash sums to the beneficiaries; however, they will prevent a negative cash flow (avoidance of associated flooding costs) from the individuals.

The avoidance of fixed negative cash flow now is also preferable to avoidance sometime in the future. The “social time preference” (STP) can be measured by an appropriate Discount Rate (STPDR) and is taken as the compound rate of interest ‘r’ (% per annum) by which ‘y’ Euros in ‘x’ years’ time is equal to one euro now.

The benefits arising from a flood relief scheme commence on the completion of the scheme and exist for the life of the works. To obtain a method of the overall benefit in present day monetary values, it is necessary to:

- (a) Estimate the benefit arising each year of the project life, termed the Average Annual Damages (AAD)
- (b) Discount the AAD to present values using the appropriate discount rate.
- (c) Total the present values to obtain the overall benefit.

The Department of Finance's discount rate for public investment is 4%. The lifetime over which the benefits are discounted is taken as 50 years. For computation purposes, it is assumed that the residual value of the scheme at the end of the period is nil. This may be regarded as somewhat conservative, since works typically have a design life of 100 years.

A.4.4 Property capping assumptions

The present value damages for any given property should not exceed its current valuation. This is to prevent justification for a flood mitigation scheme being based on the repeated flooding of a property over the project life when it would be more cost beneficial to simply buy out the property. Estimated property values have been determined for both residential and commercial properties.

Residential Properties

Average prices for apartments, bungalows, detached, semi-detached and terrace properties were derived for each AFA as there was considerable difference in property values across all AFAs. The data was extracted from www.lpt.revenue.ie. The final capping value was set at twice the market value to allow for intangible damages.

Figure A-1: Residential capping assumptions

Area of further assessment (AFA)	Property type					Electoral district
	Apartment/Flat	Bungalow	Detached	Semi-Detached	Terraced	
Corrofin	150,000.00	150,000.00	150,000.00	150,000.00	100,000.00	Corrofin
Galway City (1)	150,000.00	200,000.00	250,000.00	200,000.00	150,000.00	Menlough
Galway City (2)	200,000.00	200,000.00	250,000.00	200,000.00	200,000.00	Dangan
Galway City (3)	150,000.00	150,000.00	150,000.00	150,000.00	150,000.00	St. Nicholas
Galway City (4)	150,000.00	200,000.00	200,000.00	200,000.00	200,000.00	Nun's Island
Galway City (5)	200,000.00	250,000.00	300,000.00	250,000.00	200,000.00	Claddagh
Galway City (6)	150,000.00	150,000.00	250,000.00	250,000.00	200,000.00	Eyre Square
Galway City (7)	150,000.00	150,000.00	200,000.00	150,000.00	150,000.00	Castlegar
Galway City (8)	150,000.00	200,000.00	250,000.00	200,000.00	200,000.00	Lough Atalia
Galway City (9)	200,000.00	200,000.00	250,000.00	250,000.00	200,000.00	Salthill
Oughterard	150,000.00	150,000.00	200,000.00	150,000.00	150,000.00	Oughterard
Ballyhaunis	100,000.00	150,000.00	150,000.00	150,000.00	100,000.00	Ballyhaunis
Tuam	150,000.00	150,000.00	150,000.00	150,000.00	100,000.00	Tuam Urban

Non Residential Properties

Average commercial property values have proved to be difficult to pinpoint. The high level approach outlined within the MCM is to estimate values as a factor of 10 greater than the rateable value, broadly defined as the annual rental value of the property. However, average commercial rental values are not widely available. Commercial rateable values were provided by the relevant county councils but these values are not equivalent to the rental value of the property and are not suitable for determining capping values. The Ireland Valuation Office is currently going through a revaluation process owing to the poor correlation between the rental value of properties and the rateable value but this information is not available for the west of Ireland.

Rateable values for all properties have been obtained from the April 2008 values for South West England from 'Commercial and Industrial Floor space and Rateable Value Statistics' (<https://www.gov.uk/government/statistical-data-sets/live-tables-on-commercial-and-industrial-floorspace-and-rateable-value-statistics>) as instructed by the OPW. These UK rateable values have been multiplied by the "PPP" multiplication factor of 1.279 and uplifted by the inflation multiplication factor of 1.051 resulting in the following euro rates. Non-residential properties were capped at 10 times the below rateable income.

Table A-5: Rateable incomes for non-residential properties

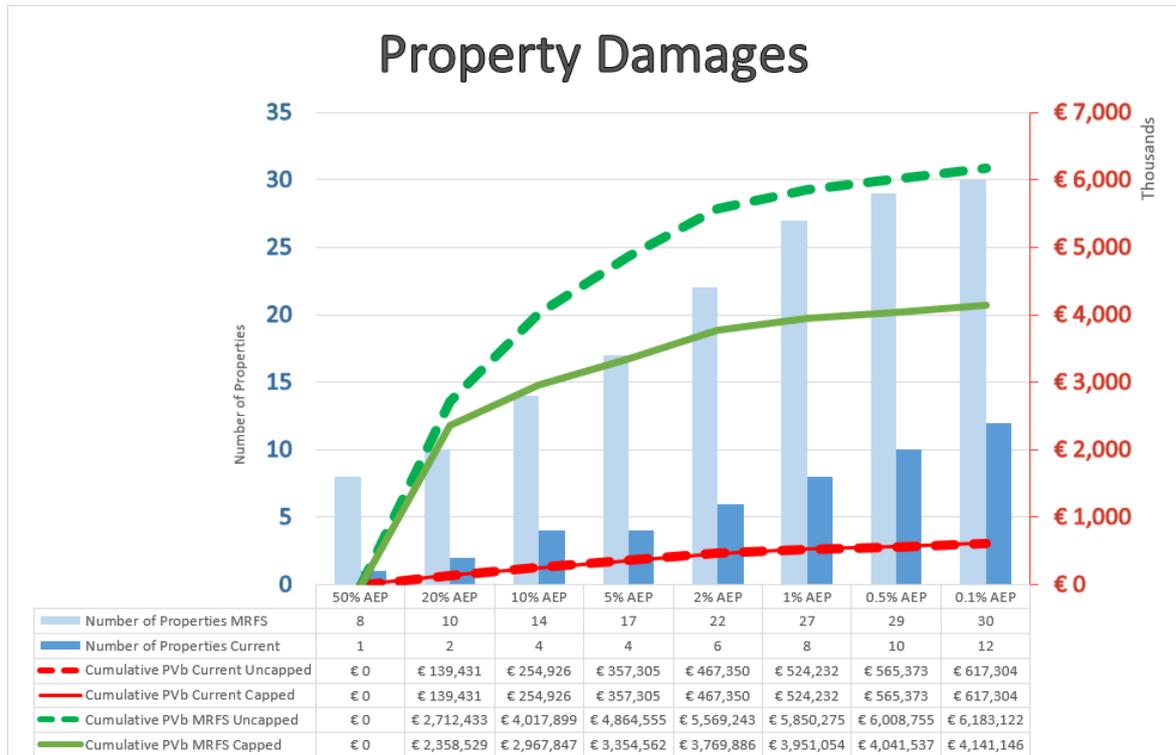
Property type	Rateable value per m ² (€)
Retail	161
Office	115
Warehouse	51
Leisure & Public	37
Industry	41

A.5 Benefit analysis

Using JBA's custom software package, FRISM, flood depths have been extracted and damages determined for each property for each of the eight defined design event probabilities. The Annual Average Damage (AAD) has then been calculated as the probability weighted sum of the damage values of each event up to and including the 0.1% AEP event. The Average Annual Damage, discounted at a rate of 4% per annum over a time-horizon of 50 years, produces the Net Present Value of the potential flood damage. An example of calculated damages is shown in Figure A-2.

It should be noted that, in the example shown in Figure A-2, the current and MRFS damages are both less than the equivalent capped damages, indicating that the value of residential and commercial properties has not impacted on the damages attributable to flood events.

Figure A-2: Damage calculation result (Sample)



The damages calculated using this method have been applied for both the verification screening and detailed options development stages of assessment.

A.6 Screening cost estimates

For each technically viable method identified as part of the screening assessment a cost estimate is provided in the relevant AFA report. An example breakdown of estimated costs for the screening assessment is shown in Table A-6 and details of the constituent parts provided in the following sections.

Table A-6: Screening costs (Sample)

Option 1- Do Existing		€	€
Do Existing - No Cost Involved			
Option 2			
Construction of retaining wall at Town Property and embankments to protect main street and isolated property		€	€
Retaining wall at Town Property			78,175
Embankment to the rear of properties on main street			7,626
Embankment at isolated property			15,253
Preliminaries	32%		32,337
Sub - Total			133,391
Optimism Bias	50%		66,696
Construction costs (Excl VAT)			200,087
Est. NPV Operation and Maintenance (Walls)		214	
Est. NPV Operation and Maintenance (Embankment Main Street)		5,864	
Est. NPV Operation and Maintenance (Embankment - isolated property)		5,864	
Optimism Bias	32%	3,821	15,763
Indicative Screening Cost			215,850

A.6.5 Construction costs

Construction costs were estimated based on typical unit and item costs (e.g. cost per metre length of reinforced concrete wall of given height, or cost of a pump of certain capacity) as set out by the unit cost database. Details of which unit and option cost have been applied are provided within the relevant AFAs reports. Summing the construction unit cost of the methods gives the Gross Capital Construction Cost.

A.6.6 Preliminaries

Preliminaries and other construction costs include the following items:

- Compound
- Site cabins and services
- Temporary power and generators
- Protection to overhead services
- Protection to underground services
- Road sweeping of public roads
- Preparation of as constructed drawings
- Health and safety
- Security
- Wheel wash provision at exits to public roads
- Manual washing prior to vehicles existing to public roads
- Supervision
- Setting out
- Mobilisation and demobilise
- Insurance

A relationship between the cost of preliminaries and the construction costs of a given scheme has been determined and is shown in Table A-7.

Table A-7: Preliminaries cost curve

Construction cost:	€100k	€250k	€500k	€1m	€2m	€5m	€10m	€15m
Total Preliminaries	€32k	€51k	€89k	€199k	€330k	€512k	€743k	€932k
Preliminaries as a % of total	32%	20%	18%	20%	16%	10%	7%	6%

In addition to the above, each of the separate unit costs includes an estimate of some of the additional preliminaries, such as temporary works, environmental mitigation and temporary flow controls. The temporary works costs are based on what would be required on all sites but are not intended to be definitive for all possible eventualities. Where non-standard, difficult or additional temporary works are deemed likely to apply the allowance for preliminaries in the individual method cost may be increased.

A.6.7 Operation and maintenance

Whole life cost estimation needs to identify all activities that constitute flood defence management practice e.g. inspection, vegetation management, repair, operations, incident management, general administration and regulatory activities. Operational costs may include annual maintenance as well as intermittent costs if relevant and proportional and data is available.

Operational costs are assumed to continue for the design life of the scheme. Present value costs for operation and maintenance have been determined using the same methodology set out in Section A.4.3, that is assuming a design life of the scheme of 50 years and a discount rate of 4%.

A.6.8 Optimism bias tool

There is a demonstrated, systematic, tendency for project appraisers to be overly optimistic when developing costs estimates for capital works. The aim of adding an optimism bias is to allow a contingency on these estimates to cater for unknowns and help ensure project promoters retain adequate project budget.

Different magnitudes of uplift or optimism bias are applied at different stages of the appraisal process. For example, a higher optimism bias is expected at the start of a project where there are a lot of unknowns, this optimism bias would expect to be reduced once detailed design has been completed and site conditions are better understood and approaches to manage risks have been identified or the additional costs associated the construction have been priced explicitly.

The proposed optimism bias has been determined from a Review of Large Public Procurement in the UK². This study reviewed cost estimates and resulting capital expenditure from public procurement projects over a period of 20 years. The findings of this review highlighted that an appropriate optimism bias for standard civil engineering projects at the outline business case stage, which broadly reflects the level of assessment in the CFRAM, is 44%. On this basis an optimism bias of 50% has been applied for all cost estimates in the WCFRAM.

² Review of Large Public Procurement in the UK, Mott MacDonald (2002).

B Screening cost summary tables

B.1 Option 2 - Wall and Embankments

Embankment (200m @ 2m high)

Single Method Capital Cost Tool	
Embankment type	Rural clay embankment with 5m sheet pile
Material	Imported
Embankment height (m) equivalent for unit cost rate	2
Embankment length (m)	200
Embankment unit rate (€/m)	€ 1,053
Over-ride unit rate (€/m)	
Total costs (€)	€ 203,800
Apply update to unit rate (CPI) if appropriate (€) (1.0)	€ 203,800
Enter other applicable costs (€)	-
Total capital cost (€)	€ 203,800
Consider amendments based on site issues/constraints (€) (Method factor 10%)	€ 224,180
Preliminaries (17%)	€ 38,110
Total capital cost (€)	€ 262,290

Operation and Maintenance Cost Tool	
Embankment length total (m)	200
Embankment O&M costs (€/m/yr)	Higher estimates €5.43
Over-ride unit rate (€/m/year)	-
Total annual O&M costs (€)	€1,086
Present value O&M costs (€)	€23,177

Embankment (40m @ 1m high)

Single Method Capital Cost Tool	
Embankment type	Rural clay embankment with 5m sheet pile
Material	Imported
Embankment height (m) equivalent for unit cost rate	1
Embankment length (m)	40
Embankment unit rate (€/m)	€ 853
Over-ride unit rate (€/m)	
Total costs (€)	€ 34,135
Apply update to unit rate (CPI) if appropriate (€) (1.0)	€ 34,135
Enter other applicable costs (€)	-
Total capital cost (€)	€ 34,135
Consider amendments based on site issues/constraints (€) (Method factor 10%)	€ 37,548
Preliminaries (17%)	€ 6,383
Total capital cost (€)	€ 43,931

Operation and Maintenance Cost Tool	
Embankment length total (m)	40
Embankment O&M costs (€/m/yr)	Higher estimates €5.43

Over-ride unit rate (€/m/year)	-
Total annual O&M costs (€)	€217.2
Present value O&M costs (€)	€4,635

Embankment (100m @ 1m high)

Single Method Capital Cost Tool	
Embankment type	Rural clay embankment with 5m sheet pile
Material	Imported
Embankment height (m) equivalent for unit cost rate	2
Embankment length (m)	100
Embankment unit rate (€/m)	€ 1,053
Over-ride unit rate (€/m)	
Total costs (€)	€ 105,339
Apply update to unit rate (CPI) if appropriate (€) (1.0)	€ 105,339
Enter other applicable costs (€)	-
Total capital cost (€)	€ 105,339
Consider amendments based on site issues/constraints (€) (Method factor 10%)	€ 115,873
Preliminaries (17%)	€ 19,698
Total capital cost (€)	€ 135,571

Operation and Maintenance Cost Tool	
Embankment length total (m)	100
Embankment O&M costs (€/m/yr)	Higher estimates €5.43
Over-ride unit rate (€/m/year)	-
Total annual O&M costs (€)	€543
Present value O&M costs (€)	€11,588

Summary

Total PV Cost	
Total capital costs (€)	€ 441,793
Total PVc costs (€)	€ 481,193
Optimism bias rate (%)	50%
Total Cost including Optimism Bias (€)	€ 721,790

C Environmental and social assessment of methods and options

C.1 Introduction

The environmental constraints and the scope of the Strategic Environmental Assessment (SEA) have been identified in the SEA scoping report. In the screening of methods and development of flood risk management solutions the possible constraints, environmental benefits and impacts associated with each method have been identified. The benefits and impacts have been considered in terms of quality, significance, duration and type.

C.2 Screening of methods

Alongside the technical and economical assessment of potential methods, an assessment into the key social, cultural and environmental issues relating to flood risk in the area were considered. This work built on the key constraints listed in the SEA scoping Report. This is included in Section 2.2 of each individual AFA POR report.

At this preliminary screening stage, methods were assessed in relation to:

- Location - would the placement of the method be located near or within a Natura 2000 site.
- Impact during construction or any operational requirements
- Presence of protected species within the area.

By outlining the key constraints, potential methods that would need to follow the full IROPI (Imperative Reasons of Overriding Public Interest) process can be discounted at the viability screening stage.

C.3 Environmental appraisal of options

C.3.1 Assessment criteria

The screening stage determined potentially viable methods and these were carried forward to full option development. In the full development of options an environmental appraisal of each viable option has been carried out and has been included in each individual POR report. The following has been considered.

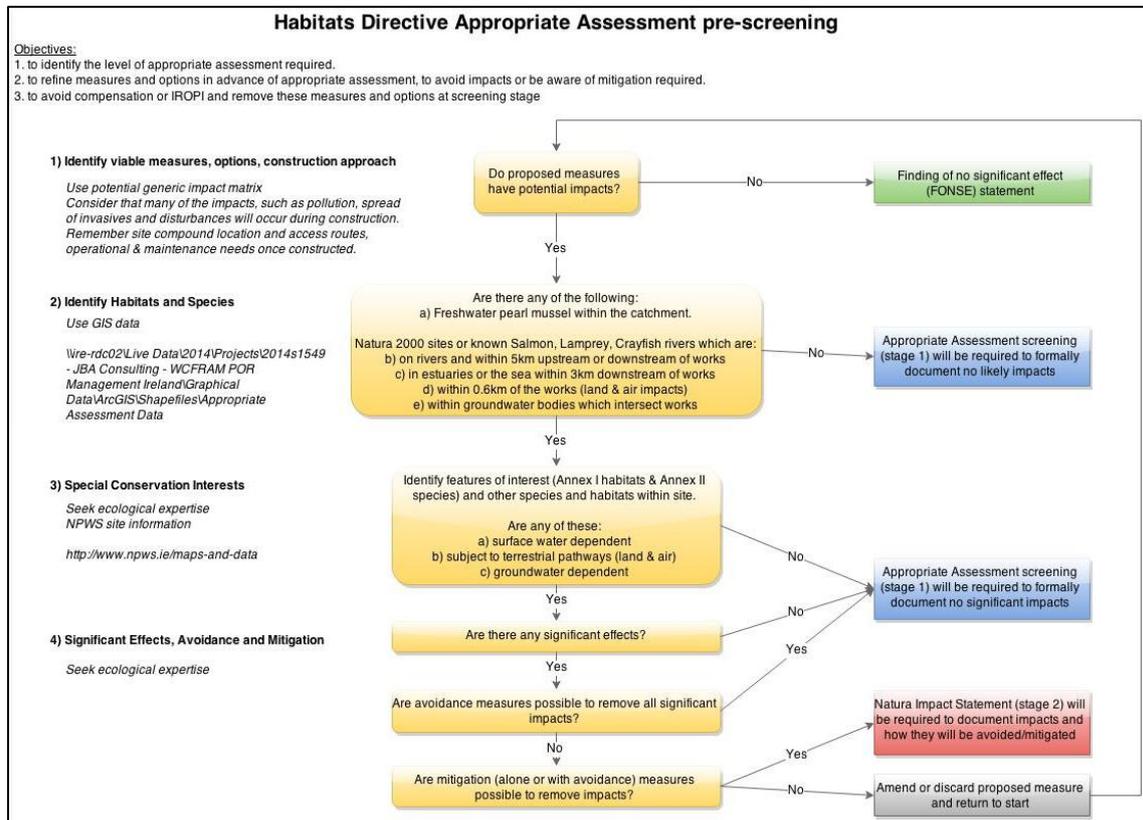
Table C-8: Environmental considerations

Habitat Loss	This is a permanent loss of habitat within the designated boundaries of a Natura 2000 site. For flood relief schemes this could arise from the construction of new structures within the site boundary, including provision for future maintenance. Dredging, bank alterations etc., and other activities can cause habitat loss.
Physical Damage	This includes degradation to, and modification of, habitats within the designated boundaries of a Natura 2000 site. This could arise in working areas and along access routes where construction works are undertaken within the site boundary.
Habitat Fragmentation	More indirect physical damage to habitats could occur, for example, through increased recreational pressure associated with certain methods, which could result in trampling, erosion or rubbish tipping.
Species Loss	Damage may be temporary or permanent.
Change in physical Regime	This is where activities result in the separation of available habitats or split extensive areas of suitable habitat. It is most likely to affect species, but can impact upon the functionality of habitats.
Changes in hydrological regime	This is a permanent loss of species such as Atlantic Salmon within the designated boundaries of a Natura 2000 site as a result of schemes e.g. removal of spawning grounds due to channel deepening and widening, loss of Otter due to damage to holts on river banks or loss of pearl mussel due to instream works. For flood relief schemes this could arise from the construction of new structures within the site boundary, dredging, channel widening, bank alterations or including provision for future maintenance. At coastal locations this may arise mainly for birds e.g. nesting terns on shingle or some rare plants. Dredging, bank alterations etc., and other activities can cause habitat loss
Disturbance (noise, visual, vibration)	These are changes to physical process that can alter the present characteristics of the Natura 2000 site (e.g. estuarine, fluvial and geomorphological processes, salinity levels, tidal regimes, erosion, deposition, sediment transport and accumulation). This could then result in degradation or loss of habitats.
Competition from non-native species	Certain activities may result in changes to the current hydrological regime. For example, a reduction or increase in the frequency, extent, duration and/or depth of flooding may affect estuarine, riverine and floodplain habitats.
Changes in water quality	Activities which may affect surface and groundwater levels, such as impoundments or defence construction, may also have adverse impacts on surface water or groundwater dependant habitats (rivers, fens, bogs, etc.) and species.
Pollution	A number of activities can result in disturbance, including visual and from noise. This is more frequently associated with construction activities, but could also be associated with the operational phases of some flood relief methods, in particular where recreational opportunities may be exploited. Disturbance can cause sensitive species, such as birds or mammals, to deviate from their normal, preferred behaviour, resulting in stress, increased energy expenditure and, in some cases, species mortality.
Landscape and Visuals	The visual impacts of the proposed options were assessed using the existing landscape ratings and status for the areas as outlined in the County Development and Local Area Plans.
Archaeology & Cultural Heritage	The potential impacts of the proposed flood management options were assessed against the archaeological and architectural features in the areas of the proposed works. Architectural Conservation Areas in town were taken into consideration during the assessments.

C.3.2 Habitats Directive Appropriate Assessment pre-screening

Pre-screening in relation to the Habitats Directive was carried out to examine the potential impacts on Natura 2000 sites early in the design process. Where an option could potentially involve Stage 3 & 4 of the AA process, this option was re-examined and in most cases options that would require an IROPI approval process were rejected and alternative options sought. This is illustrated below in Figure C-3.

Figure C-3: Habitats Directive Appropriate Assessment pre-screening





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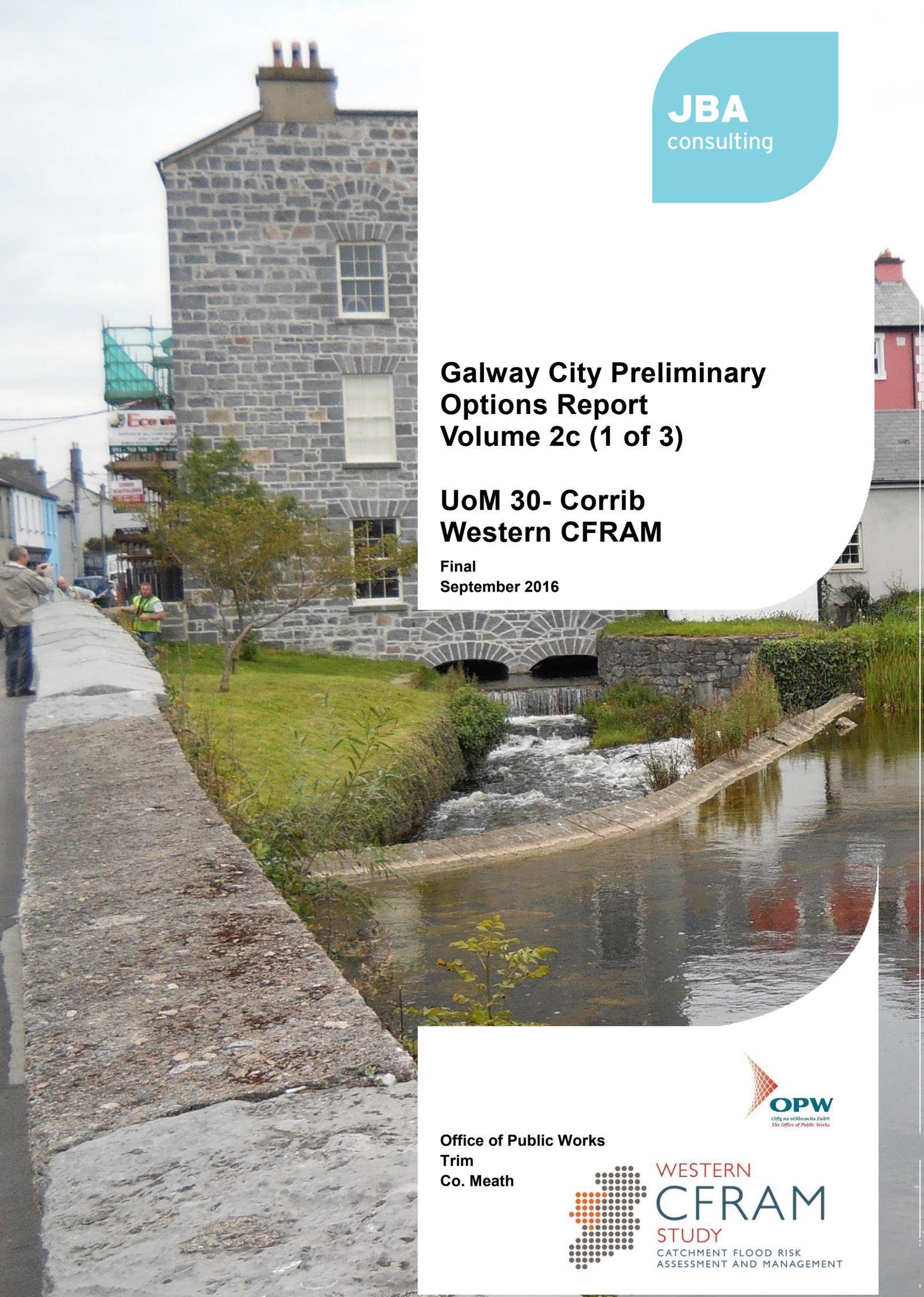
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Galway City Preliminary Options Report Volume 2c (1 of 3)

UoM 30- Corrib Western CFRAM

Final
September 2016



Office of Public Works
Trim
Co. Meath



WESTERN
CFRAM
STUDY
CATCHMENT FLOOD RISK
ASSESSMENT AND MANAGEMENT

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Glossary

AAD	Average annual damages
AEP	Annual exceedence probability
AFA	Area for further assessment
BCR	Benefit cost ratio
CC	Climate change
CFRAM	Catchment-based flood risk assessment and management study
CPI	Consumer price index
DEM	Digital elevation model (Includes surfaces of structures, vegetation, etc)
DTM	Digital terrain model ('bare earth' model; does not include surfaces of structures, vegetation, etc
FHRC	Flood Hazard Research Centre
FRISM	Flood risk metric tool
FRM	Flood risk management
FRMP	Flood risk management plan
FRR	Flood risk review
GIS	Geographical information system
HEFS	High-end future scenario
HPW	High priority watercourse
IROPI	Imperative Reasons of Overriding Public Interest
LA	Local authority
LAP	Local area plan
LIDAR	Light detection and ranging
MCA	Multi-criteria analysis
MCM	Multi-coloured manual
MPW	Medium priority watercourse
MRFS	Mid-range future scenario
NDHM	National digital height model
OPW	Office of Public Works
OSi	Ordnance Survey Ireland
PCD	Public consultation day
POR	Preliminary options report
PPP	Purchase price parity
PVd	Present value damages
SAC	Special area of conservation
SEA	Strategic environmental assessment
SPA	Special protection area
SSA	Spatial scale of assessment
STP	Social time preference
STPDR	Social time preference discount rate

SUDS Sustainable Urban Drainage Systems

UK United Kingdom

UoM Unit of management

WCFRAM Western catchment-based flood risk assessment and management study

WTP Water treatment plant

WWTW Wastewater treatment works

1 Introduction

1.1 Scope of Report

This report details the preliminary options investigation for addressing flood risk in Galway City. The report should be read in conjunction with the Preliminary Options Overarching Report.

The Preliminary Options Investigations represent the next phase of the Western CFRAM study. The work already completed has identified the scale and extent of flood risk within Galway City. Reports which are relevant to this AFA are:

- Western CFRAM Flood Risk Review Report
- Western CFRAM UoM 30 - Inception Report
- Western CFRAM UoM 30 - Hydrology Report
- Western CFRAM UoM 30 - Hydraulic Modelling Report
- Western CFRAM UoM 30 - Corrib Hydraulic Modelling Report: Volume 2c - Galway City
- Western CFRAM UoM 30 - Hydraulic Modelling Report: Volume 3 - Flood Risk maps

Using the work already completed the OPW have identified a requirement to develop methods to manage flood risk, both now and into the future, within Galway City. The scope of this study is to identify a preferred flood risk management option for Galway City.

The work completed includes the screening of possible methods to identify technically feasible and economically viable structural and non-structural methods to manage flood risk sustainably. From these preferred options have been identified, consulted on, and appraised against societal, environmental and cost criteria to identify a single recommended option. The final recommendations from this study will feed into the overarching Flood Risk Management Plan for Galway City.

1.2 Flood Risk Overview

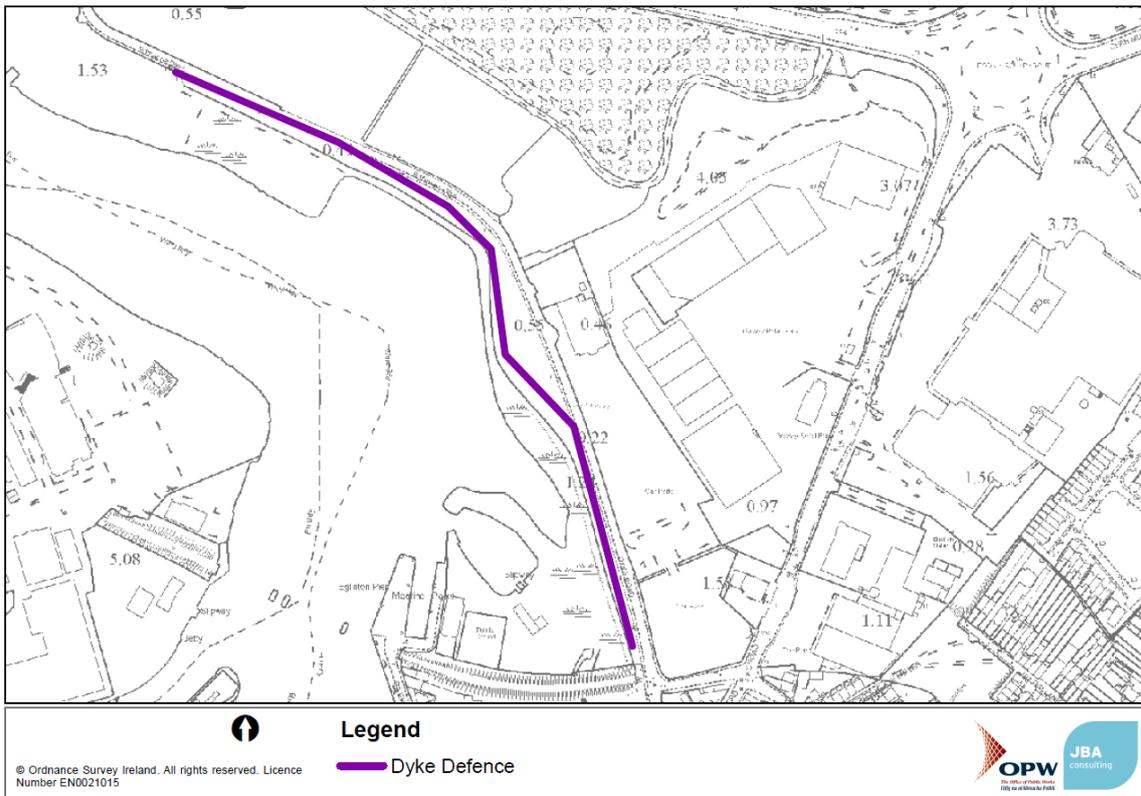
1.2.1 Current Flood Risk

Flood risk in Galway City is a result of a number of mechanisms. The areas of Salthill along the coastal front are subject to flooding by tidal inundation and wave overtopping. The latter seems to be more significant and this is reflected in recent flood events. The lower reaches of the River Corrib i.e. the canal tail races, Claddagh basin and downstream of Salmon Weir Barrage are mainly exposed to coastal flooding. This flooding is mainly as a result of a surge tide water levels, with wave overtopping being less of an attributing factor. Properties around Spanish Arch, Docklands and Claddagh basin are affected in the tidally influenced reaches.

The Dyke Road consists of an embankment as shown in Figure 1-1. The embankment is critical to preventing flooding to areas of Castlegar and Terryland. The embankment has history of seepage problems and also experienced some damage around 2007. This was repaired by the OPW. The flood level from the River Corrib is contained by the dyke in the 1% AEP current event but the required freeboard¹ (0.3m) is not provided for in this event. The dyke overtops in the 0.1% AEP event and flooding is widespread in the low lying area that the dyke protects. As the area is not impacted in the design event, 1% AEP event standard, the flood risk methods described in Section 3.4 were not considered for this area. Recommendations and non-structural methods however, will be made in later sections regarding the dyke defence.

¹ Freeboard is the safety factor that ensures that a defence performs with a high degree of certainty to the required standard.

Figure 1-1: Dyke Road defence



There is a low risk of fluvial flooding from the canals in Galway City in the current scenario. There is some overtopping in the 0.1% AEP event on the canals in the Nuns Island area.

1.2.2 Flooding at Salthill

Figure 1-2 and Figure 1-3 shows an overview of the flooding predicted to be experienced in the 0.5% AEP for tidal inundation and wave overtopping. The figure shows that the wave overtopping extent has a more significant impact. This is due to the dynamic interaction as waves break on coastal frontage, and not all the momentum is removed.

Figure 1-2: Overview of wave over-topping flooding in Salthill

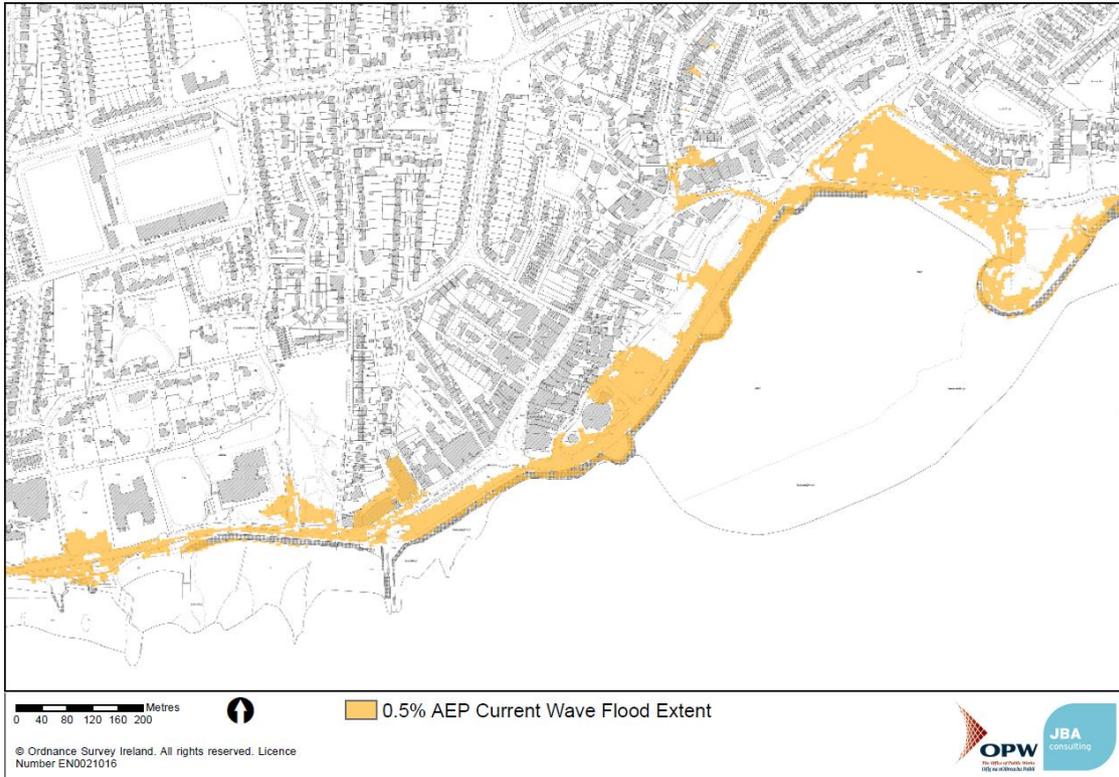
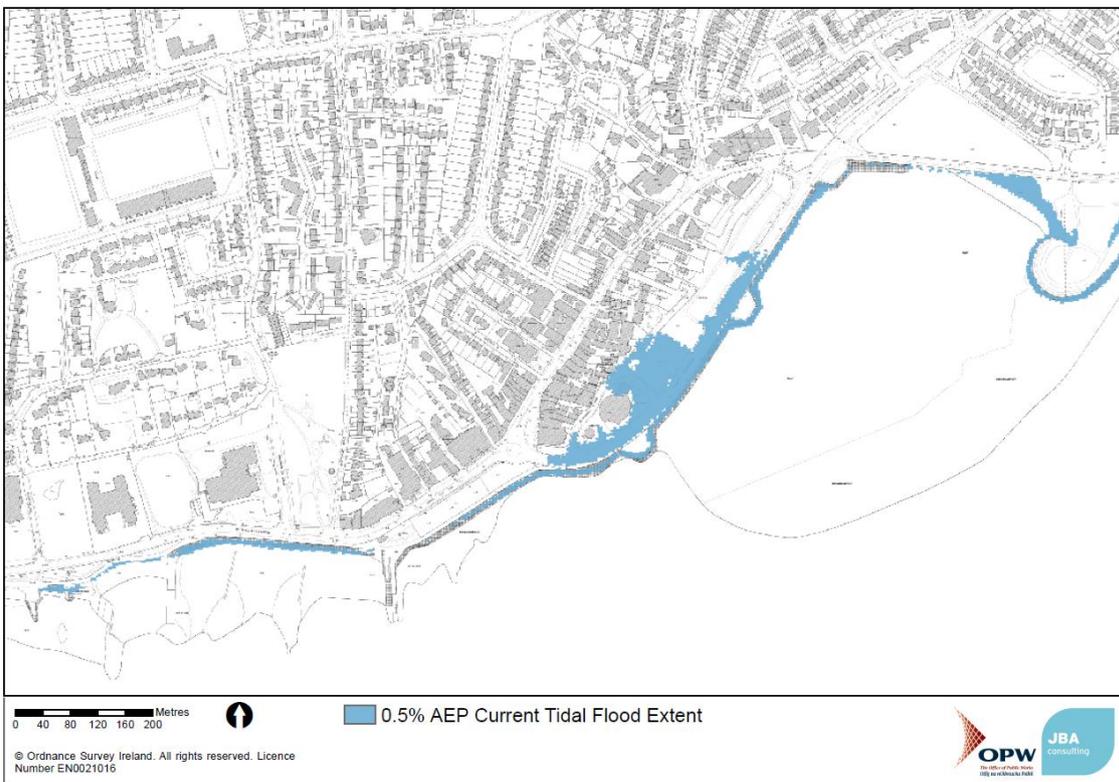


Figure 1-3: Overview of still water level (tidal) flooding in Salthill



1.2.3 Flooding at Spanish Arch

Figure 1-4 and Figure 1-5 shows an overview of the flooding from both fluvial and tidal sources for the 1% AEP event and 0.5% AEP event respectively around the Spanish Arch area of Galway City. There is flooding of commercial and residential properties along Quay Road, Flood Street, Dock Road and Merchants Road in the 0.5% AEP tidal event.

Figure 1-4: Overview of fluvial flooding at Spanish Arch

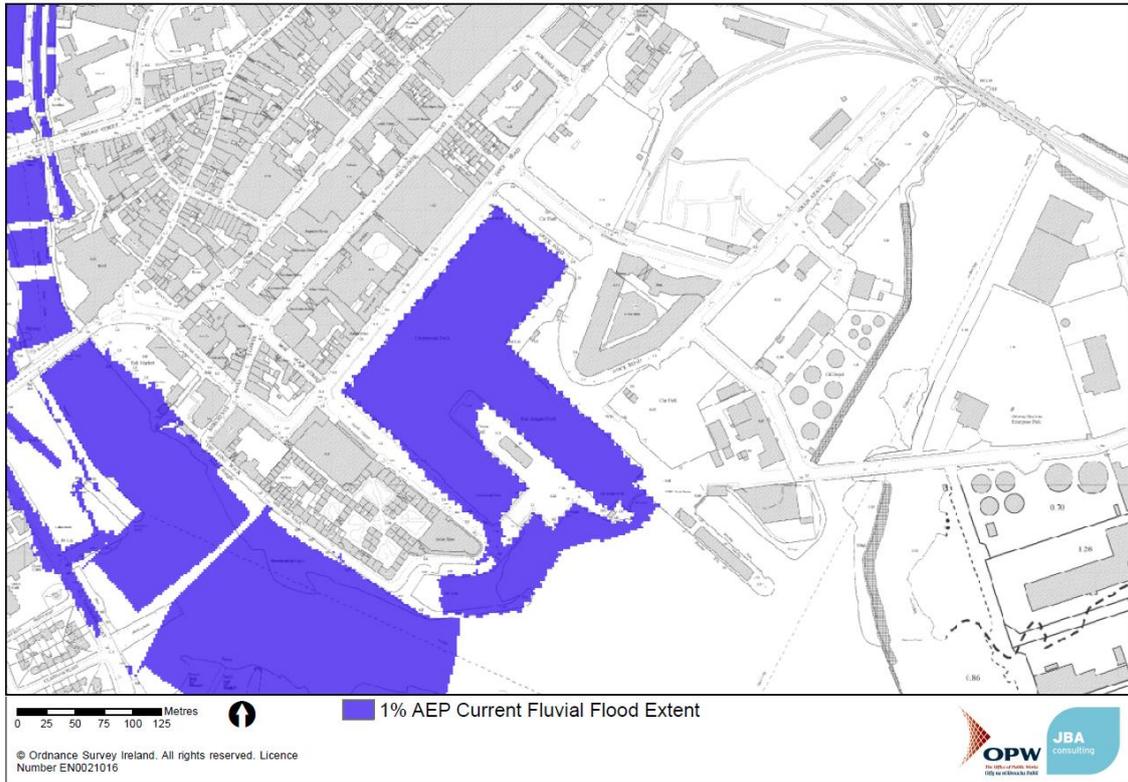
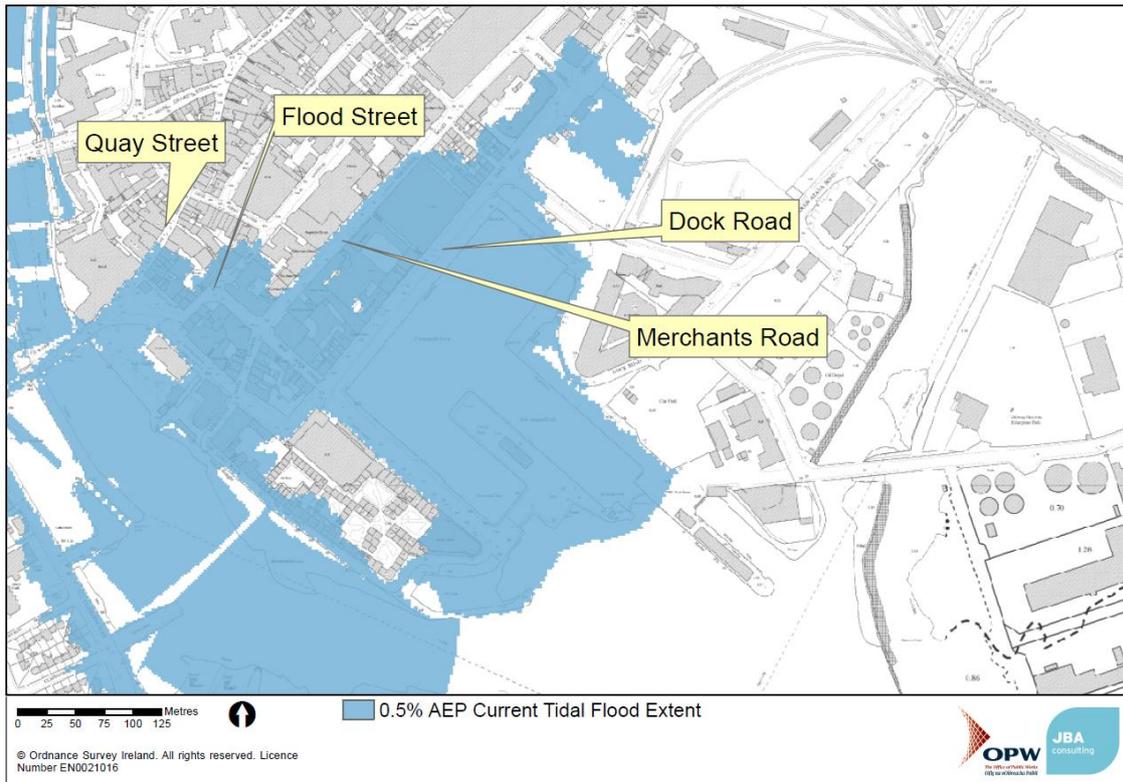


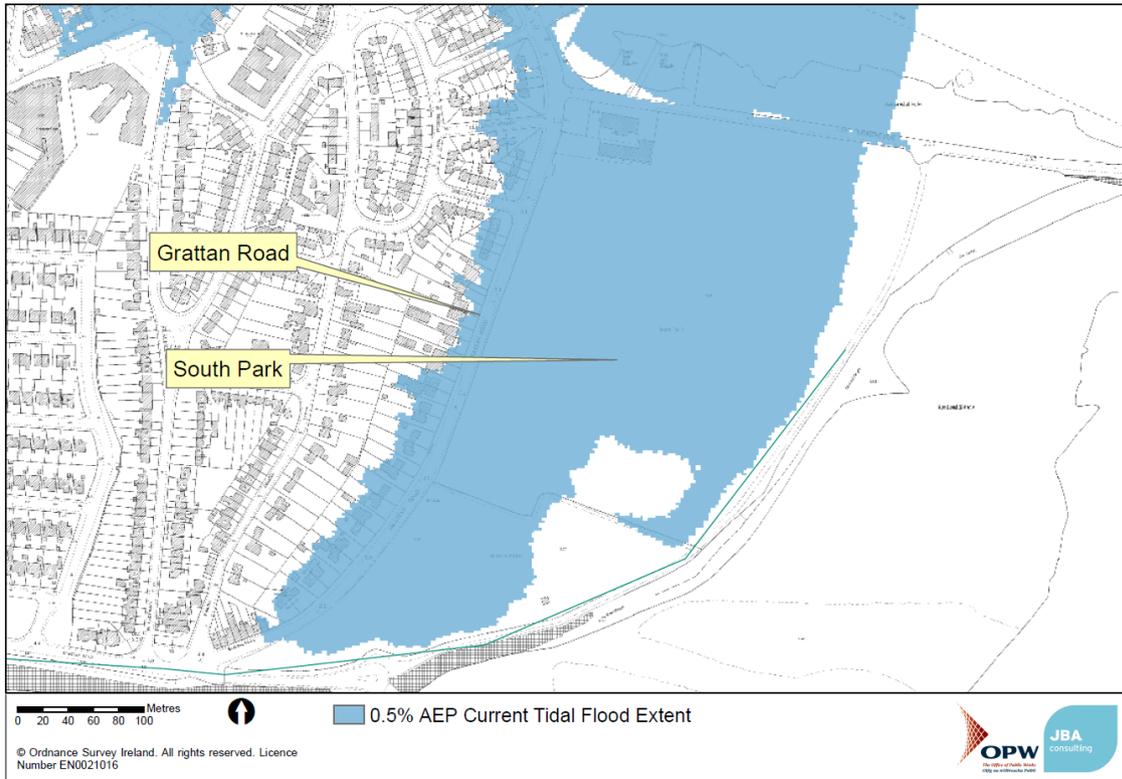
Figure 1-5: Overview of still water level (tidal) flooding at Spanish Arch



1.2.4 Flooding at Claddagh

Figure 1-6 shows an overview of the 0.5% AEP tidal flooding at the Claddagh area of Galway City. Low lying areas within South Park are affected along with the properties adjacent to Grattan Road.

Figure 1-6: Overview of still water level flooding Claddagh area



1.2.5 Flooding at Father Griffin Road

Figure 1-7 and Figure 1-8 Figure 1-6 shows an overview of the 0.5% AEP tidal flooding at Father Griffin Road

Figure 1-7: Overview of fluvial flooding at Father Griffin Road

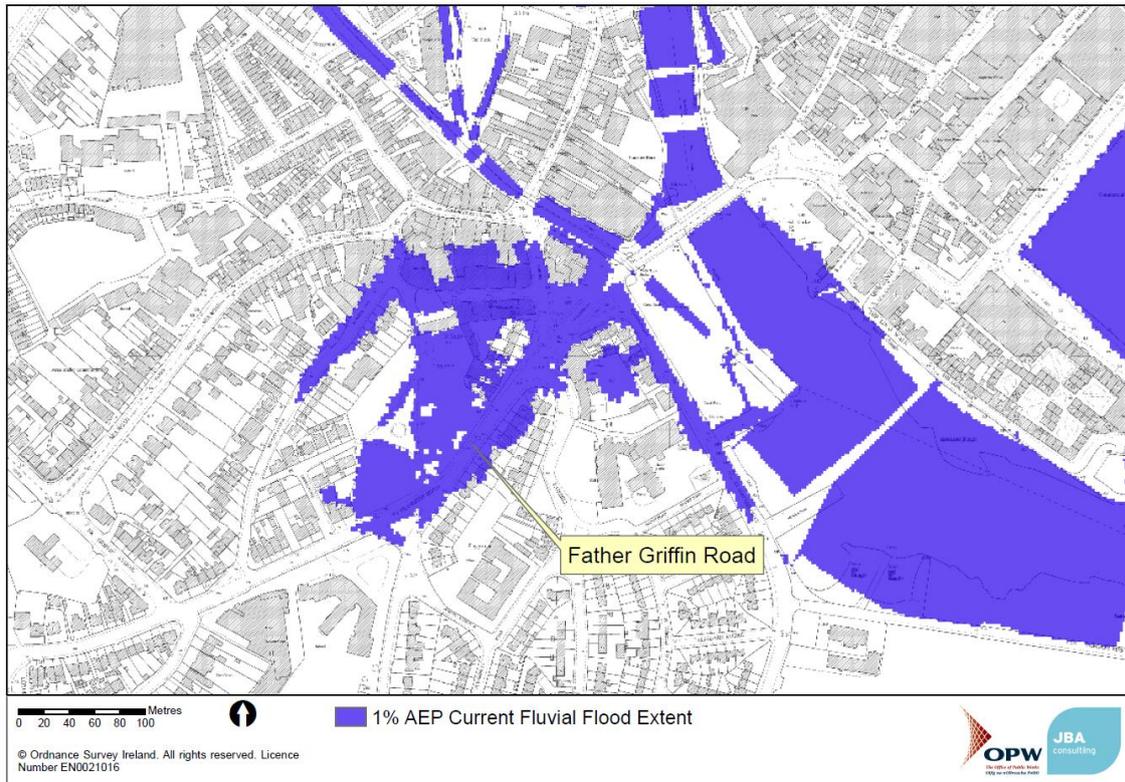
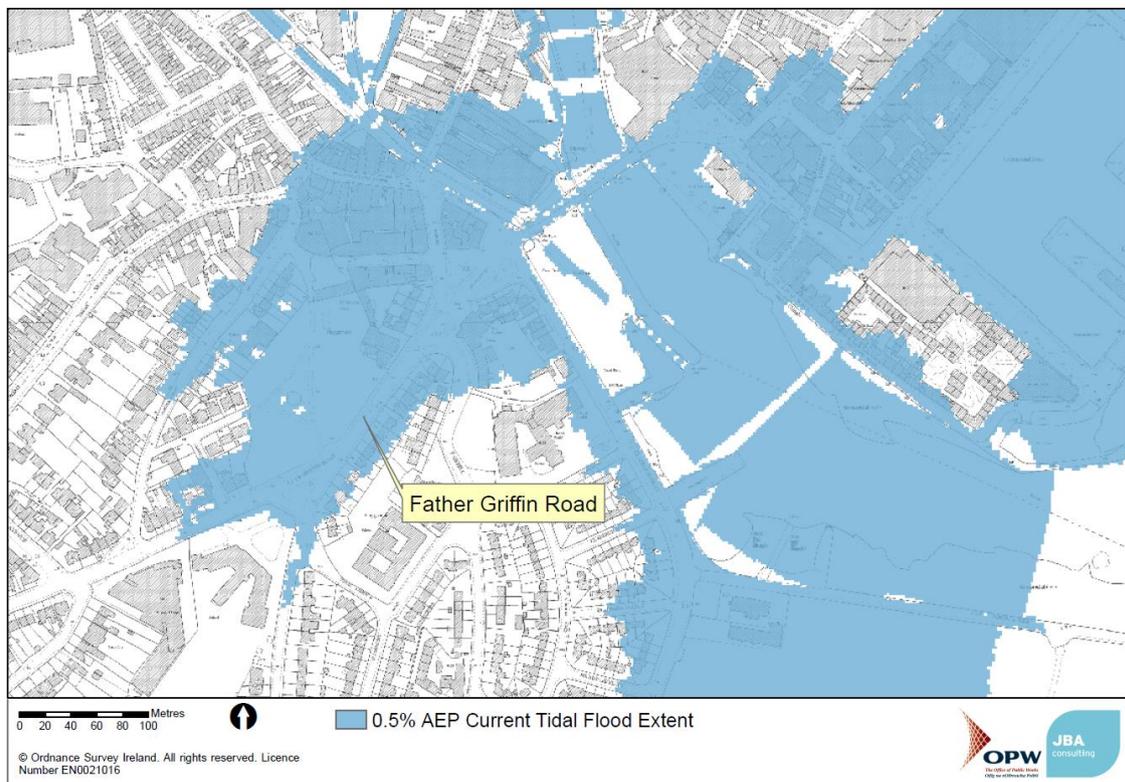


Figure 1-8: Overview of still water level flooding at Father Griffin Road



1.2.6 Future Flood Risk

The future scenarios, based upon the CFRAM specification climate change projections significantly alter the profile of flood risk in Galway City. Figure 1-9, Figure 1-10 and Figure 1-11 below show the current and medium range future extents for the 1% AEP fluvial and 0.5% AEP tidal design events. The increase in sea level of 500mm over the course of the next 100 years under the medium range forecast is the main driver of flood risk in the lower reach of the River Corrib. The 500mm increase in sea level will lead to more frequent flooding with depths increasing dramatically for the 1% event. The fluvial MRFS flood risk is driven largely by the tidal boundary (rise in sea level) not the increased fluvial inflow. The downstream boundary of the fluvial hydraulic model is subject to the sea level increase, hence the flood increased extent shown in Figure 1-10. The fluvial risk at the Dyke Road embankment increases also with overtopping predicted to occur. The overtopping at Dyke Road does not affect properties. This flood risk will be examined later in section 4.8, climate change adaptation.

Figure 1-9: Current and future (MRFS) 0.5% AEP tidal flood extent

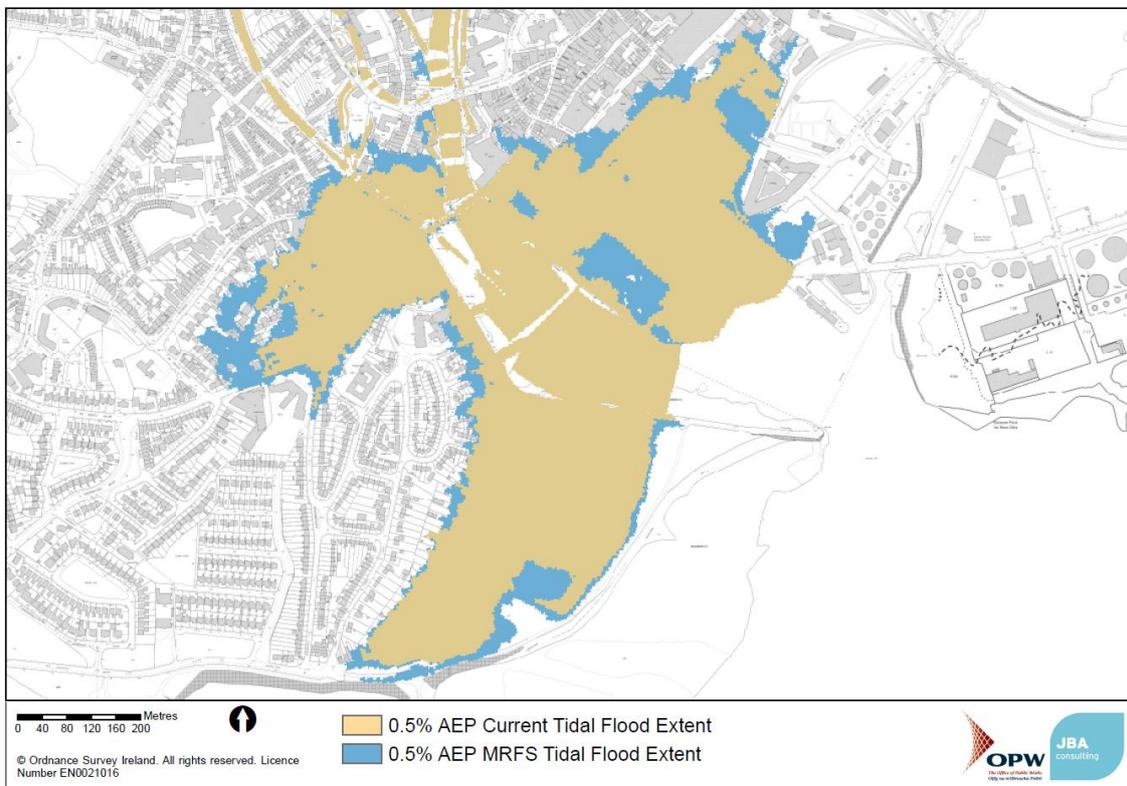


Figure 1-10: Current and future (MRFS) 1% AEP fluvial flood extent downstream

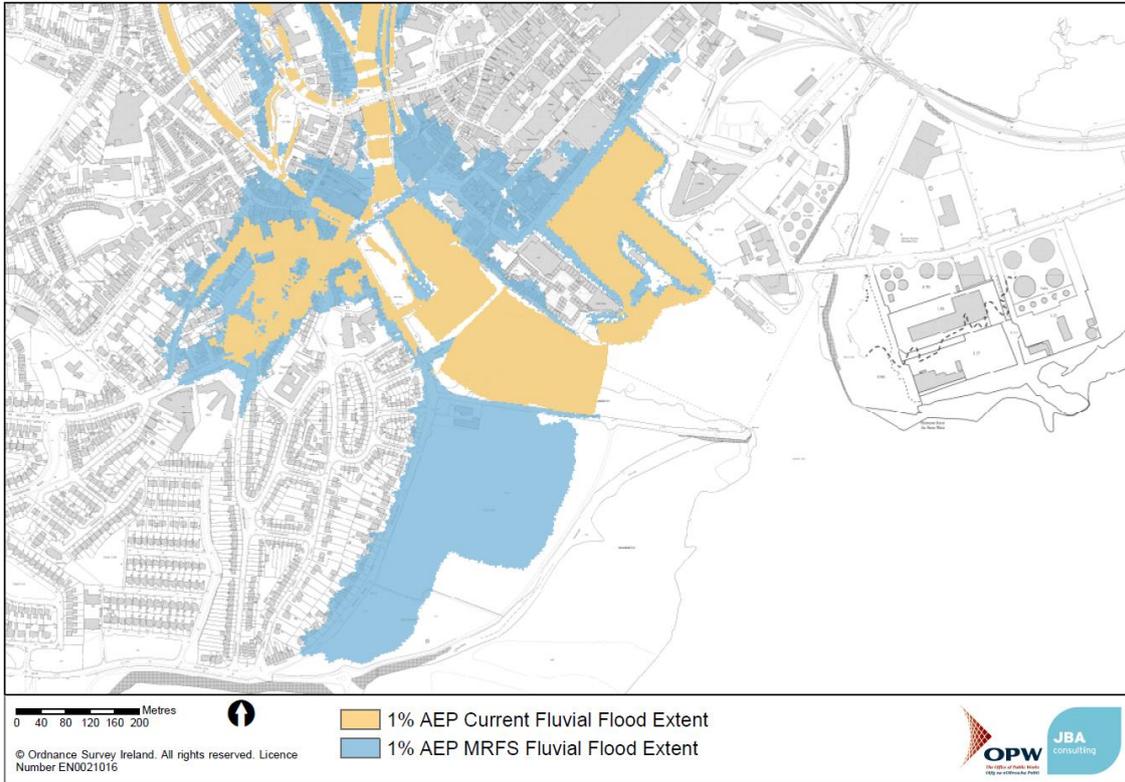
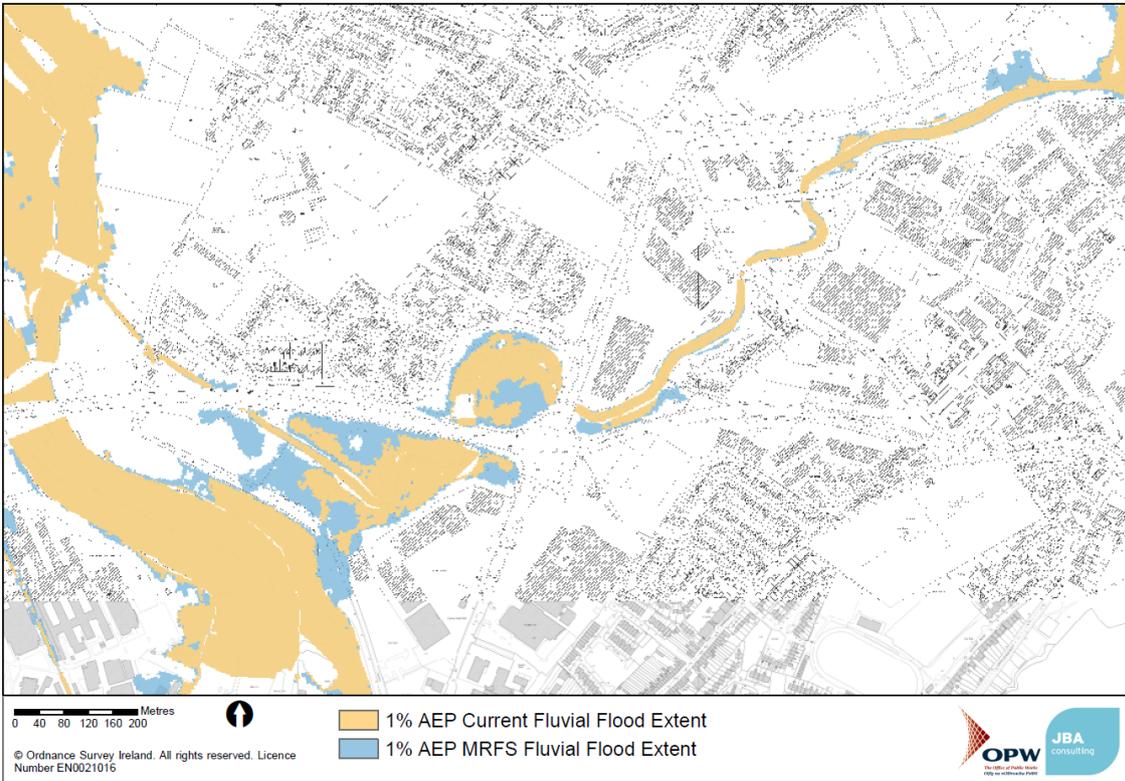


Figure 1-11: Current and future (MRFS) 1% AEP fluvial flood extent Dyke Road and Terryland



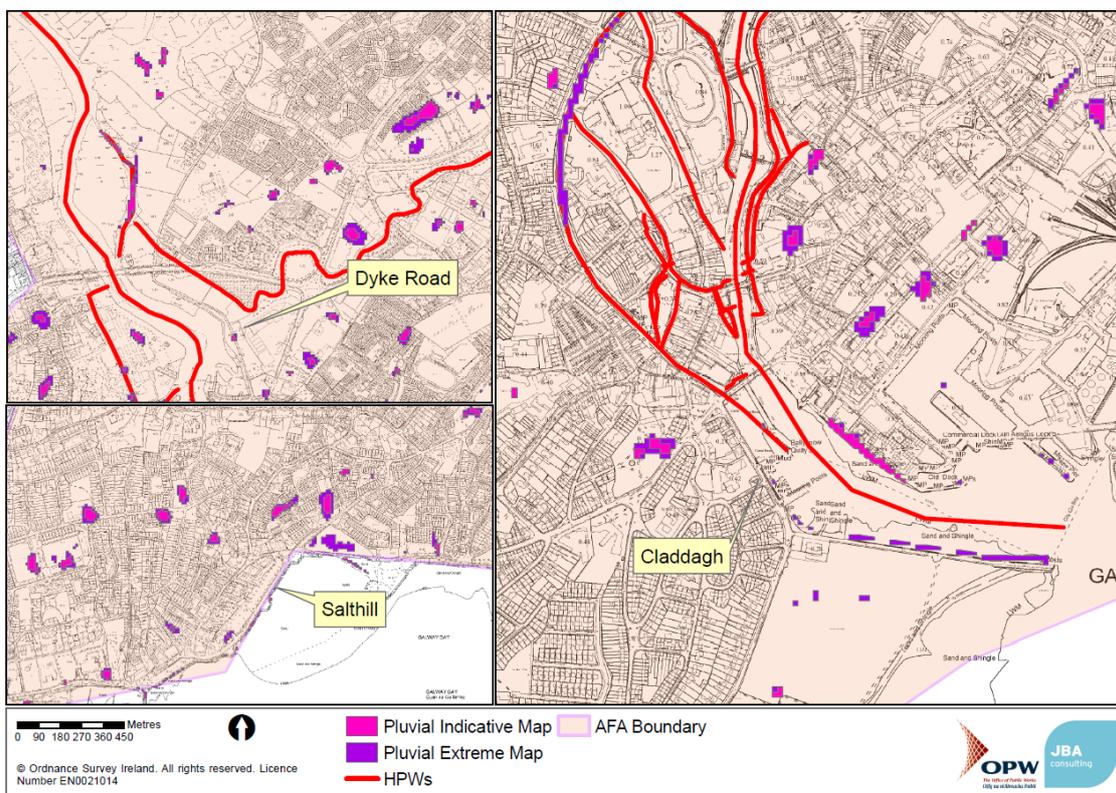
1.2.7 Pluvial, Groundwater and Sewer Flood Risk

There is a moderate risk of pluvial in Galway City. The pluvial risk from the PFRA is indicated in Figure 1-12. This risk will need to be considered as part of any flood management methods.

There is a groundwater flood risk in the Castlegar and Terryland area. Water in this area discharges through a sinkhole which can back up cause flooding. This isn't a high flood risk based on the lack of past flood events impacting on any property but it is a risk to be noted.

There is a sewer flood risk is present in the areas of Spanish Arch and Dock Road. This is from backing up of drains during high tides so a pumping station may be needed to avert this flood risk. From consultation with Galway City Council is was confirmed to be an issue and they may be putting a plan in place to address the problem.

Figure 1-12: Pluvial flood risk maps



Although there are some karst features in the Galway City AFA, no historic flooding has occurred from groundwater flooding. Groundwater flooding is outside the scope of this CFRAM study but it has to be considered as part of any flood management method.

1.3 Economic Benefit

To provide an understanding of the likely scale of a cost beneficial scheme within Galway, a preliminary assessment of the benefits associated with the protection of properties to the 1% AEP fluvial event and to the 0.5% AEP coastal event has been completed, this is effectively the design standard event at the AFA level and assumes any scheme will remove all properties from the 1% AEP fluvial and the 0.5% AEP flood extent. Full details of the methodology used to determine these benefits are set out in Appendix A.

There is no flooding in the current 1% AEP fluvial event and all damages shown are associated with the 0.5% AEP coastal event. Uncapped benefits for the whole AFA are €8.26m. For the MRFS 1% AEP fluvial event and the 0.5% AEP coastal event, uncapped damages increase to €191m. This reduces with capping to €99.3m.

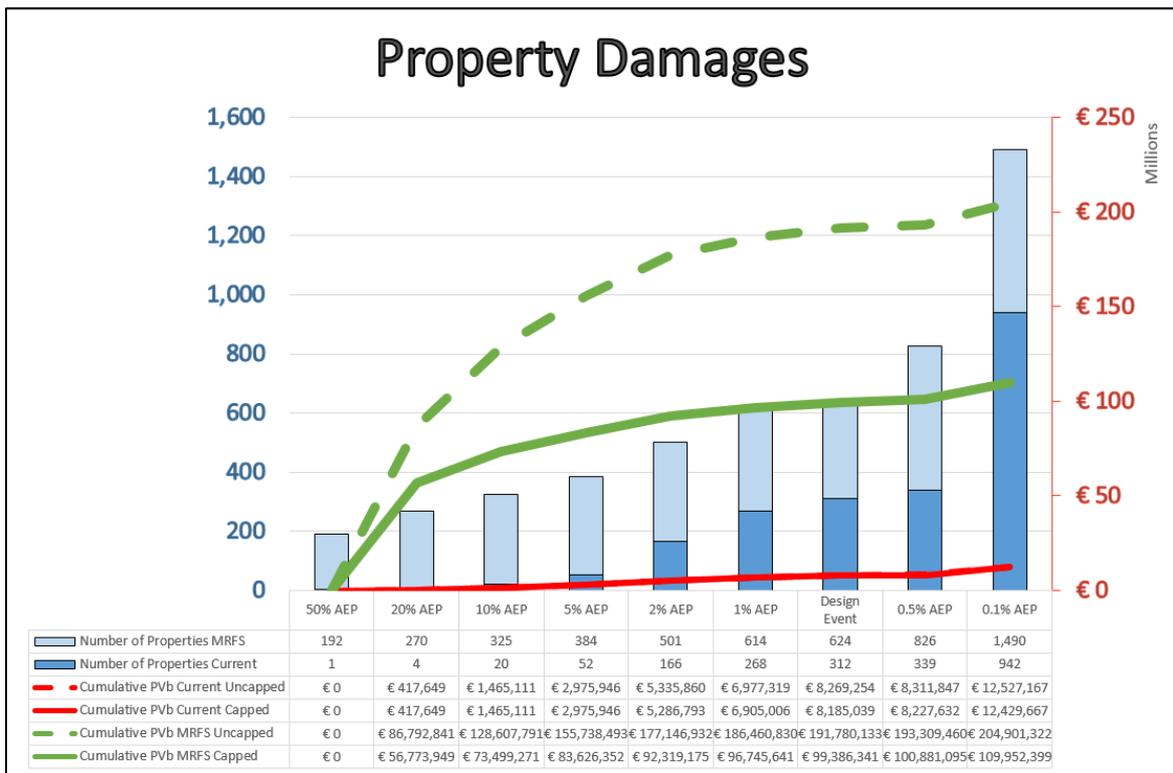
1.3.1 Flood Cell Economic Benefit

Table 1- shows the number of properties flooding during the different design events and the cumulative damages for each return period for the current event within the Galway City flood cell 1. Figure 1-14 gives shows the distribution of property damages in Galway City.

Figure 1-13 show the number of properties flooding during the different design events for both the current and MRFS events. They also show the cumulative damages for each of the return periods which can be presumed to give a rough indication of likely scheme benefits associated with a given standard of protection

It should be noted that damages due to traffic disruption have been excluded from the calculation of the economic damages, as it will typically not be significant within the overall damages. This may not be the case in Galway, where significant parts of the inner city network would close causing considerable disruption. Galway does not currently have a ring road so there is a considerable amount of through traffic. Without a detailed traffic flow analysis, it is not possible to estimate such damages. This should be considered in the any scheme taken forward to detailed design for the area.

Figure 1-13: Current Scenario - Property Damages (Note: The design event column is the 1% fluvial and the 0.5% AEP tidal damages)



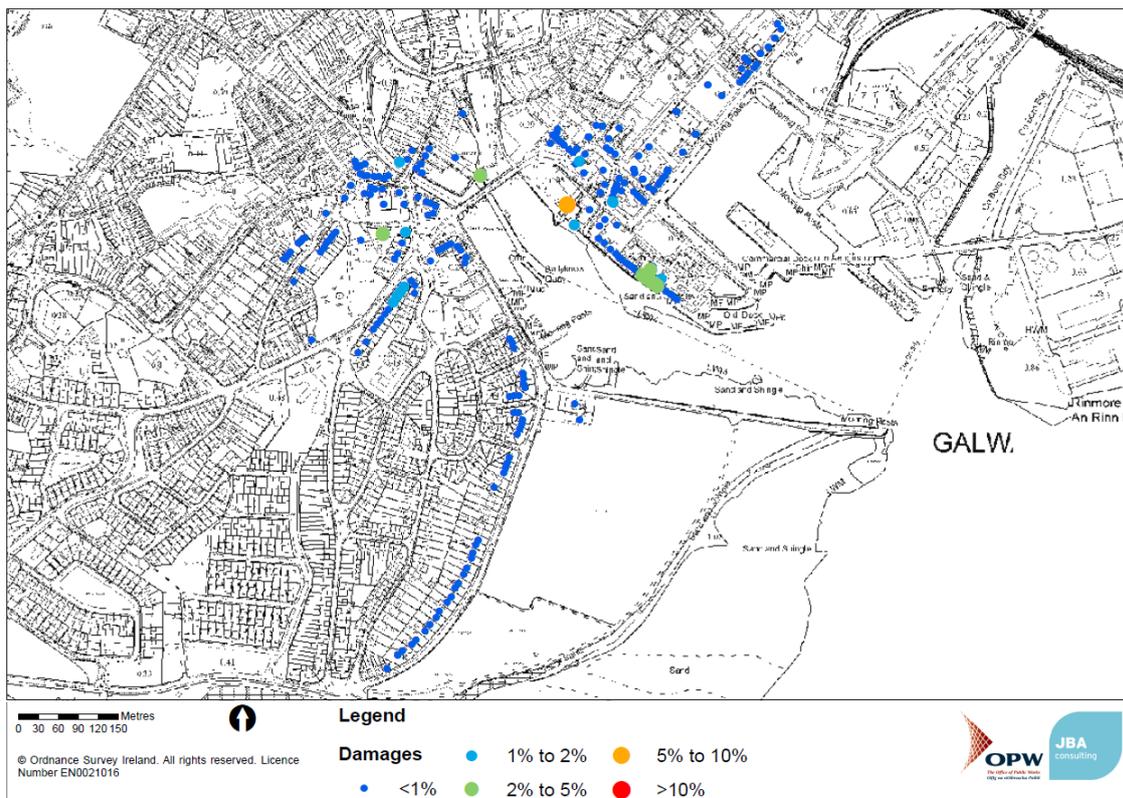
1.3.2 Flood Cell Economic Benefit

Table 1- shows the number of properties flooding during the different design events and the cumulative damages for each return period for the current event within the Galway City flood cell 1. Figure 1-14 gives shows the distribution of property damages in Galway City.

Table 1-2: Flood Cell 1 - Galway City Property Damages (current) Capped

	Return Period (% AEP)								
	50%	20%	10%	5%	2%	1%	Design Event	0.5%	0.1%
	Current								
No. of properties	1	4	20	52	166	267	305	332	923
Flood Cell 1: Galway City ((€million)	0	0.417	1.465	2.975	5.286	6.905	8.185	8.213	12.333

Figure 1-14: Distribution of property damages Galway City



Similarly, Table 1- show the same data for the current event in the Flood Cell 2 - Salthill. Figure 1-15 gives shows the distribution of property damage in Salthill. Only four properties are shown, however seven properties are impacted. This is because some properties share the same postal address but are independent buildings adjacent to each other and therefore have been plotted on the same point.

Total damages in the 0.5% AEP design event only amount to €14,541. With flooding of properties only experienced in the 1% AEP. Wave overtopping is a complex process controlled by the state of the sea (depth, wave properties) and the geometry of local flood defences. There are some uncertainties inherent in the modelling process of wave overtopping such as the manual schematisation of flood defences, the initial wave heights, the storm duration and the output results being estimates of the mean overtopping discharge rather than the exact values. Wave overtopping values are based on the ICPSS² and ICWWS³ still and wave data. The results may not replicate the frequency of flooding and appear to under estimate damage. Wave overtopping occurs regularly but limited property damages occurs. It should be noted that the Leisure Centre used to flood frequently but has since been removed from the flood extent due to the construction of an embankment. Further studies are needed to confirm damages for Salthill.

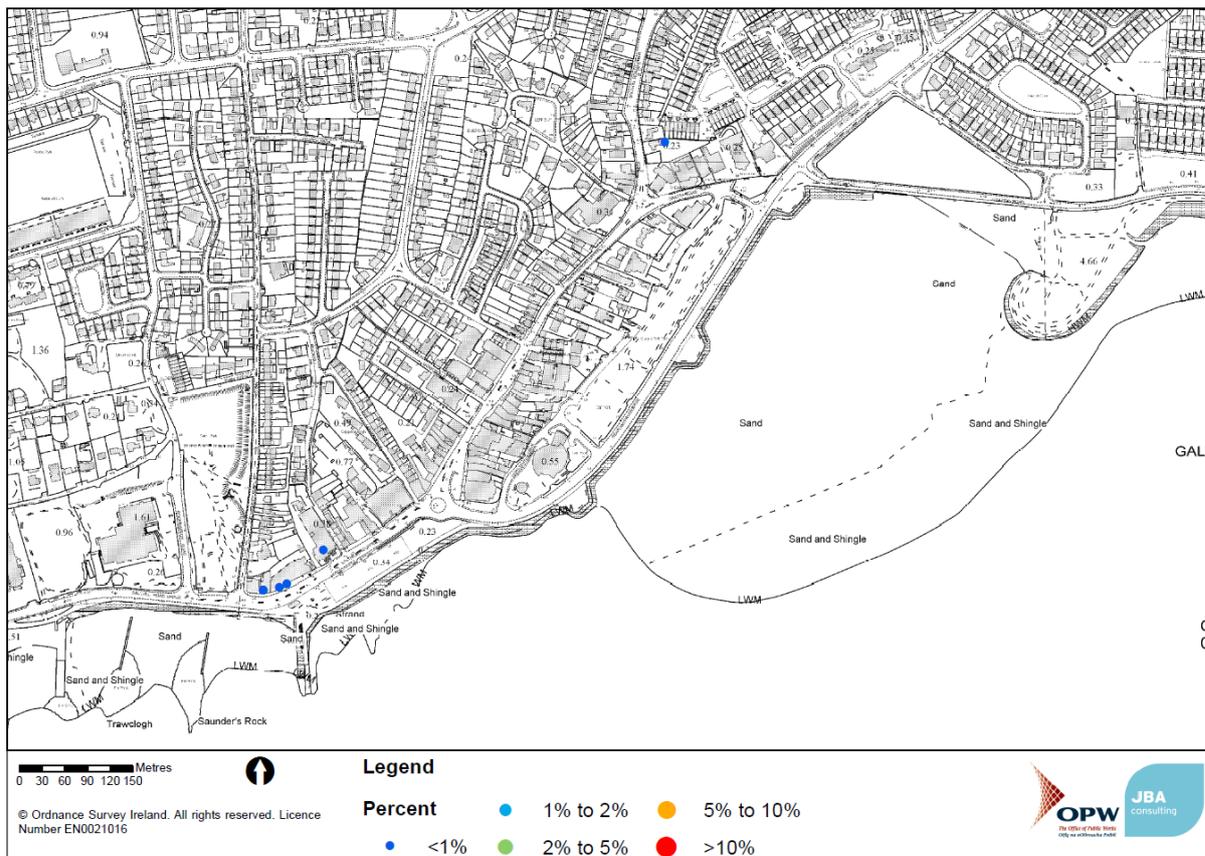
Table 1-3: Flood Cell 2- Salthill Property Damages (current) Capped

	Return Period (% AEP)						Design Event	0.5%	0.1%	
	50%	20%	10%	5%	2%	1%				
	Current									
No. of properties	0	0	0	0	0	1	7	7	19	
Flood Cell 2: Salthill (€)	0	0	0	0	0	312	14,541	14,541	96,426	

² Irish Coastal Protection Strategy Study - <http://www.opw.ie/en/floodriskmanagement/floodanderosionmapping/icpss/>

³ Irish Coastal Water Level and Wave Study

Figure 1-15: Distribution of property damages Salthill



1.3.3 Commercial Properties where 0.1% Design Event Damages Exceeded €500,000

OPW guidance states the requirement for a survey of the threshold levels for flooding of major commercial properties (those with estimated potential damages greater or equal to €500,000 for an event of annual exceedence probability of 0.1% in the AFA). In Galway 7 properties were highlighted and their thresholds were surveyed. This are listed in Table 1-3.

Table 1-3: Commercial Properties with Damages exceeding €500,000

Property Number	Easting	Northing	LiDAR Level (0.15 threshold)	Surveyed Threshold Level
1	129850.24	226095.56	5.36	5.50
2	129926.71	226119.32	5.48	5.56
3	129974.24	226131.54	5.40	5.54
4	130006.83	226131.54	5.29	5.60
5	130059.79	226151.23	5.27	5.25
6	130271.80	226405.98	5.55	5.98
7	130450.82	226724.82	5.11	5.44

All the above properties only flood in the 0.1% Fluvial Event. The individual changes in damages is shown in Table 1-2 and this results in a €2,224,212 reduction in 0.1% event damages but does not affect the design event damage.

Table 1-2: Change in 0.1% Damages based on the threshold survey

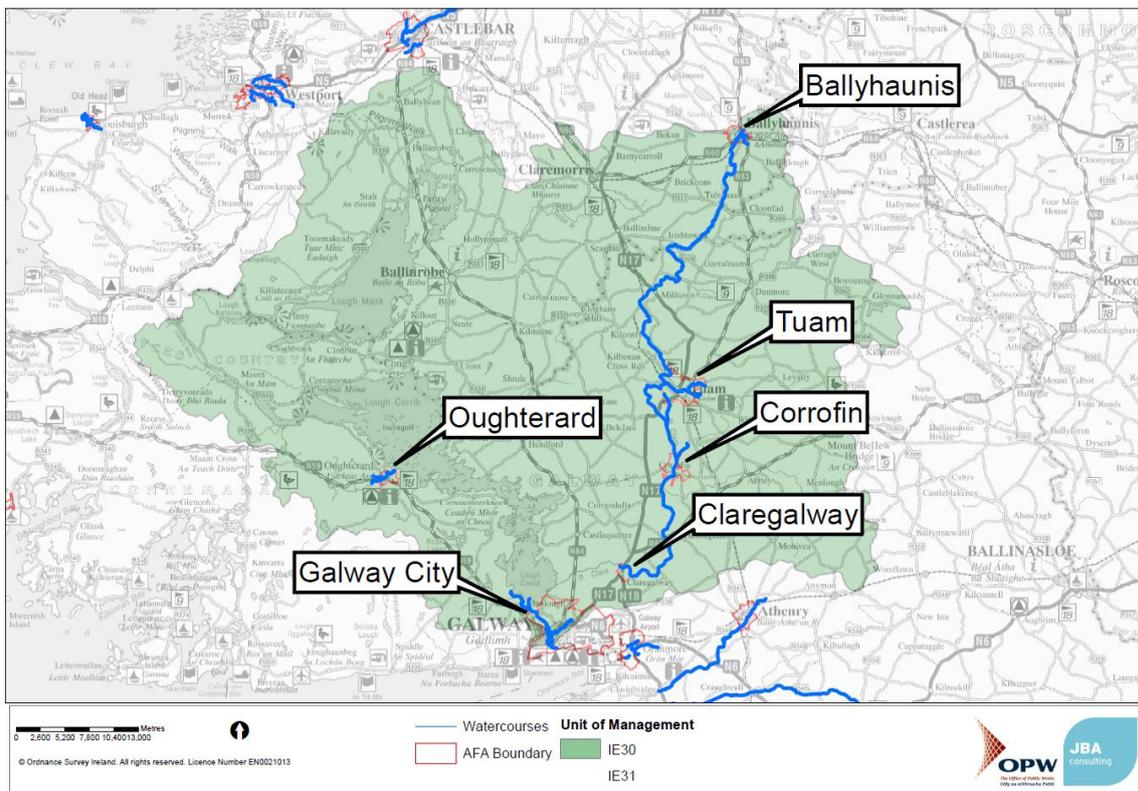
Property Number	AREA (m ²)	Level of Flooding (m AOD)	Depth of Flooding (LiDAR) (m)	Damages € (LiDAR)	Depth of Flooding (Threshold) (m)	Damages € (Threshold)	Difference in the 0.1% AEP Damages €
1	1,059	6.039	0.670	573,495	0.539	453,787	119,706
2	2,319	6.030	0.547	1,442,918	0.470	1,118,342	974,124
3	567	6.029	0.621	534,641	0.499	506,584	28,057
4	1,602	6.028	0.728	2,329,913	0.428	1,401,822	928,091
5	1,992	6.026	0.748	1,694,909	0.776	1,744,451	-49,542
6	1,252	5.980	0.429	603,133	0.300	404,353	198,780
7	1,291	5.544	0.430	469,308	0.404	444,312	24,996
Reduction in 0.1% AEP Event Damages							2,224,212

2 Scheme Spatial Scales of Assessment

2.1 Overview

This section documents the analysis of spatial scales of assessment and the identification of flood cells for Galway City in terms of options appraisal. The interactions between flood risk, hydrology, hydraulic, economic, social, cultural and environmental aspects of Galway City have been considered. Figure 2-1 shows the location of Galway City in relation to other AFAs within the Corrib UoM. This section will discuss the hydraulic connectivity of the site with other AFAs and in particular, justify where there is no such interconnectivity.

Figure 2-1: Corrib UoM Overview



2.2 Spatial Scales of Methods

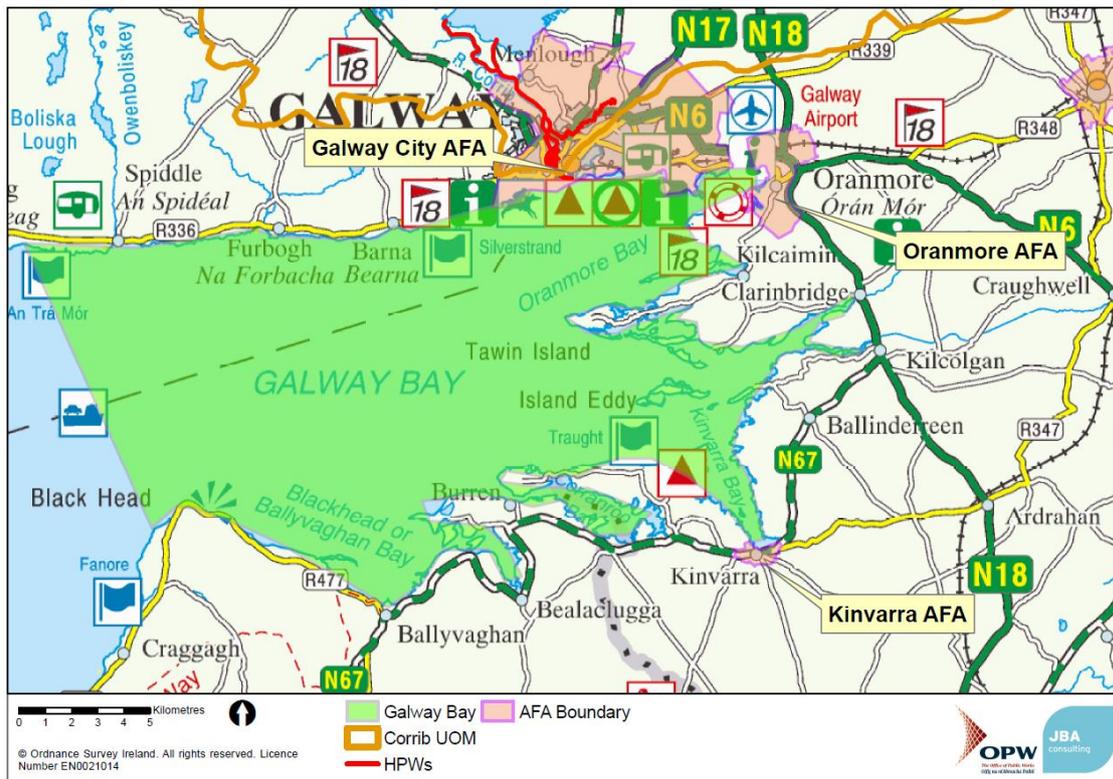
2.2.1 Unit of Management Spatial Scale

There are multiple AFAs within the Corrib Unit of Management, all of which are upstream of Galway City. These are Ballyhaunis, Tuam, Claregalway, Corrofin and Oughterard. Non-structural methods such as planning and development control, SuDs, targeted public awareness campaigns and development of emergency plans will be assessed at the UoM scale in cooperation with the relevant authorities.

2.2.2 Sub-Catchment Spatial Scale - Galway Bay

Galway City is located at the northern side of Galway Bay. Both the Galway City and the Oranmore AFA are situated along the northern coastline of the Galway Bay, Figure 2-2. Tidal flooding is predictable and tends to coincide with the scheduled high tide. The consideration of a forecasting system in conjunction with other AFAs in the same area, namely Oranmore and Kinvarra is appropriate at this spatial scale. Forecasting on the River Clare / Corrib with a catchment area of over 1,000km² has been investigated.

Figure 2-2: AFAs within Galway Bay



2.2.3 AFA Spatial Scale - Galway City

Localised structural methods will be assessed on an AFA scale. This will include analysing the suitability of flood containment methods. Any containment methods in Galway City will not have an effect on water levels in other AFAs due to Galway City being downstream of these other AFAs. Any flood method within the bay is likely to impact on the SAC. In the case of flood containment methods, with required construction adjacent to an SAC these impacts should be mitigated and accounted for.

2.3 Key Environmental, Social and Cultural Constraints

This section summarises the social, cultural and environmental issues relating to flood risk in Galway City and the spatial scales to be considered.

2.3.1 West of Ireland (Mayo, Galway, Sligo)

Galway City is the largest urban centre within the province of Connaught and the West of Ireland. It is also the fourth most populous city in the Republic of Ireland. The city is located at the mouth of the River Corrib with the main urban centre extending outwards from the banks of the Corrib and along the coast line. The National Spatial Strategy identified Galway City as a Gateway city, which by context means the concentration of population, education and job opportunities within the city are favourable for future growth.

The city's location means it is vulnerable to different types of flooding including fluvial, coastal and wave overtopping. The city has been historically known for its flooding and this was seen again more recently in the storms of winter 2013/14. The flooding of parts of Galway City may well have an impact on its hinterland and also may impact the wider economic-socio development of the rest of Ireland. Many tourists are attracted to Galway City where the unique urban landscape is coupled with historic canals and open sea views. Any damage by flooding will impact these amenities and facilities available to tourists such as cafes, pubs and restaurants.

In terms of any environmental impact, Galway Bay is a designated SAC and the Natura 2000 designated site. These are important internationally and so any detriment to the habitats or species could potentially have an impact on a European scale.

The Architectural Conservation Areas in Galway City are of importance from a historical and cultural perspective. These areas can be open places or groups of structures. In relation to the prevention of flooding, structural methods may alter the characteristics of these designated areas. Long Walk, Lower Dominic Street and Dock Road are all designated conservation areas within Galway City in which flood risk is present.

2.3.2 Galway Bay

The coastline of Galway City along with the River Corrib itself is part of the Inner Galway Bay SAC. The features of interest and conservation objectives of these European designations are likely to require a full Natura Impact Statement as part of the Appropriate Assessment for projects or plans. All structural and some non-structural flood management methods are likely to have impacts through surface water, land & air and groundwater pathways.

Table 2-1: Designated Sites of International Importance⁴

Description	Extent	Designation
Galway Bay Complex cSAC	Marine, intertidal and coastal areas from Silverstrand around the inner bay area to Oranmore Bay including some adjoining wetlands and woodland areas.	Proposed Natural Heritage Areas, Ramsar Site (wetlands of international importance).
Lough Corrib Complex cSAC	River Corrib and islands and bordering wetlands and terrestrial habitats of ecological merit.	Lough Corrib SPA, Proposed Natural Heritage Areas, Ramsar Site.
Inner Galway Bay SPA	Marine and intertidal area including Galway Bay, Lough Atalia and Lough Rusheen.	Inner Galway Bay SPA, Proposed Natural Heritage Areas, Ramsar Site.

On a local scale Galway City has many pubs, cafes and shops that are affected during flood events. Flooding is likely to affect this trade as will disruption during construction of any structural methods. The city's location and scenic views within an urban backdrop is an essential amenity of the town and the town's tourist trade is reliant on these picturesque views being maintained.

⁴ Galway City Development Plan 2011-2017

3 Screening of Possible Methods and Options

3.1 Introduction

A flood risk management option consists of one or more combinations of flood risk management methods; a method being one distinct approach to flood risk management in a specific location such as a flood wall or flood warning system. Flood risk management options consist of all methods required to deliver mitigation at the relevant spatial scale.

This section provides an overview of the screening of all possible flood methods to arrive at a suite of viable methods that have then been carried forward to detailed modelling and the identification of feasible options in Section 4. The purpose of the screening process is to filter out methods that are not acceptable or viable either alone or in combination with other methods, for the SSA under consideration.

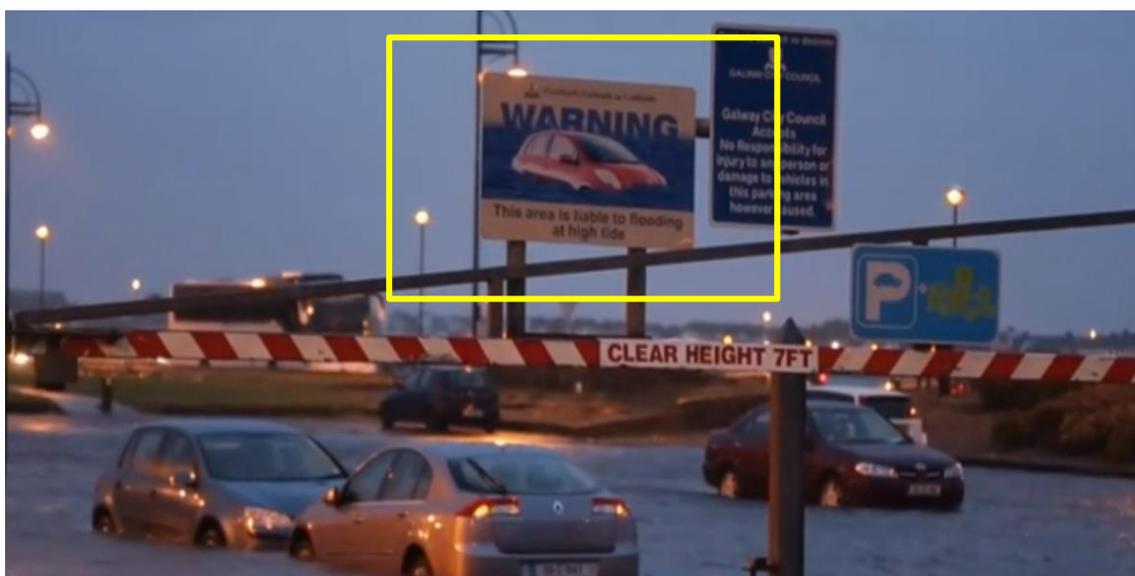
3.2 Existing Scenario

To analyse the impact of flood management methods it is first necessary to assess the existing scenario. Currently, the OPW issues a high tide advisory. The OPW uses a national tidal and storm surge forecasting system along with a European Flood Awareness System (EFAS) which provide provides probabilistic early flood forecasting information. This high tide warning is issued to local authorities. Galway City and local newspapers are proactive in issuing warnings through various forms of media such as twitter, Facebook, see Figure 3-1 and have even erected warning signs in areas of known flood risk. But even with these warnings, damage to cars still occurs. Figure 3-2 shows a sign in a Salthill car park that is prone to flooding with advisory signs and cars flooded in the background. This is a photograph from an event in August 2015.

Figure 3-1: Flood warning on the 6th October



Figure 3-2: Flood warning and flooded cars, August 2015⁵

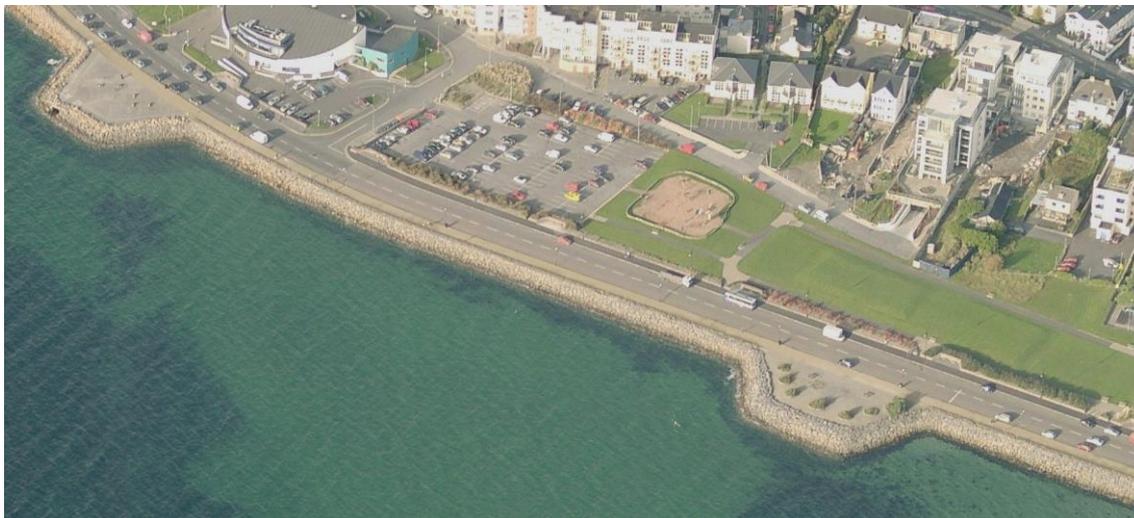


The existing coastline along Salthill consists of an earthen embankment that is rock armour protected on the seaward side. This type of defence is not a formal defence as identified by the

⁵ Connacht Tribune

OPW and its maintenance regime is unknown. Figure 3-3 is an aerial photograph showing the coastline described at Salthill.

Figure 3-3: Salthill Promenade⁶



Galway City have used a temporary barrier recently along the Spanish Arch quay wall. This defence is shown in Figure 3-4 and involves inflating a plastic tube with water to provide a barrier to the incoming tide and therefore preventing flooding. The dam was first used in January 2015 at Spanish Arch.

Figure 3-4: Temporary flood defence⁷ at Spanish Arch

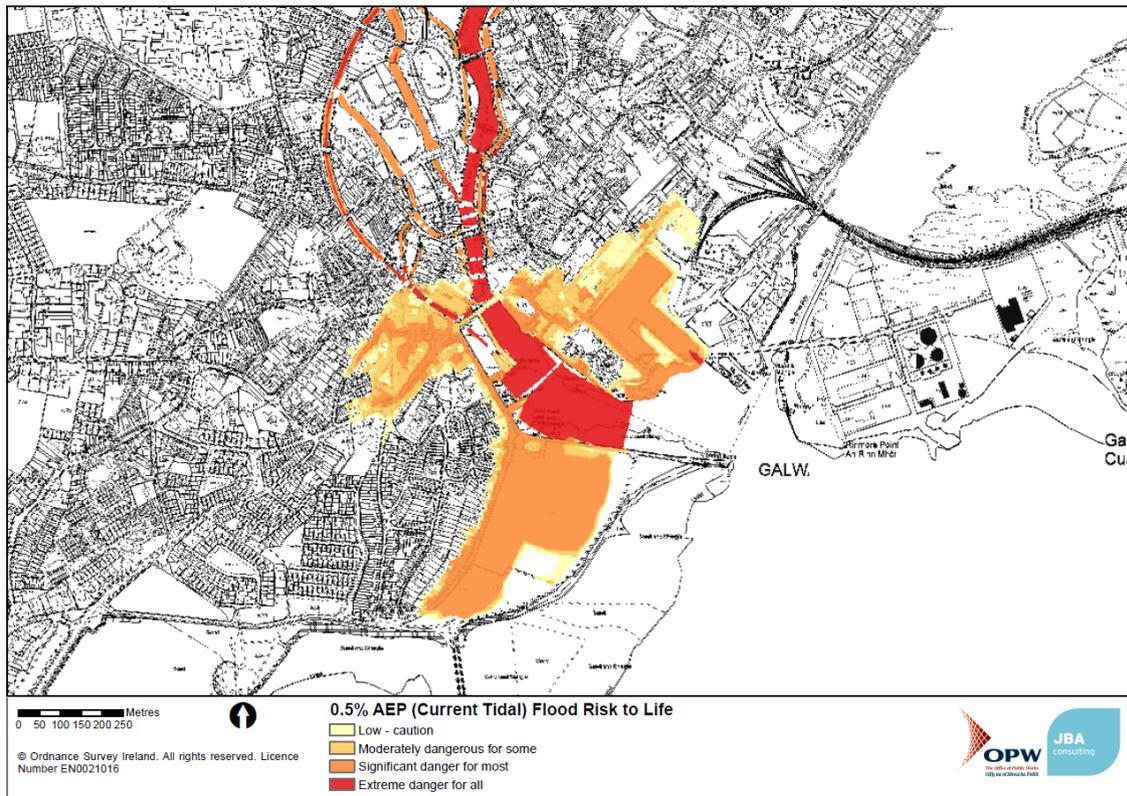


Flood hazard maps have been produced that show the 'Risk to Life'. These indicate the level of risk to human life based on depth and velocity. Figure 3-5 shows the risk levels in Galway City in the current scenario. An economically, environmentally and socially acceptable solution to alleviate flooding is sought to protect the town.

⁶ Bing Maps

⁷ <https://vimeo.com/117614740> - "Galway City Council Install Flood Defence at The Spanish Arch" from Galway City Council

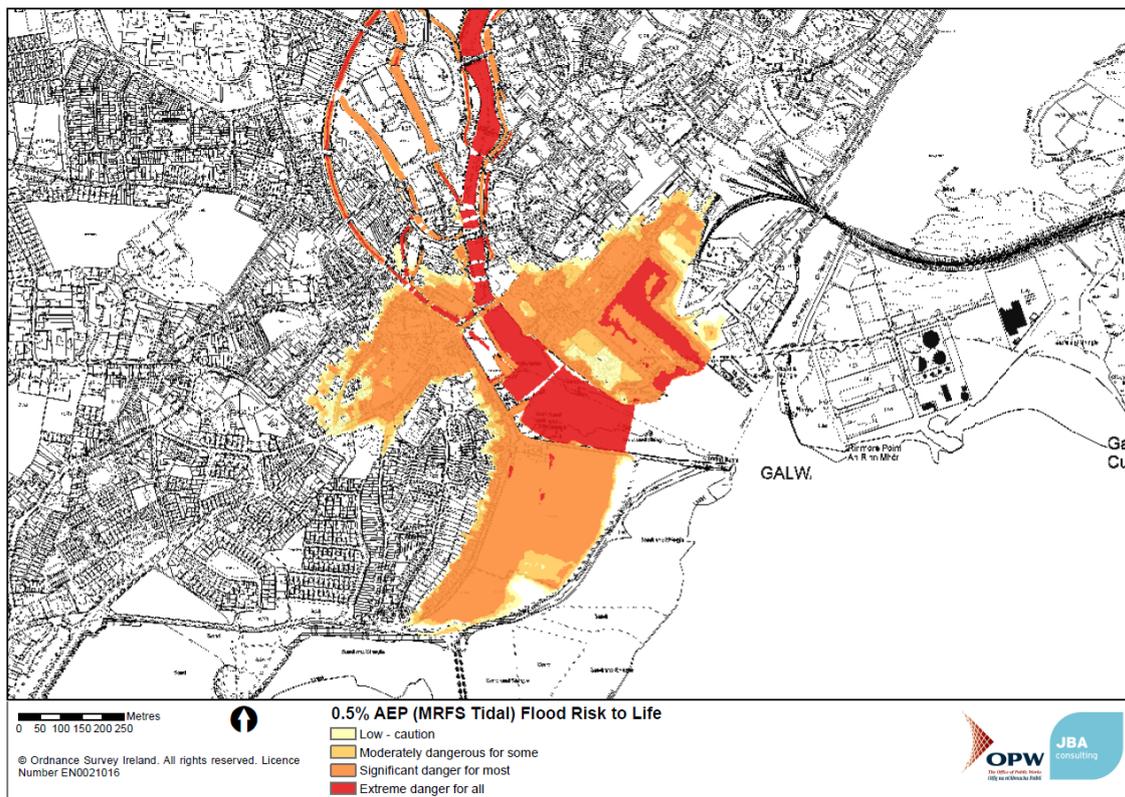
Figure 3-5: 'Risk to life' mapping Current Scenario



3.3 Future Scenario

The area of land flooded which poses a significant danger to most significantly increases with climate change. There are some areas of extreme danger to all. With extensive exposure to high flood hazard all people and buildings will be vulnerable, irrespective of their age, health and wellbeing. Figure 3-6 shows the risk levels in Galway City in the MRFS scenario.

Figure 3-6: 'Risk to life' mapping MRFS Scenario



3.4 Screening of Possible Flood Risk Management Methods

The objective of the screening process is to develop a long list of technically feasible and economically viable methods to feed into the option identification stage. Options have only been discounted at this stage on technical, environmental, health and safety or economic grounds, however, the process has also required social and adaptability constraints identified as part of the work to be recorded to support the further development of options and the SEA process.

Details of the cost estimates are provided in Appendix A and an overview of the screening considerations for environmental and social constraints is provided in Appendix C.

Information was recorded under the following criteria as follows:

- **Technical** - Methods were screened on feasibility only, requiring a high level description of what the likely method would entail. Where methods were not considered to be technically feasible or not relevant to the site no further consideration has been given.
- **Economic** - Technically feasible methods have been reviewed for economic viability. As noted previously, approximate average annual benefits of protecting to a 0.5% AEP event standard are €8.18 million. Any standalone methods or combination of methods will be required to cost less than this, in order to achieve a benefit cost ratio of 1:1. Method factors are used also which adjusts the total capital cost for each method based on known and particular site issues and constraints.
- **Health and Safety** - The degree of health and safety risk during construction and operation was assessed at a level appropriate to the screening stage. Risks have been recorded for future reference, however if the risk could not be managed or mitigated then the method was screened out.
- **Environmental** - The environmental screening has made use of the SEA scoping report and has taken into account the key environmental constraints noted in Section 2.2. Methods may be rejected on the basis that a method may have a detrimental impact on an environmentally or culturally valuable or protected site, and may need to complete the costly IROPI process to proceed.

Table 3-1 shows the results of the screening process for each method considered. A method can Pass or Fail the above criteria. A method must pass all four criteria to be considered viable. The below criteria were also considered at the screening stage however methods were not rejected based on these criteria but the key constraints were noted.

- **Social and Cultural** - Again methods were not rejected based on social and cultural constraints at the screening stage however the constraints were noted.
- **Adaptability to Climate Change** - The likely impacts of climate change have been assessed at an early stage to determine the suitability of identifying methods based on current flood risk, where there is a significant increase in flood risk in the future, methods will need to be reviewed in light of this risk. Galway City is significantly affected by the effects of climate change with damages increase from €8.18M in the current scenario to €99.3M in MRFS Scenario. Any methods preferred for the city will have to be sustainable and adaptable to the potential impacts of Climate Change.

Only structural methods have been screened. Non-structural methods such as planning and development control, SuDS, targeted public awareness campaigns and development of emergency plans will be assessed at the UoM scale and are detailed in the overarching UoM Report with issues relevant to this AFA discussed in Section 4.

Table 3-1: FRM Method Screening

Possible Flood Risk Management Method	Technical	Economic	Health and Safety	Initial Screening Result	Comment
Do Existing	Pass	Pass	Fail	Not Viable	<p>Due to the high proportion of properties of affected (312), there remains a high risk to life, which will increase with climate change. The "risk to life" maps show that there is a "significant risk to most" in the current scenario.</p> <p>A number of social infrastructure receptors will remain at risk of flooding or be disrupted. The amenity the promenade is significantly affected during an event.</p>
Tidal and coastal Methods					
Tidal Barrier	Fail	-	-	Not Viable	<p>There is not sufficient capacity behind the tidal barrage to contain the River Corrib when it closes for the period of high tide. This assumes the shortest route for tidal barrage across the mouth of the River Corrib downstream of Lough Atalia. It may also fail on environmental grounds and it would put a lot more freshwater into the naturally saline Lough Atalia. The tidal barrier would also have to be placed in a designated special area of conservation. As alternative options exist this method would not pass the Habitats Directive Appropriate Assessment, without demonstrating an Overriding Public Interest (IROPI) case.</p>
Flood Containment Methods					
Rehabilitation and extension of Existing Walls.	Pass	Pass	Pass	Viable	<p>There are very few walls in the current situation that are protecting Galway City from flood risk. Many of the walls in Galway City are not high enough and there are many gaps which mean the walls become ineffective in preventing flood risk.</p> <p>Specific details:</p> <p>The parapets along Wolf Tone Bridge could be to act as a retaining wall, and their connection detail to the bridge is unknown. Some parts of this parapet at Eglinton Canal may be of sufficient standard to be rehabilitated. Further condition assessment will prove whether this can or cannot be achieved.</p>
Walls	Pass	Pass	Pass	Viable	<p>Defence walls are required in a number of areas to defend Galway City to a 0.5% AEP tidal standard.</p> <p>Specific areas: Nimmos Pier: Discussed in section 3.4.1.1</p>

Possible Flood Risk Management Method	Technical	Economic	Health and Safety	Initial Screening Result	Comment
					Claddagh Quay: Discussed in section 3.4.1.2 Raven Place and Eglinton Canal: Discussed in section 3.4.1.3 Wolf Tone Bridge: Discussed in section 3.4.1.4 Spanish Arch/Merchants Quay: Discussed in section 3.4.1.5 Long Walk and New Dock: Discussed in section 3.4.1.6
Embankments	Pass	Pass	Pass	Viable	Embankment are viable in the following areas to defend Galway City to a 0.5% AEP tidal standard. Specific areas: Nimmo's Pier: Discussed in section 3.4.1.1 Salthill Area 1 Discussed in section 3.4.1.7 Salthill Area 2: Discussed in section 3.4.1.8
Demountable Walls	Pass	Pass	Pass	Viable	Demountable gates will be needed at numerous locations the AFA to provide access to slipways and quays.
Road Raising	Pass	Pass	Pass	Viable	Road raising is needed where roads form part of the defence line. Specific areas: Nimmos Pier: Discussed in section 3.4.1.1 Spanish Arch/Merchants Quay: Discussed in section 3.4.1.5 Long Walk and New Dock: Discussed in section 3.4.1.6 Salthill Area 3: Discussed in section 3.4.1.8
Flood Storage Methods					
River Corrib	Fail	-	-	Not Viable	Lough Corrib lies upstream up Galway City which naturally attenuates the flow reaching the city. The level is controlled by the operation of the Salmon weir. Enhanced control of water levels upstream in order to reduce fluvial flows would cause overtopping of upstream defences and elevated water levels on the canals. There would be significant environmental impacts as well. This method would not reduce the risk of tidal flooding.
Flood Conveyance Methods					
Flow diversion -	Fail	-	-	Not Viable	No flow diversion will reduce the risk in the current scenario. The fluvial risk is currently

Possible Flood Risk Management Method	Technical	Economic	Health and Safety	Initial Screening Result	Comment
using Flood Relief Culvert					managed on Nun's Island by a network of semi regulated canals, mill leats and channels. Enhancing these would not reduce upstream water levels in the Corrib, but could have significant impacts locally in the canal network.
Culvert upgrading works	Fail	-	-	Not Viable	No culvert upgrading will reduce the risk in the current scenario.
Individual Property Protection Methods					
Relocation of Properties	Fail	-	-	Not Viable	There are too many properties affected to for relocation. A lot these properties are the core centre of Galway Centre which is affected which is important to the economic growth of the city.

3.4.1 Flood Risk Management Areas

The screening of possible flood risk management options in Galway City was broken down and examined in a number of areas. These areas were chosen based on the nature of the area, type of options been considered and the location of each area. The areas are shown in Figure 3-7 and Figure 3-8. The areas will be discussed individually in the following sections as:

- Nimmos Pier
- Claddagh
- Raven Place and Eglinton Canal
- Wolfe Tone Bridge
- Spanish Arch/Merchants Quay
- Long Walk and New Dock
- Salthill Area 1
- Salthill Area 2

Figure 3-7: Galway City Areas

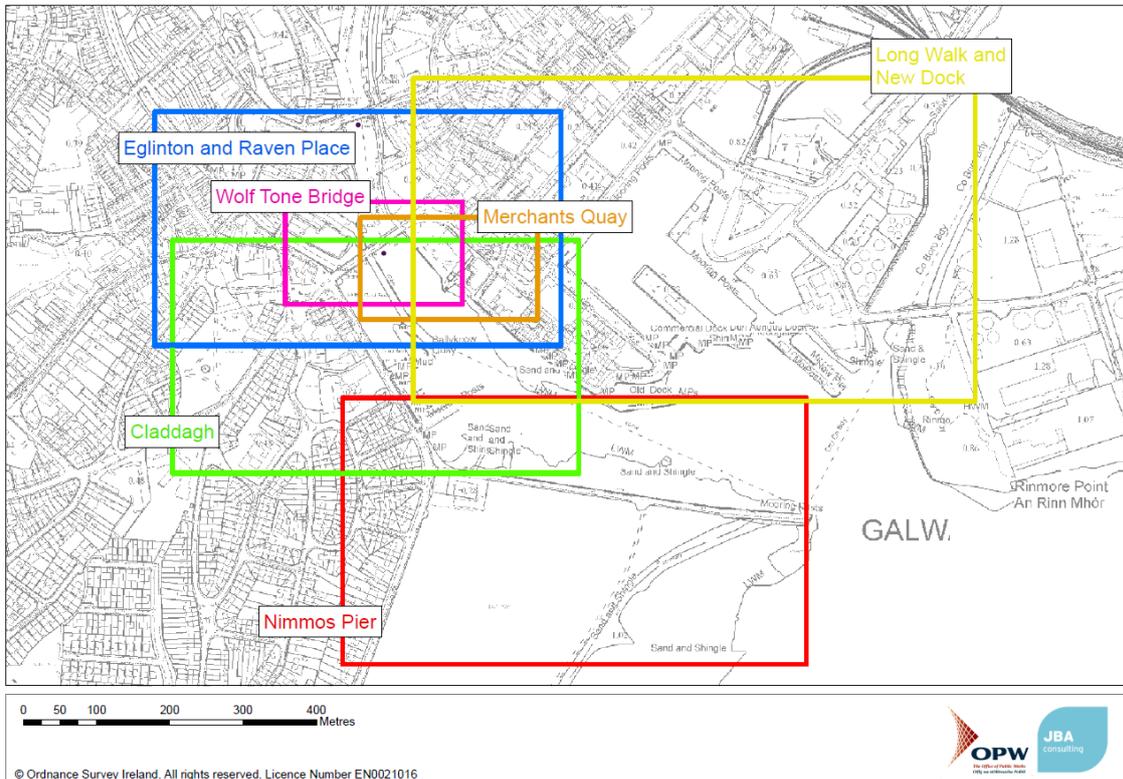
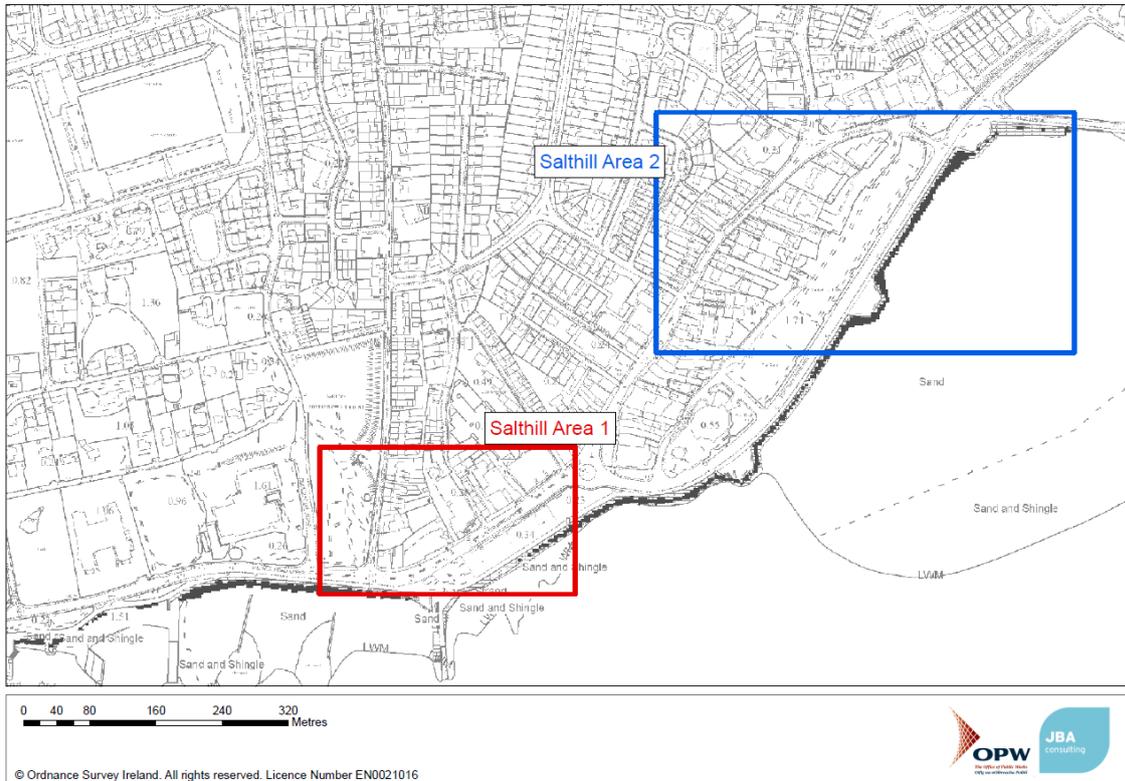


Figure 3-8: Salthill Areas



3.4.1.1 Nimmos Pier

<p>Outline of Methods</p>	<p>Structural methods to defend the 0.5% AEP tide event and protect properties along Grattan Road. Option A is the placement of a quay wall at the front with demountable access points. Option B involves the placement an embankment set back from the existing Quay wall.</p>
<p>Are the methods adaptable to climate change</p>	<p>Due to the required guarding height walls will be raised a minimum of 1.15m above ground levels. This results in walls being above the MRFS. The embankment is easily adaptable and a demountable access can be increased easily.</p>
<p>Summary of key considerations</p>	<p>Key constraints are environmental concerns, due to an old landfill site being in proximity to construction and also the Galway Bay SAC. Access issues have to be considered also for the public. There is also limited space on the road for construction of Quay walls. The visual and architectural heritage of the area will be key considerations also.</p>

Figure 3-9: Nimmo's Pier Option A

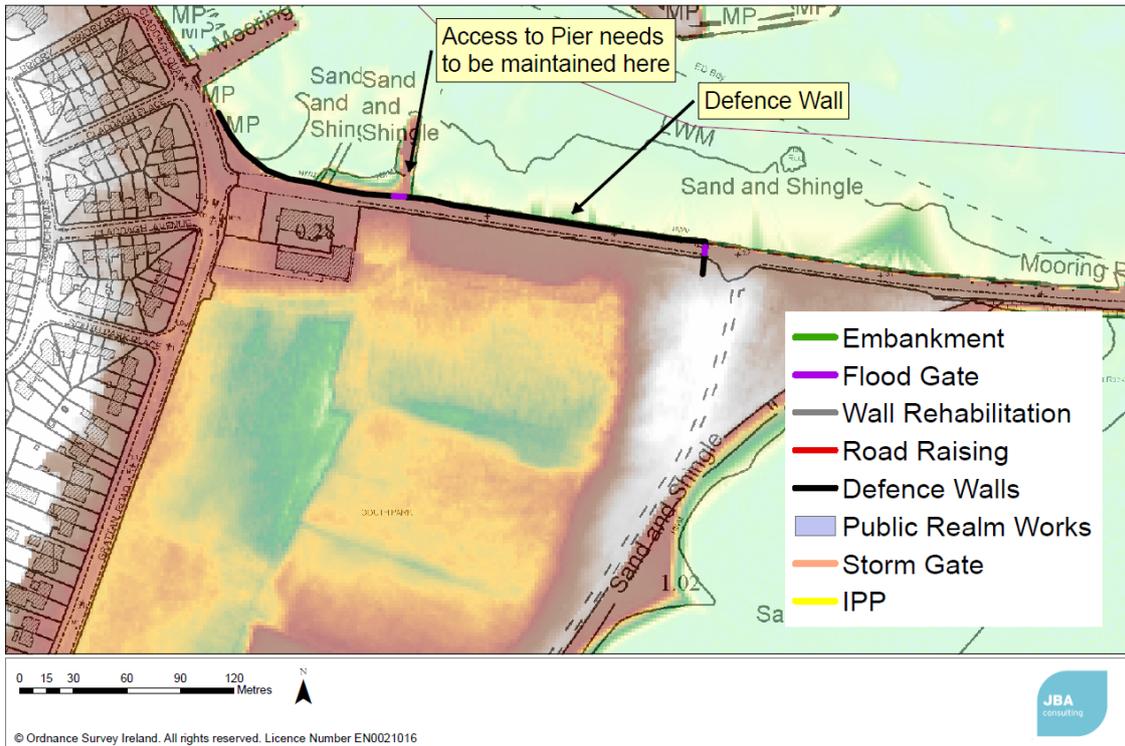


Figure 3-10: Nimmo's Pier Option B

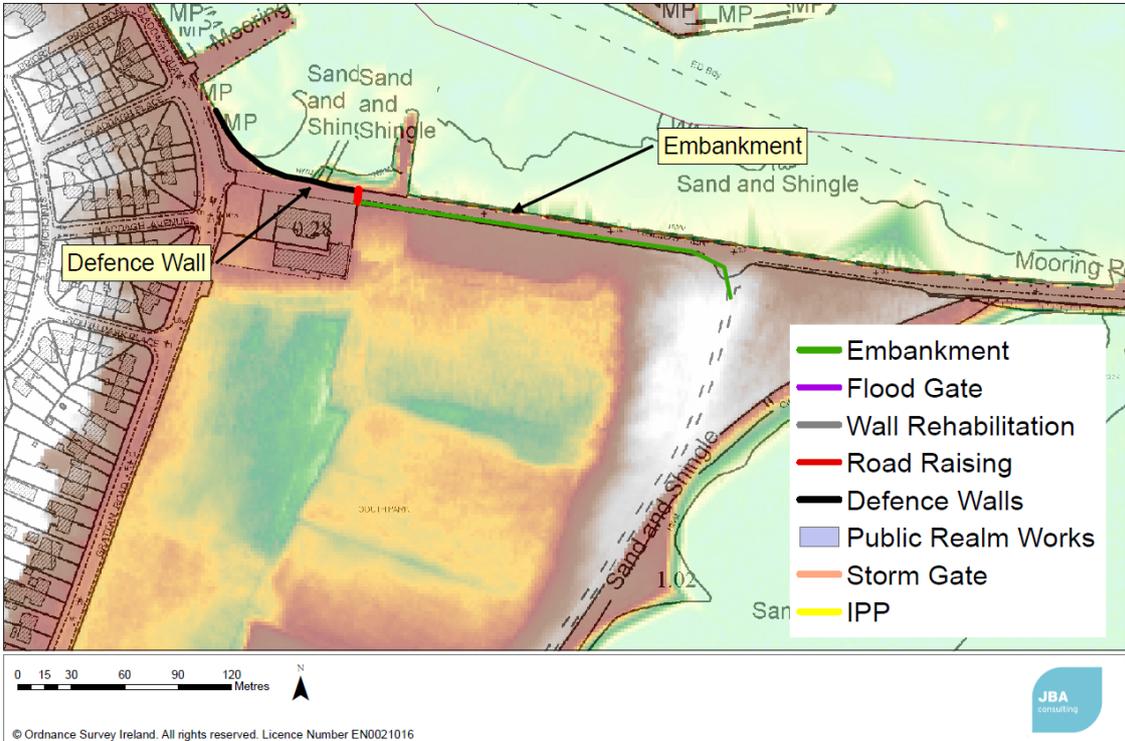


Table 3-2: Nimmo Pier option individual costs (Appendix B.1)

Method	Comment	Height (0.3m freeboard)	Cost
Option A			
Construction of Quay Wall	311m of Quay Wall (Method factor 1.25)	1.2m	€0.921m
Flood gate	1 No. 4m wide access for car. 1 No. 2m wide access for car for people. (Method factor 1.1)	1.2m	€0.024m
	Total Construction Costs		€0.945m
	Preliminaries (7%)		€0.066m
	Total Capital Costs		€1.011m
	Operation, Maintenance and Event Costs		€0.003m
	Total PVc Costs		€1.015m
	Total Costs including optimum bias (50%)		€1.523m
Option B			
Construction of Quay Wall	98m of Quay Wall (Method factor 1.25)	1.2m	€0.290m
Embankment	Open ground imported clay bank 1m high. 230m in length (Method factor 1.25)	1m	€0.039m
Road raising	20m of road raising (Method factor 1.3)	1m	€0.021m
	Total Construction Costs		€0.346m
	Preliminaries (7%)		€0.024m
	Total Capital Costs		€0.370m
	Operation, Maintenance and Event Costs		€0.014m
	Total PVc Costs		€0.385m
	Total Costs including optimum bias (50%)		€0.578m

3.4.1.2 Claddagh Quay

<p>Outline of Methods</p>	<p>Structural methods to defend the 0.5% AEP tide event and protect properties of adjacent to Claddagh Basin, Father Griffin Road and Raven Place. Option A is the placement of a quay wall along the Claddagh Basin with demountable access points provided.</p>
<p>Are the methods adaptable to climate change</p>	<p>Due to the required guarding height walls will be raised a minimum of 1.15m above ground levels. This results in walls being above the MRFS.</p>
<p>Summary of key considerations</p>	<p>There is also limited space on the road for construction of Quay walls. The outfall of existing drainage in a flood event is a concern and there may need to be a pumping station. There are a number of access points that have to be maintained so flood gates will be required. The visual and architectural heritage of the area will be key considerations also. Existing railing on in place along the Claddagh Quay.</p>

Figure 3-11: Claddagh Quay Option A

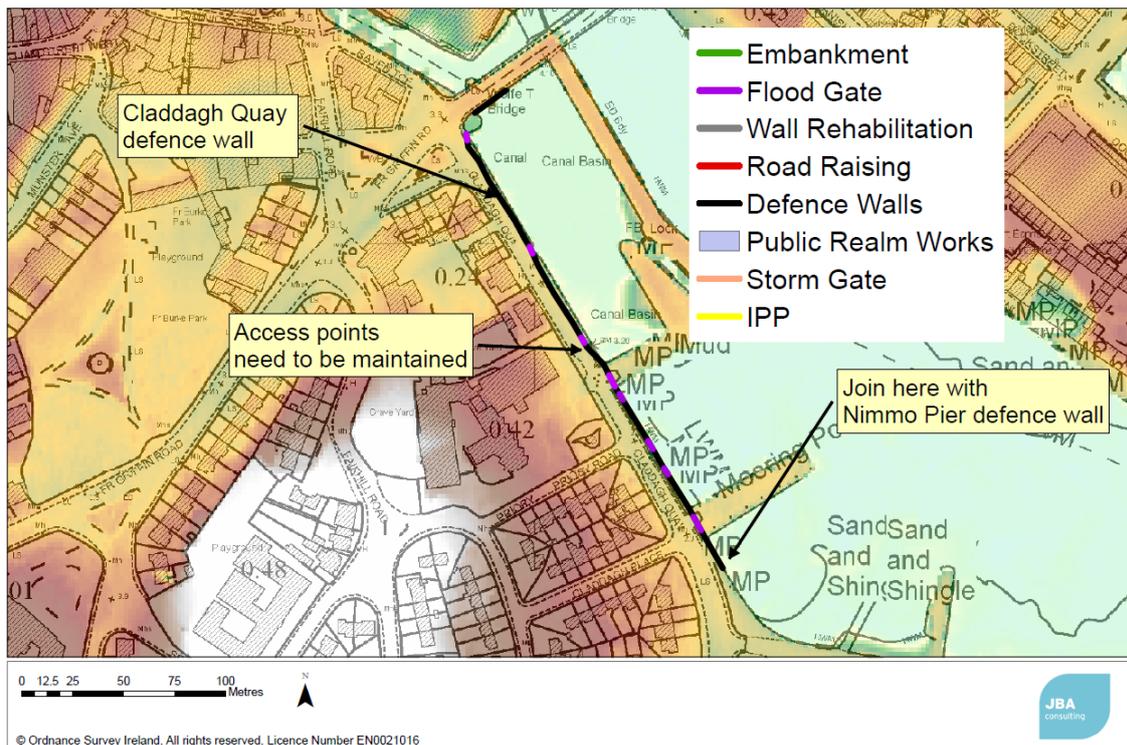


Table 3-3: Claddagh Quay option individual costs (Appendix B.2)

Method	Comment	Height (0.3m freeboard)	Cost
Option A			
Construction of Quay Wall	355m of Quay Wall (Method factor 1.30)	1.2m	€0.797m
Flood gates	2 No. 4m wide access for car 6 No. 2m wide access for car for people. (Method factor 1.1)	1.2m	€0.130m
	Total Construction Cost		€0.898m
	Preliminaries (7%)		€0.063m
	Total Capital Cost		€0.961m
	Operation, Maintenance and Event Costs		€0.015m
	Total PVc Costs		€0.976m
	Total cost including optimum bias (50%)		€1.465m

3.4.1.3 Raven Place and Eglinton Canal

Outline of Methods	Methods to defend the 0.5% AEP tide event and protect properties of Dominic Street, Raven Place and Father Griffin Road. Option A is the placement of a walls at the front with demountable access points provided.
Are the methods adaptable to climate change	Due to the required guarding height walls will be raised a minimum of 1.15m above ground levels. This results in walls being above the MRFS along Raven Place. The left bank of Eglinton Canal property level defence is preferred and this is not easily adaptable to Climate Change.
Summary of key considerations	The existing foundation of the canal walls is unknown. There are a number of access points that have to be maintained. There are several buildings forming the bank of the canal so space is very limited. The visual and architectural heritage of the area will be key considerations also.

Figure 3-12: Raven Place and Eglinton Canal options (Appendix B.3)

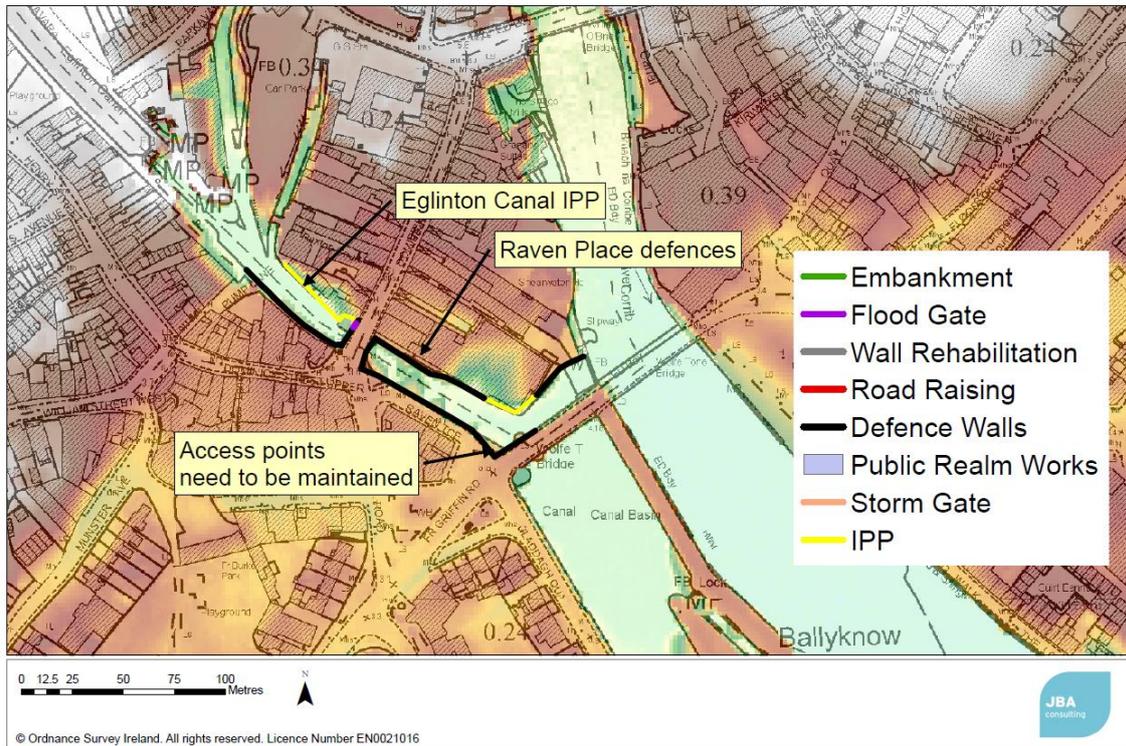


Table 3-4: Raven Place and Eglinton Canal option individual costs

Method	Comment	Height (0.3m freeboard)	Cost
Option A			
Construction of Quay Wall	259m of Quay Wall (Method factor 1.25)	1.2m	€0.767m
Flood gates	3 No. 2m wide access for car for people. (Method factor 1.25)	1.2m	€0.053m
Property Level Defences	1 Office 4 Terraced Housing (Method factor 1.2)	0.6m	€0.029
	Total Construction Costs		€0.849m
	Preliminaries (7%)		€0.059m
	Total Capital Costs		€0.909m
	Operation, Maintenance and Event Costs		€0.017m
	Total Costs		€0.928m
	Total Costs (Including Optimum Bias 50%)		€1.392m

3.4.1.4 Wolfe Tone Bridge

<p>Outline of Methods</p>	<p>Methods to strengthen and tie defences together around the Wolfe Tone Bridge which extends across the Eglinton canal also. This will reduce water flowing onto the Wolfe Tone Bridge and flooding properties on the left and right bank of the River Corrib.</p>
<p>Are the methods adaptable to climate change</p>	<p>This area is not highly adaptable to Climate change. Whilst the current parapets provide protection in the current scenario, these will be overtopped in the future scenario.</p>
<p>Summary of key considerations</p>	<p>There is a parapet existing on the bridge but whether it forms an effective defence is unknown. The bridge parapet consists of a thin RC wall. There are three access points which will have to be maintained also. The visual and architectural heritage of the area will be key considerations also.</p>

Figure 3-13: Wolfe Tone Bridge options

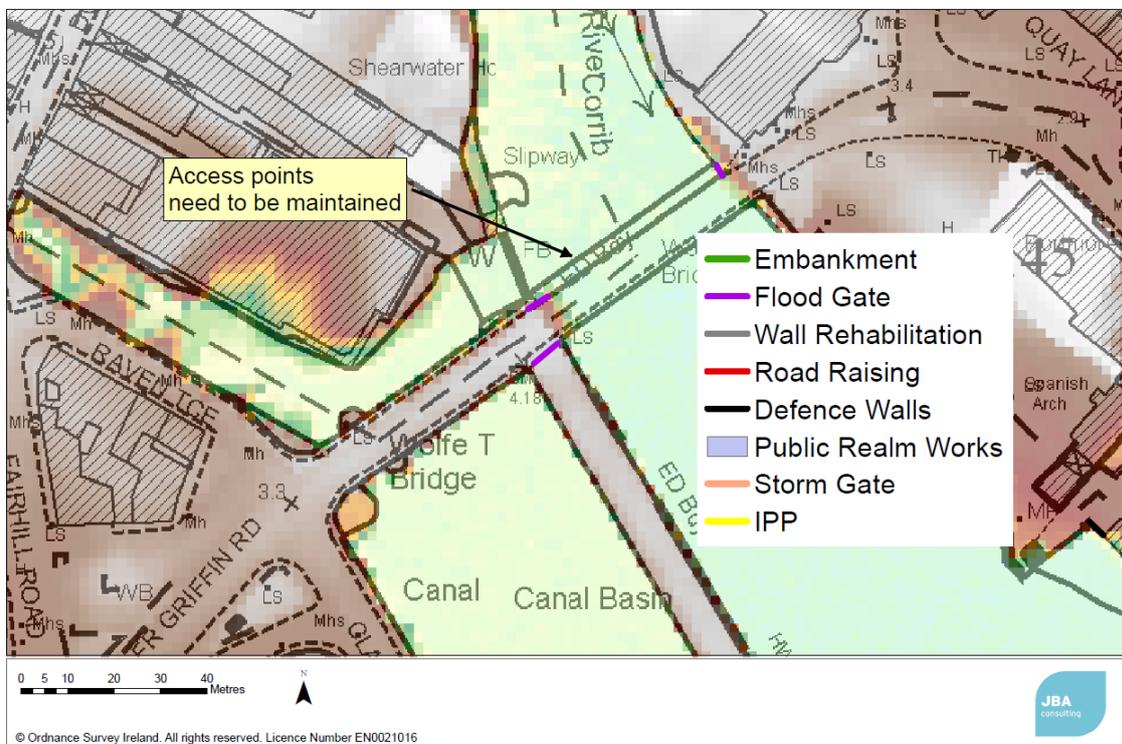


Table 3-5: Wolfe Tone Bridge option individual costs (Appendix B.4)

Method	Comment	Height (0.3m freeboard)	Cost
Option A			
Flood gates	3 No. 4m wide access for people access. (Method factor 1.2)	1.2m	€0.060m
	Total Construction Costs		€0.060m
	Preliminaries (10%)		€0.004m
	Total Capital Costs		€0.064m
	Operation, Maintenance and Event Costs		€0.005m
	Total Costs		€0.069m
	Total Costs (Including Optimism Bias 50%)		€0.104m

3.4.1.5 Spanish Arch/Merchants Quay

Outline of Methods	A defence is needed to prevent flood risk. Walls are excessively high in this area due to the low quay wall. Option A is the placement of a quay wall at the front with demountable access points. Option B is a setback defence with public realm works incorporated. Due to the public and various uses for the area a flood defence incorporated into a public realm provision may be best suited to this vibrant location. Also the historic Spanish Arch structure is to be left unaltered in the development of the flood risk management measures. This will involve consultation with city council and stakeholders.
Are the methods adaptable to climate change	The public realm works and demountable defences are adaptable, however it will have increased negative impacts in an area that utilises same as a public amenity area
Summary of key considerations	Walls are excessively high in this area due to the low quay wall. Wall can be set back to higher ground in the back which will reduce height. The visual and architectural heritage of the area will be key considerations also.

Figure 3-14: Spanish Arch/Merchants Quay Option A

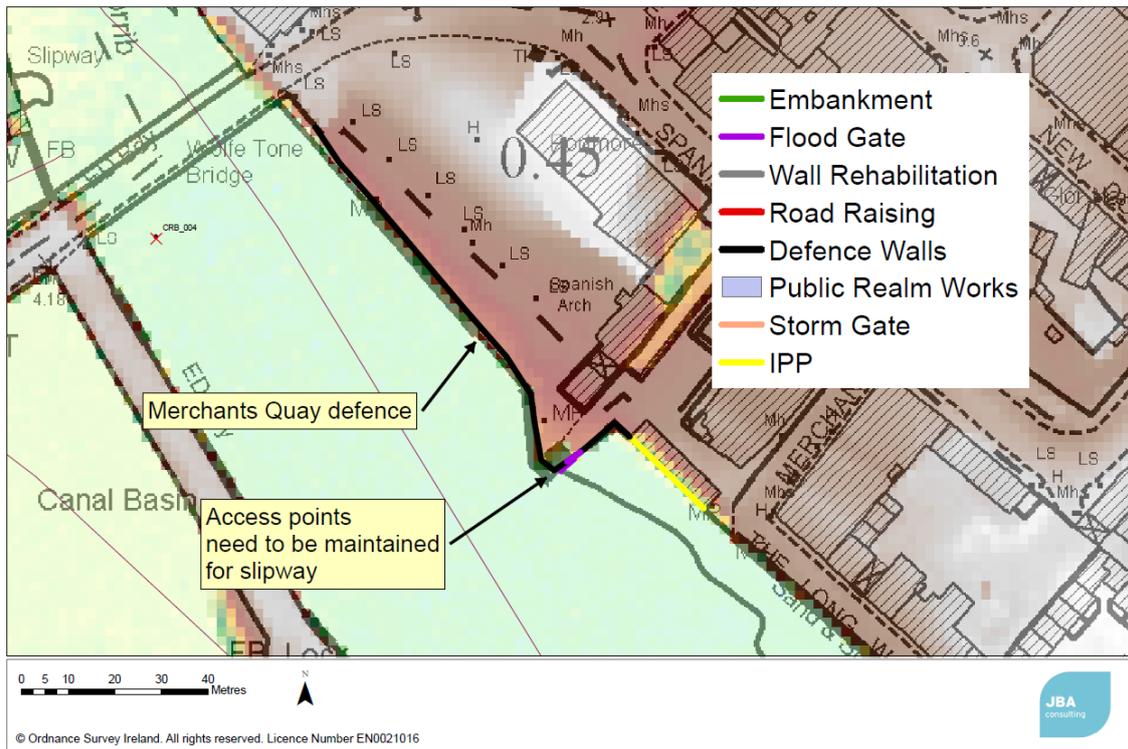


Figure 3-15: Spanish Arch/Merchants Quay Option B

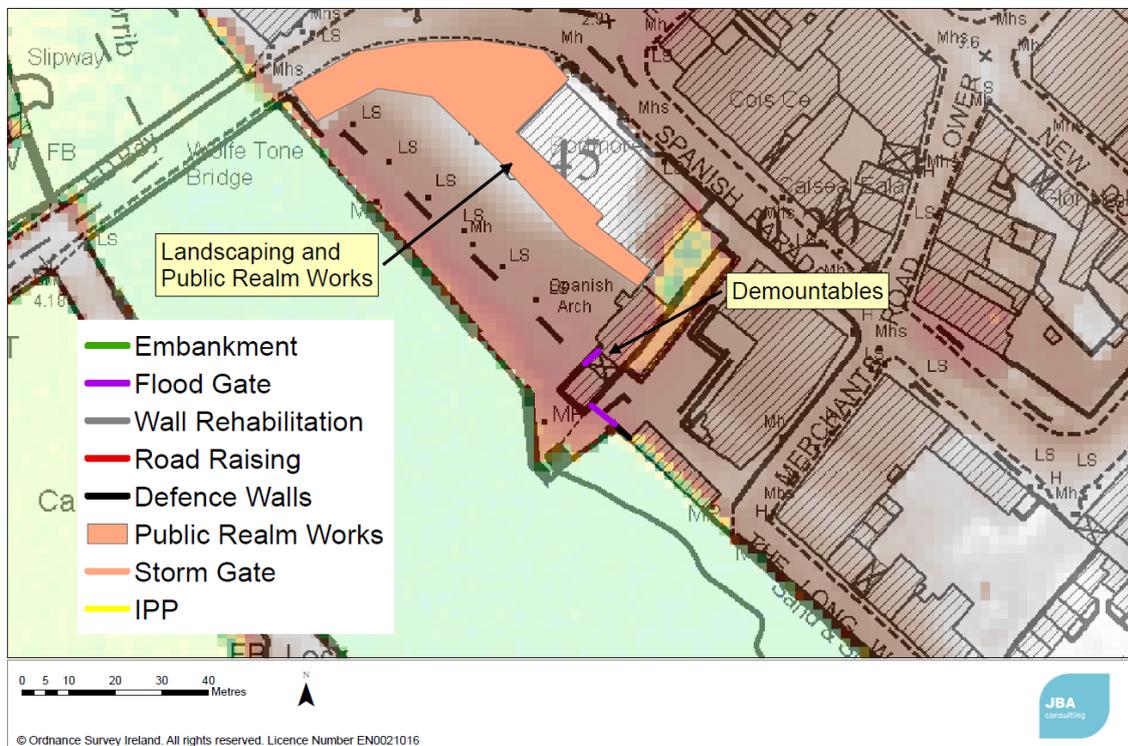


Table 3-6: Spanish Arch/Merchants Quay option individual costs (Appendix B.5)

Method	Comment	Height (0.300m freeboard)	Cost
Option A			
Construction of Quay Wall	113m of Quay Wall (Method factor 1.25)	1.2m	€0.423m
Flood gate	1 No. 4m wide access for car. (Method factor 1.20)	1.2m	€0.020m
Property Levels Defence	1 Shop (Method factor 1.2)	0.6m	€0.009m
	Total Construction Costs		€0.453m
	Preliminaries (10%)		€0.032m
	Total Capital Costs		€0.485m
	Operation, Maintenance and Event Costs		€0.007m
	Total Costs		€0.492m
	Total Costs (Optimism Bias 50%)		€0.738m
Option B			
Construction of Quay Wall	5m of Quay Wall (Method factor 1.25)	1.2m	€0.019m
Landscaping and Public realm defence	Depends on landscaping scheme adopted. Nominal cost	0.6m	€0.300m
Flood gate	2 No. 4m wide access for car and public. (Method factor 1.20)	1.2m	€0.036m
Property Level Defences	1 Shop	0.6m	€0.009m
	Total Construction Costs		€0.365m
	Preliminaries (7%)		€0.026m
	Total Capital Costs		€0.391m
	Operation, Maintenance and Event Costs		€0.007m
	Total Costs		€0.398m
	Total Costs (Optimism Bias 50%)		€0.598m

3.4.1.6 Long Walk and New Dock

<p>Outline of Methods</p>	<p>A defence is needed to prevent flood risk propagating through the dock and flooding Dock Road, Flood Street and ties with defences on Spanish Arch/Merchants Quay. There are different options available in this area. Option A is the placement of a quay wall at the front with demountable access points and a retro fit of the existing storm gate to prevent egress of water in the dock. Option B is the placement of a wall around the dock which avoids the dock gate retro fit.</p>
<p>Are the methods adaptable to climate change</p>	<p>Due to the required guarding height walls will be raised a minimum of 1.15m above ground levels. This results in walls being above the MRFS. The embankment height is easily adaptable.</p>
<p>Summary of key considerations</p>	<p>Walls are very long to cover the whole dock and harbour frontage. Limited space along Long Walk. The condition of the walls on Long Walk are poor in places. The Dock gate is a major uncertainty in how it could be used to perform as a flood defence. Various access points will have to be maintained. The visual and architectural heritage of the area will be key considerations also.</p>

Figure 3-16: Long Walk and New Dock Option A

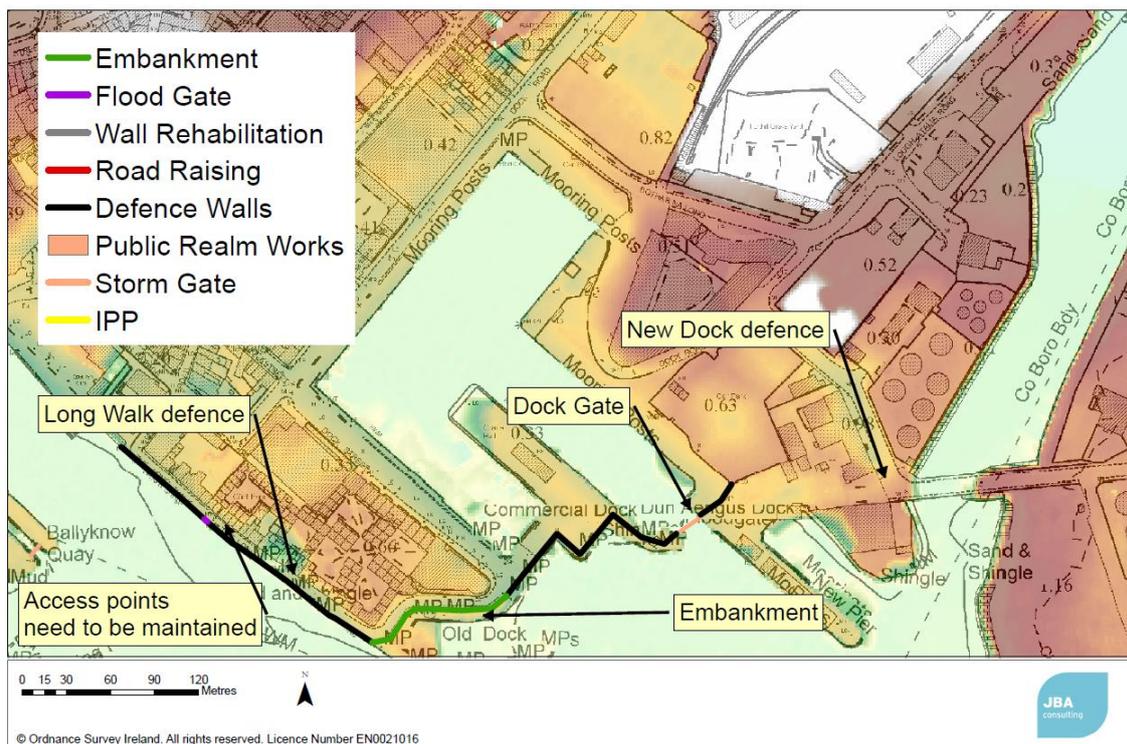


Figure 3-17: Long Walk and New Dock Option B

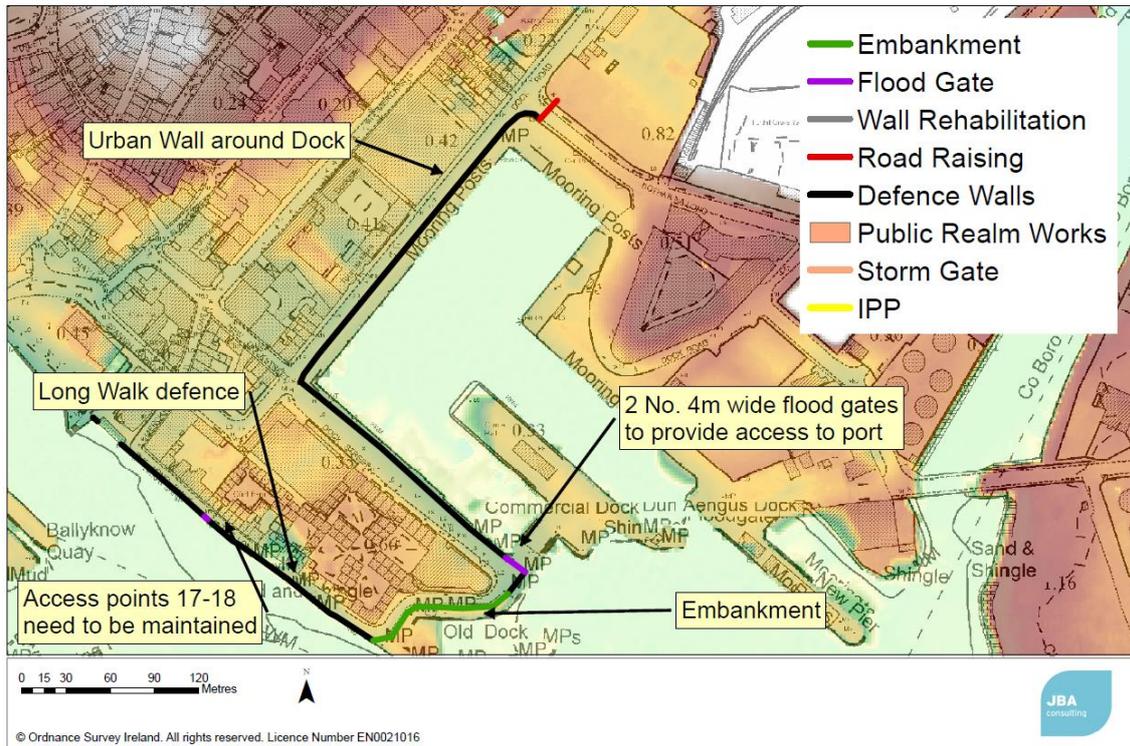


Table 3-7: Long Walk and New Dock option individual costs (Appendix B.6)

Method	Comment	Height (0.3m freeboard)	Cost
Option A			
Construction of Quay Wall	409m of Quay Wall (Method factor 1.25)	1.2m	€1.211m
Embankment	105m clay embankment 1.5m in height (Method factor 1.2)	1.5m	€0.039
Flood gate	2 No. 2m wide access for public access. (Method factor 1.2)	1.2m	€0.034m
Retro-fit Dock Gate	Major assumption or provision of new storm gate.	1m	€3.00m
	Total Construction Costs		€4.281m
	Preliminaries (7%)		€0.300m
	Total Capital Costs		€4.581m
	Operation, Maintenance and Event Costs		€0.012m
	Total Cost		€4.593m
	Total Cost including Optimism bias (50%)		€6.889m
Option B			
Construction of Quay Wall	239m of Quay Wall (Method factor 1.2)	1.2m	€0.680m
Construction of Urban Wall	435m Retaining Wall, Urban (with stone cladding) (Method factor 1.2)	1.2m	€0.692m
Flood gate	2 No. 4m wide access to dock. 2 No. 2m wide access for public access. (Method factor 1.25)	1.2m	€0.091m
Embankment	105m clay embankment 1.5m in height (Method factor 1.2)	1m	€0.039m
Road raising	20m of road raising (Method factor 1.25)	1m	€0.019m
	Total Construction Costs		€1.520m
	Preliminaries (7%)		€0.106m
	Total Capital Costs		€1.627m
	Operation, Maintenance and Event Costs		€0.019m
	Total Cost		€1.646m
	Total Cost including Optimism bias (50%)		€2.460m

3.4.1.7 Salthill Area 1

<p>Outline of Methods</p>	<p>The coastal facing commercial properties shown below are at risk from wave overtopping flooding. The shop fronts are not designed to prevent ingress. The properties could benefit from property level protection but it could be quite difficult considering the wooden panels forming the frontage and the amount of windows present. The shops could be retrofitted with solid walls from the ground to a height of 1m and then windows possibly above this height. Flood gates in the doorways would be provided also. Flood gates are also needed to prevent basement and car park flooding also. This would then allow sufficient protection to the properties which would prevent overtopping waves entering the property.</p>
<p>Are the methods adaptable to climate change</p>	<p>The effectiveness of IPP will reduce in future scenarios but may provide a reduction in damages and lesser frequency of damages occurring to the properties</p>
<p>Summary of key considerations</p>	<p>Standard property protection is not applicable here. Tenants and building owner will need to consider changing the shop frontage.</p>

Figure 3-18: Salthill Area 1 Option A

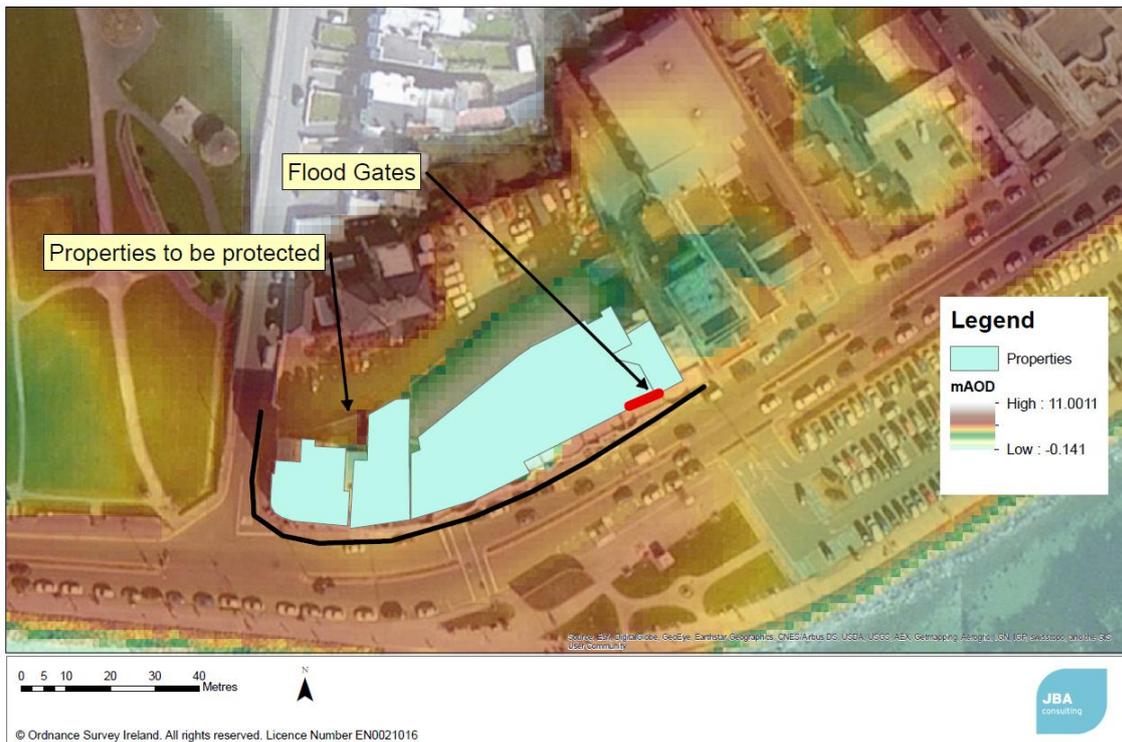


Table 3-8: Salthill Area 1 option individual costs (Appendix B.7)

Method	Comment	Height (0.300m freeboard)	Cost
Option A			
Property level protection	6 No. of Shop fronts to be fitted for property level protection (Method factor 1.6 due to the type of shop fronts present)	1m	€0.079m
Flood gate	2 No. 4m wide access to car park. (Method factor 1.2)	1.2m	€0.040m
	Total Construction Costs		€0.120m
	Preliminaries (7%)		€0.008m
	Total Capital Costs		€0.128m
	Operation, Maintenance and Event Costs		€0.025m
	Total Costs		€0.155m
	Total Costs including Optimism Bias		€0.233m

3.4.1.8 Salthill Area 2

Outline of Methods	A defence is needed to prevent flood risk to properties facing the promenade and also further into the White Strand area of Salthill. There is existing landscaped high ground which can form defence through embankments. This can then be linked to high ground by road raising at both ends of the embankment.
Are the methods adaptable to climate change	The embankment area can be easily raised but consideration of visual impacts is needed. It may not be possible to carry out further road raising due to the constraints on finish floor levels of properties and access points
Summary of key considerations	Visual aspects will be a challenge but it can be landscaped with the public realm in mind. Surface water pumps may be required in an event to avoid backing of the sewerage systems.

Figure 3-19: Salthill Area 2 Option A

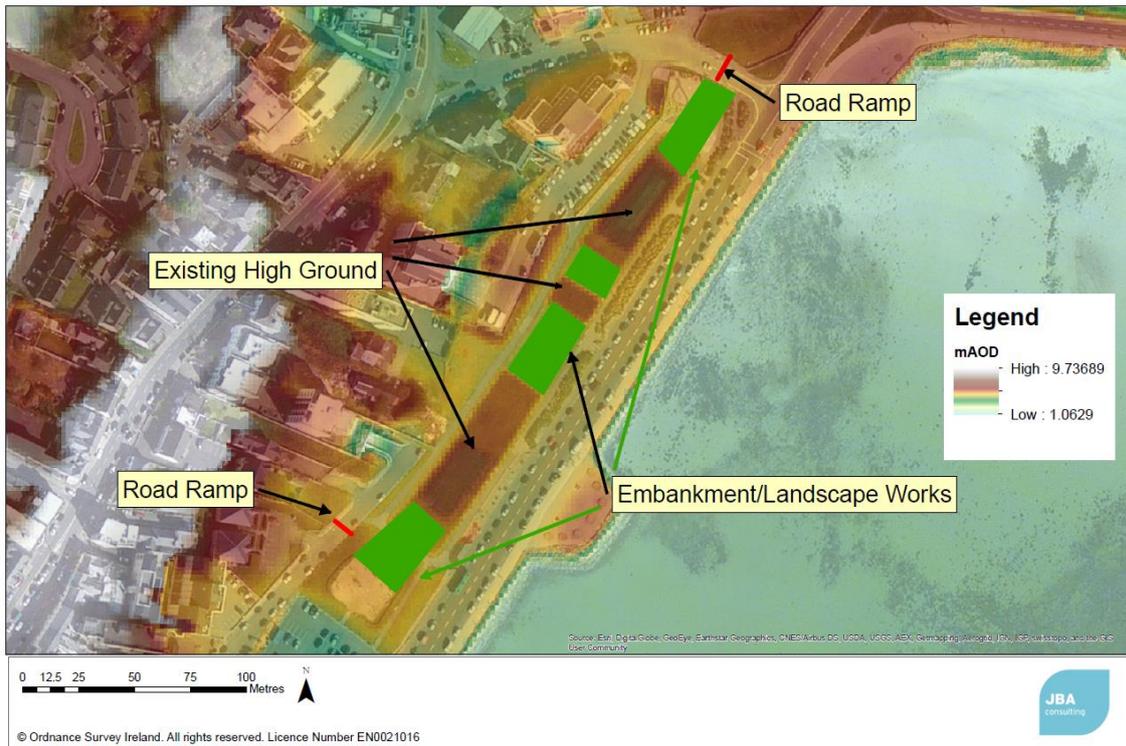


Table 3-10: Salthill Area 2 options individual costs (Appendix B.8)

Method	Comment	Height (0.300m freeboard)	PV Cost
Option A			
Construction embankment	220m Rural clay imported embankment (Method factor 1.2)	1m	€0.048m
Road raising	2 Road raising areas. 30m each. (Method factor 1.25)	1m	€0.058m
	Total Construction Costs		€0.106m
	Preliminaries (15%)		€0.007m
	Total Capital Cost		€0.113m
	Operation, Maintenance and Event Costs		€0.008m
	Total Costs		€0.121m
	Total Costs (Including Optimism Bias)		€0.182m

3.4.2 Possible viable methods

Following the screening process, the viable methods in order to help alleviate flooding in the AFA are listed in Table 3-11.

Table 3-11: Possible Viable Methods

Structural Methods
Construction of Walls
Flood gates
Embankments
Road Raising

3.4.3 Screening of possible options

In order to protect Galway City from flood risk it is necessary to combine a number of structural methods. It is not possible to defend all properties by one method alone. The possible options are complicated further by the wave overtopping mechanism of flooding present in Salthill. Wave return walls could reduce the flood risk but there is there is little flooding by still water level in the 0.5% AEP event. The justification for the new sea walls would only arise from meeting the MRFS design standard along with the current design standard.

Table 3-12: Summary of options for Galway City

Option	Summary	Design Standard	Cost	Benefits	BCR (to design standard)
Option 1	<p>Do Existing</p> <p>This option would continue the existing scenario of Arterial Drainage maintenance and provide non-structural methods only such as raising awareness.</p> <p>The lack of any walls and poor condition of many existing walls would continue to expose a number of properties, people and infrastructure in Galway City to considerable risk.</p>	n/a	n/a	n/a	n/a
Option 2	<p>Flood Containment</p> <p>This option involves the placement of quay defence walls, flood gates, landscaping and public realm defences in order to protect against the 0.5% AEP design event with an average defence height of 1.2m required. This includes a freeboard allowance of 0.3m. The defence line would extend from the dock continuing along Long Walk and Spanish Arch. The properties in the Claddagh area, along Grattan road and Father Griffin would be provided protection also by placing a quay wall along the Claddagh basin and Nimmo's pier. Property line defences and localised raising will be employed in Salthill</p>	1% AEP fluvial 0.5% AEP tidal Current	€7.01	€8.18	1.16

At this level of detail, the scheme for Galway City AFA is cost effective. It has been noted from consultation with the City Council that bespoke and more expensive flood wall finishes and

approaches would be desirable in the protected conservation areas. The cost of such works, such as glass panelled flood retaining walls and self-closing barriers would tip the scheme to a non-cost beneficial scheme and limit the potential for national OPW funding.

A breakdown of the estimated costs for the options for Galway City is presented in Table 3-13. It is noted that for the screening stage the additional cost allowances only included optimism bias, maintenance and preliminaries to reduce the risk of omitting potentially cost beneficial options at this stage. Full details of the assumptions made in the cost estimates are provided in the Appendix A. Individual methods costs are detailed in Appendix B. The most cost beneficial option is carried forward because a non-cost beneficial option would not gain national OPW funding. The option chosen also has less risk in terms of cost uncertainty.

Table 3-13: Most cost beneficial option

	Cost (million)
Flood forecasting system (assumed to tie in with most cost beneficial option)	€0.000m
Nimmo's Pier Option B	€0.578m
Claddagh Quay Option A	€1.465m
Raven + Eglington Option A	€1.392m
Wolfe Tone Bridge Option A	€0.104m
Spanish Arch/Merchants Quay Option B	€0.598m
Long Walk Option + New Dock Option B	€2.470m
Salthill Area 1 Option A	€0.233m
Salthill Area 2 Option A	€0.182m
Total	€7.025m
Predicted damages avoided over lifetime of the scheme	€8.185
Indicative Benefit Cost Ratio (BCR)	1.17

3.4.4 Managing Residual Risks

Options will need to incorporate further actions to manage the residual risks that remain with structures in place. These actions address the likelihood of structures failing or flood gates not being installed, and then if necessary protecting from hazards if exposed.

To reduce the likelihood of defence failure, asset ownership and responsibilities need to be clearly allocated to include asset inspection, maintenance and when necessary refurbishment of structural elements.

Extreme floods greater than the design standard and future climate change increases in flood risk could exceed the standard of proposed structural methods. The exposure to hazard in these circumstances can be managed through planning policies, development control, flood forecasting, warning and emergency response plans. Where the exposure to flood hazards in extreme events cannot be reduced individual property protection and property resilience methods can be implemented.

Table 3-13 shows that there are cost beneficial options covering the full AFA at the current design standard.

The sensitivity of the BCR to different cost estimates for each option is presented in Table 3-14 and shows that all options perform consistently well under all sensitivity tests, with increased construction costs only marginally resulting in a non-cost beneficial scheme.

Table 3-14: BCR sensitivity to cost estimates

Option	BCR				
	Baseline	3% discount rate	5% discount rate	+50% construction costs	-50% construction costs
Option A Do Existing	n/a	n/a	n/a	n/a	n/a
Option B Flood Containment	1.17	1.13	1.21	0.78	1.75

A breakdown of the estimated costs for the options in Galway City are presented in Table 3-16.

Table 3-15: Indicative Screening Costs for Flood Containment Option A

Option 1 Do Existing		€
Do Existing - No Cost Involved	-	-

Table 3-16: Indicative Screening Costs for Flood Containment Option B

Option 2 Flood containment to 1% AEP for fluvial risk and 0.5% AEP for tidal risk design standard.		€
Construction costs		
Nimmo's Pier		346,481
Claddagh Quay		898,458
Raven Place and Eglinton Canal		849,929
Spanish Arch/Merchants Quay		365,670
Wolfe Tone Bridge		60,479
Long Walk and New Dock		1,520,800
Salthill Area 1		120,000
Salthill Area 2		106,151
Construction costs - Subtotal		4,267,969
Preliminaries	7%	298,758
Capital costs - Subtotal		4,566,727
Optimism Bias	50%	2,283,364
Capital costs - Total		6,850,091
Operation, Maintenance and Event Costs		

Nimmo's Pier		14,699
Claddagh Quay		15,797
Raven Place and Eglinton Canal		18,781
Spanish Arch/Merchants Quay		7,449
Wolfe Tone Bridge		5,178
Long Walk and New Dock		19,925
Salthill Area 1		27,157
Salthill Area 2		8,142
Operation and maintenance - Subtotal		117,128
Optimism Bias	50%	58,564
Operation and maintenance costs - Total		175,692
Option cost for cost benefit analysis		7,025,783
Benefit to Cost Ratio		1.17

4 Development of Viable Options

4.1 Overview

Following the screening stage, a viable option has been identified in Galway City to protect against flooding in the 1% AEP event and 0.5% Tidal event. This section further develops the potentially viable option and assess its viability further. It will involve the detailed modelling of the methods to confirm are they technically viable, full development of costs as needed at this outline design stage and an environmental assessment of the options. Adaptability for climate change, operational requirements and the health and safety implications of the proposed methods was considered. Multi Criteria Assessment (MCA) was carried out which was taken forward to aid in the selection of the preferred option and the prioritisation of funding on a national scale will make use the MCA outcomes.

4.2 Technical Viability

A technically viable has been identified in Galway City with some common methods across the different areas. The following sections discuss methods in the flood risk management areas identified in Section 3.4.1. For health and safety reasons, the minimum wall heights proposed will be 1.2m in height. No pumping stations are included in the following options for Galway City. The issue of surface water drainage is an existing problem which is currently being addresses by Galway City Council and Irish Water.

4.2.1 Nimmo's Pier

The methods in the area involves the placement of an embankment set back from the quay wall and river bank. The embankment will tie back to a new quay wall which will be constructed where space does not permit the provision of an embankment. Tying to the quay wall across the road can be by road raising or demountable gates for access. A constraint for the embankment is the old landfill site to the south which there is very little information about. Before any works, it should be investigated where exactly the boundary of the landfill cells is located and if there are any seepage issues which could contaminate environmentally sensitive areas. The average wall would need to be 0.58m to maintain a 0.5% tidal standard of protection which contains a 0.3m freeboard tolerance. Figure 4-2 shows the 0.5% AEP event water levels against the existing ground and proposed defence heights. It should be noted that a minimum defence height of 1.2m would be used to ensure a guarding height that would not present a health and safety risk to the public.

1% AEP Flood Level (mOD)	3.790
1% AEP MRFS Flood Level (mOD)	4.290
Average Height (m)	0.58m
Length (m)	311m

Figure 4-1: Area of Nimmo Defence

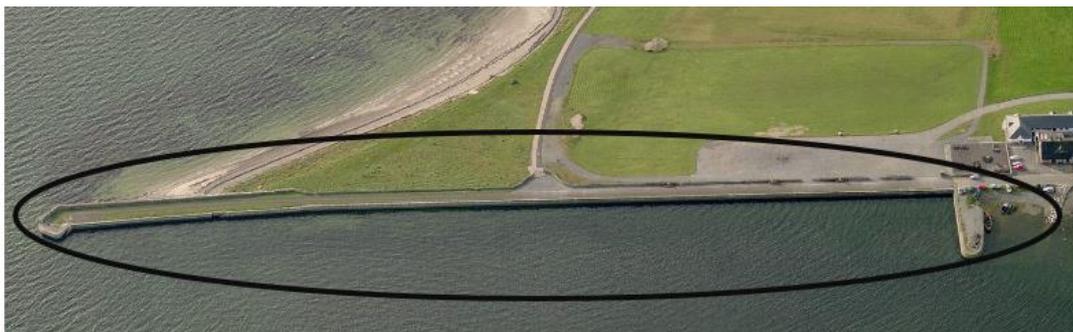
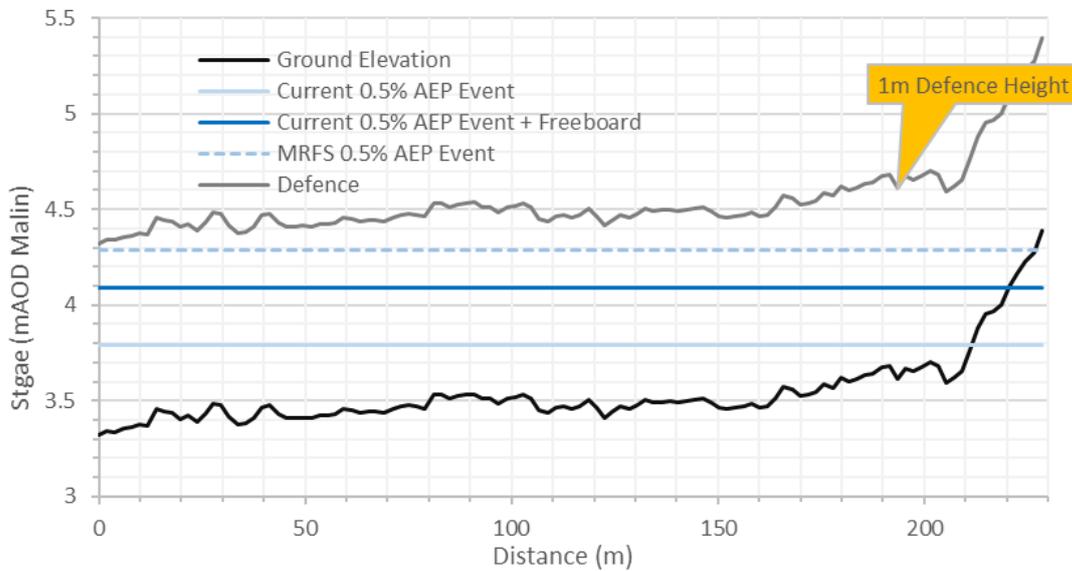


Figure 4-2: Nimmo Pier defence (Note: Defence is an embankment set back from Quay wall, therefore, a guarding height of 1.2m is not required)



4.2.2 Claddagh Quay

The flood risk management methods at Claddagh involve the placement of a quay wall along the Claddagh basin. There is limited space for the construction of quay walls and traffic management will be important in this part of Galway City. Figure 4-4 shows the limited space between the existing quay wall and road. Access points to the Claddagh Bain will be provided through demountable gates. The average wall would need to be 0.92m to maintain a 0.5% AEP tidal standard of protection which includes a 0.3m freeboard tolerance. Figure 4-3 shows 0.5% AEP event water levels against the existing ground and proposed defence heights. The ground is generally flat with no particular rise or fall in either direction.

1% AEP Flood Level (mOD)	3.850
1% AEP MRFS Flood Level (mOD)	4.274
Average Height (m)	1.2m
Length (m)	355m

Figure 4-3: Claddagh Quay Defence

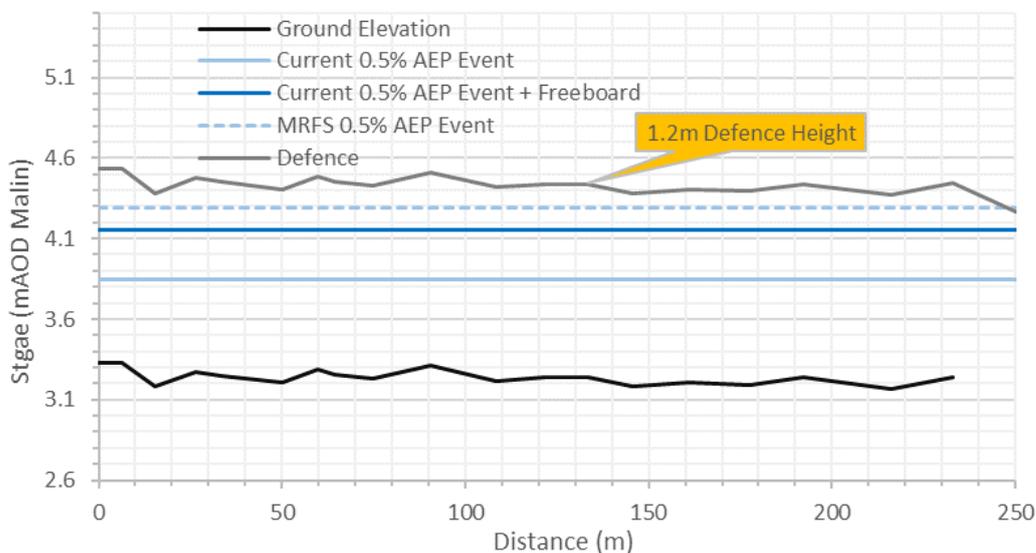


Figure 4-4: Claddagh Road



4.2.3 Raven Place and Eglinton Canal

At Raven Place methods include the placement of a quay walls along canal banks. There is extremely limited space on the left bank side with buildings encroaching onto the canal to within 1m in places. Figure 4-6 shows the proximity of building to the canal on the left bank. Property line defences may be best suited in some places where views and access may want to be maintained. Other access points to the canal will be provided through demountable gates. The average wall of the left bank of Raven place would need to be 0.611m to maintain a 0.5% AEP tidal standard of protection which contains a 0.3m freeboard tolerance. Figure 4-5 shows 0.5% AEP event water levels against the existing ground and proposed defence heights.

1% AEP Flood Level (mOD)	3.870
1% AEP MRFS Flood Level (mOD)	4.370
Average Height (m)	1.2m
Length (m)	259m

Figure 4-5: Raven Place Left Bank Option A

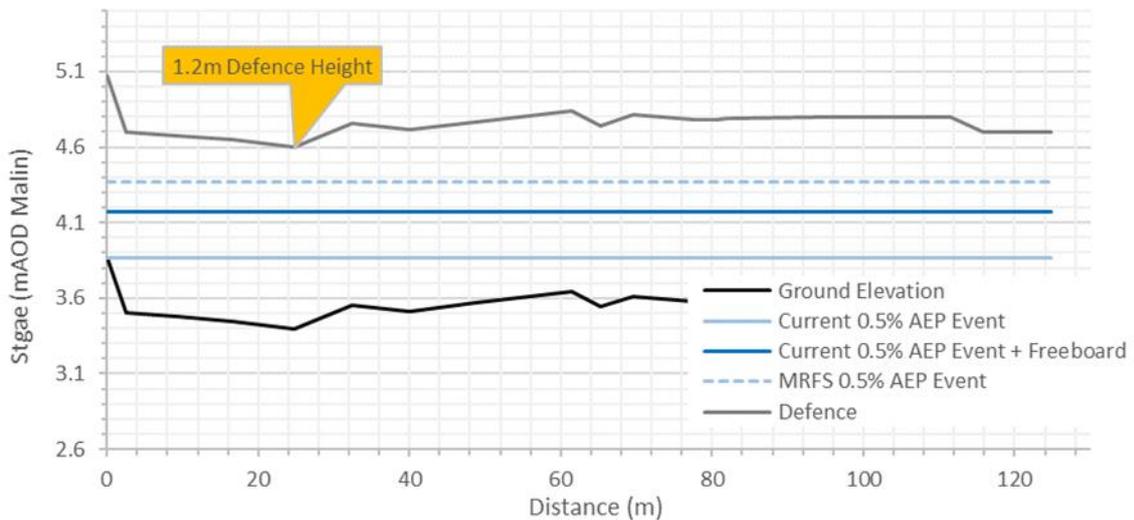
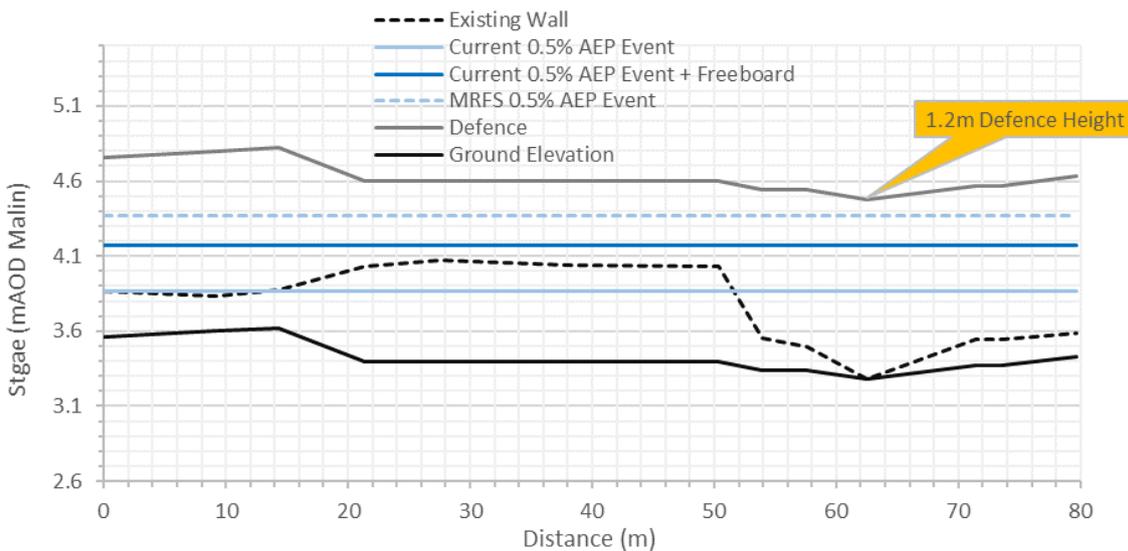


Figure 4-6: Raven Place Site Images



The right bank at Raven place has an existing wall in place but it is not sufficiently high to provide the 0.5% AEP tidal standard of protection. The right bank wall is very close to an urban road so traffic management should be considered during the construction. Figure 4-7 shows 0.5% AEP tidal event water levels against the existing ground and proposed defence heights.

Figure 4-7: Raven Place Right Bank Defence



At Eglinton Canal methods include the placement of a quay walls along the left bank. Figure 4-6 shows the proximity of building to the canal on the left bank. The average wall of the left bank of Raven place would need to be 0.75m to maintain a 0.5% AEP tidal standard of protection which contains a 0.3m freeboard tolerance. Figure 4-8 shows 0.5% AEP event water levels against the existing ground and proposed defence heights for the area. The right bank forms the wall side of buildings on the Eglinton Canal. Because the space is so limited, property level protection

methods are proposed in this location. Figure 4-9, looking upstream shows the works considered in this area.

Figure 4-8: Eglinton Canal Left Bank Defence

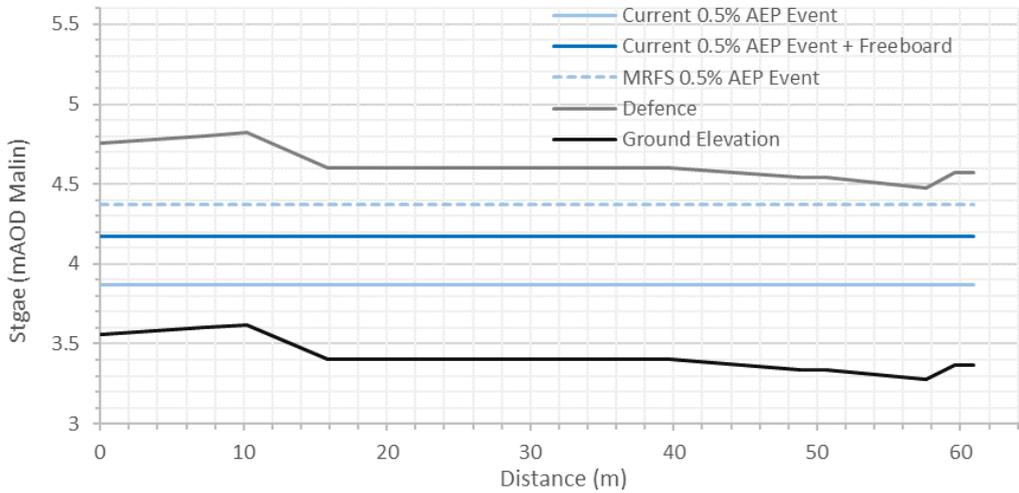


Figure 4-9: Eglinton Canal (L) Proposed wall left bank (R) IPP right bank



4.2.4 Wolfe Tone Bridge

The Wolfe Tone Bridge will need to have defences for the 0.5% AEP tidal event. There is a pedestrian footbridge attached to the upstream face of the bridge which will need demountable gates to prevent floodwaters flowing onto the streets. Figure 4-10 shows 0.5% AEP event water levels against the existing ground and proposed defence heights and Figure 4-11 shows the existing parapet of the bridge with access points. Further investigation into the structural capacity of the bridge itself and parapet wall will have to be completed to ensure 0.5% AEP tidal standard can be maintained.

1% AEP Flood Level (mOD)	3.880
1% AEP MRFS Flood Level (mOD)	4.380
Average Height (m)	n/a
Length (m)	n/a

Figure 4-10: Wolfe Tone Bridge Defence

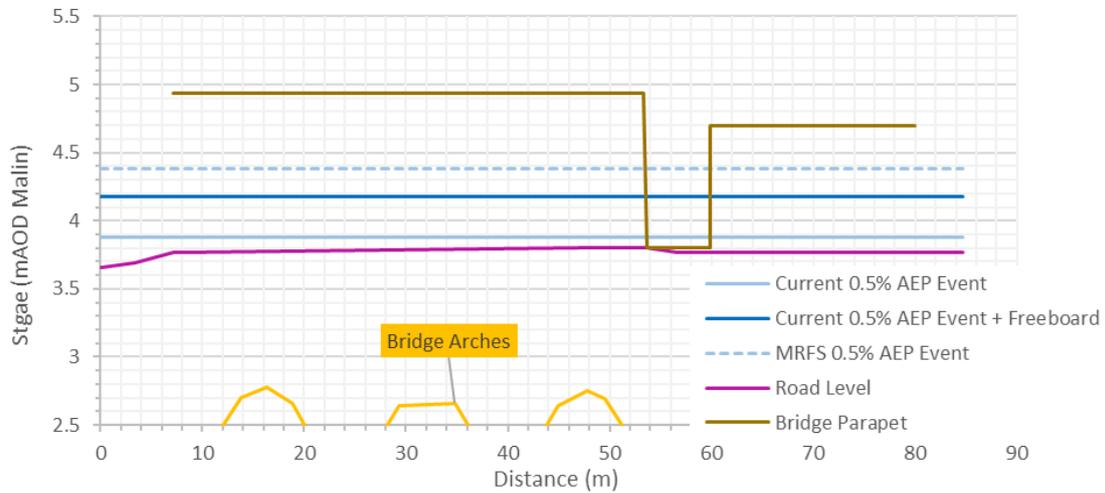


Figure 4-11: Wolfe Tone Bridge Site Images



4.2.5 Spanish Arch/Merchants Quay

Instead of placing a wall at the bank edge to protect the Spanish Arch/Merchants Quay area the defence line is set back to more naturally elevated area. This defence line is shown in Figure 4-13. Public realm works aim to incorporate multi-functional open space areas while having the function of flood defence method. This type of method is best suited to this area so that the character of the area can be maintained. Figure 4-14 shows some example of public realm works carried out and proposed in Carlow and Cork respectively. Setting by the defence line also has the advantage of decreased defence heights with an average of 0.300m needed to achieve the 0.5% AEP standard of protection. Figure 4-12 shows 0.5% AEP event water levels against the existing ground and proposed defence heights.

1% AEP Flood Level (mOD)	3.790
1% AEP MRFS Flood Level (mOD)	4.280
Average Height (m)	0.300m
Length (m)	126m

Figure 4-12: Spanish Arch/Merchants Quay Defence

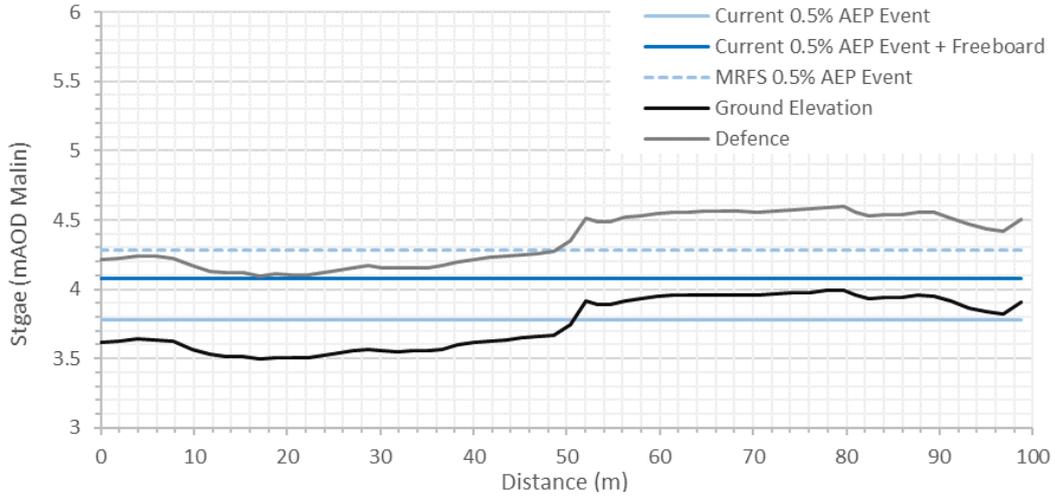


Figure 4-13: Spanish Arch/Merchants Quay Option B Image



Figure 4-14: Examples of Public Realm Works Carlow Flood Relief Scheme (L) Before (R) After, (Below) Proposed Public Realm Works for Cork City





4.2.6 Long Walk and New Dock

The preferred option for the area avoids the retro fit of the dock gate and instead a flood defence wall is placed around the dock to provide protection to properties. Figure 4-15 and Figure 4-16 show the 0.5% AEP event water levels against the existing ground and proposed defence heights for Long Walk and the New dock. There is sufficient space for construction around the dock but space is very limited along the Long Walk road. Figure 4-17 shows the bank where the quay wall would be placed.

1% AEP Flood Level (mOD)	3.790
1% AEP MRFS Flood Level (mOD)	4.280
Average Height (m)	1.2m
Length (m)	409m

Figure 4-15: Long Walk Defence

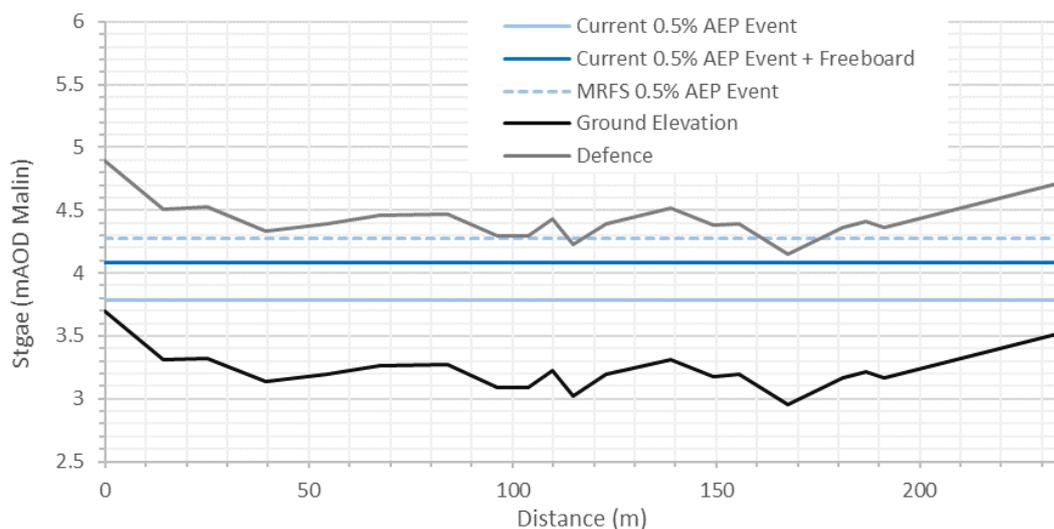


Figure 4-16: New Dock Defence

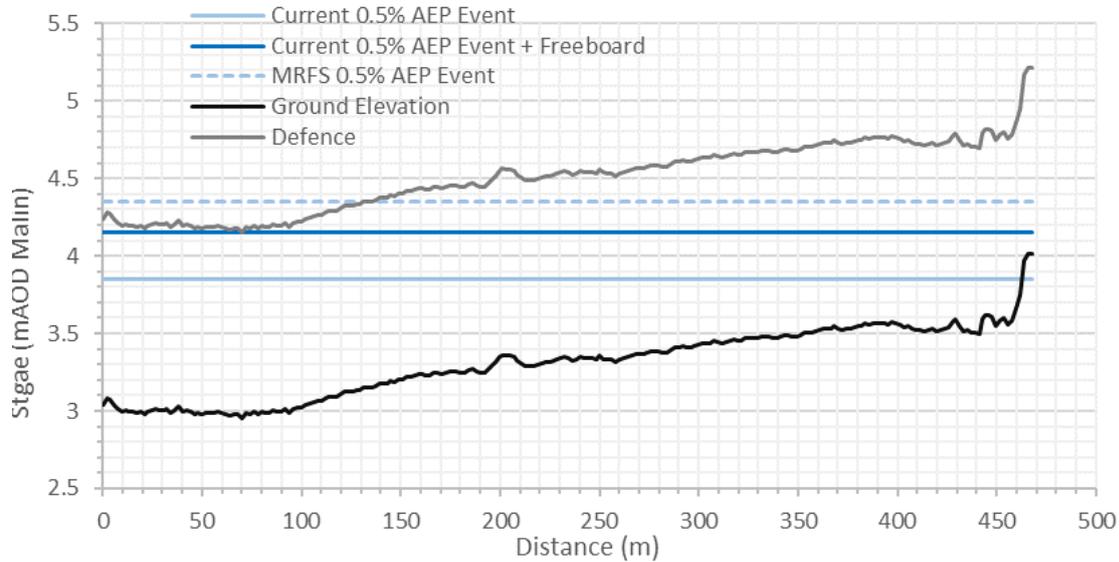
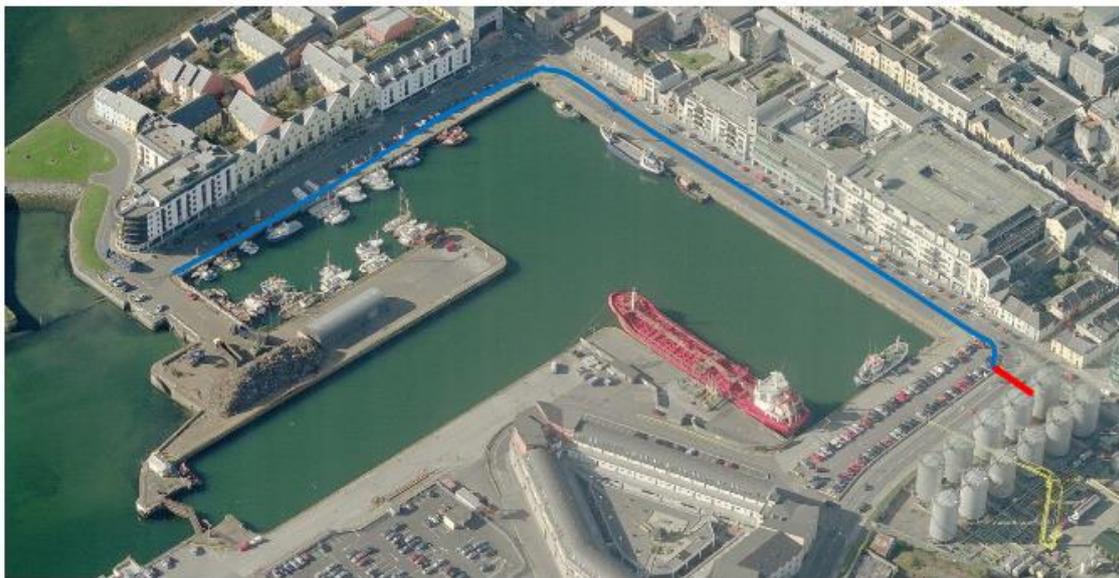


Figure 4-17: Aerial view of proposed defence walls around Dock⁸



4.2.7 Salthill Area 1

Methods around the Salthill Area 1 involve using resilience methods along a property frontage and road rising to reduce the impact of wave action and floodwaters entering into the properties. Because the duration of flooding is relatively short and the depths are shallow, property line defences would be best suited to these properties. Long term options could incorporate a full refurbishment of the shop front with flood protection in mind. Rock armouring could reduce wave overtopping rates but would have environmental impacts that would be difficult to mitigate for, and the cost of these extensive marine works would be considerably more than the available benefits.

4.2.8 Salthill Area 2

Salthill Area 2 involves creating a barrier to wave overtopping volumes and stopping these volumes reaching properties further inland at Salthill. The defence height would have to be sufficient to dissipate and reflect incoming waves. The existing raised embankments do this quite well so the proposed embankments would tie all the embankments together. Figure 4-18 shows the typical line linking existing embankments and Figure 4-19 shows the existing ground profile of the

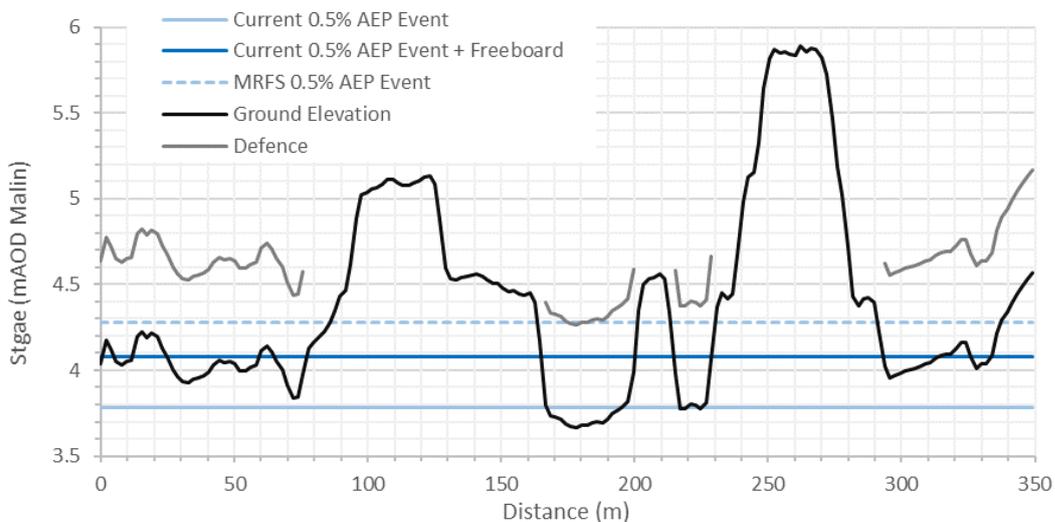
⁸ Bing Maps

alignment. Rock armouring could also be used to reduce wave overtopping rates, but have similar impacts to Area 1.

Figure 4-18: Salthill Area 2 defence line



Figure 4-19: Salthill Area 2 Option A



4.3 Environmental Assessment

An assessment is included in the environmental appraisal of the option which can be found in Appendix E. It discusses the potential impacts and benefits of the option as well as mitigation to be implemented. The mitigation and best practice available is considered likely to succeed in preventing significant impacts on the River Corrib SAC, Galway Bay SAC and the habitats and species in the area, given the location, nature and scale of the works and the option is deemed environmentally viable.

4.3.1 Social Cultural and Tourism Impacts

Galway City is the largest urban centre and focal point the province of Connaught and the West of Ireland. The National Spatial Strategy identified Galway City as a Gateway city, which by context means the concentration of population, education and job opportunities within the city are favourable for future growth.

Tourist are attracted to many parts of Galway City, but the city is known for its river and coastal front in terms of the scenic views. Reducing the risk of flooding to tourist attractions and activities will help towards maintaining sustainable levels of local employment.

The proposed scheme will reduce the risk of flooding to high value views, architecture and archaeology, however the construction of 1.2m high walls, where no walls are currently present has the potential for significant permanent negative impacts. There is a number of features on the Record of Protected Structures and the following Architectural Conservation Areas could be permanently altered:

- The City Core
- Lower Dominic Street
- The Long Walk
- Dock Road

To mitigate for potential visual impacts and adjustment to the visual setting of architectural features and views, will require high quality urban design of flood defence structures. The Galway City Draft Development Plan 2017-2023 will require new development to enhance the character or setting of protected structures and enhance the character and special interest of Architectural Conservation Areas. Such mitigation methods are likely to increase the cost of flood defences as associated urban landscaping works may be necessary.

Galway City Centre is designated a Zone of Archaeological Potential which covers all of the areas for flood defences in the city centre (it excludes Salthill). The following extract from the Galway City Draft Development Plan 2017-2023 highlights the protection given within this zone and the assessment and mitigation methods that will be necessary.

Under National Monuments legislation all underwater archaeological structures, features and objects are protected. Given the location of Galway at the mouth of the Corrib with an extensive coastline, there is potential for underwater archaeological remains. Where development is taking place it is important that archaeological site reports for sites are compiled. Where appropriate, the Council will require impact assessment, monitoring, surveying or excavation of the archaeological heritage of a site during the development process.

As discussed above in the construction impacts, the heritage of Galway City is recognised as a valuable cultural and tourism asset which contributes to the economic vitality of the city. Despite the significant change in setting, the option will protect valuable architecture and archaeology from flooding. Property Line defences in Salthill will alter the appearance of building fronts, but has the potential to enhance the visual appearance.

Environmental Impacts

In terms of any environmental impact, Galway Bay is a designated SAC and a Natura 2000 designated site. These are important internationally and so any detriment to the habitats or species could potentially have an impact on a European scale. As an estuary there is a high potential for as yet undiscovered archaeological findings in the sediment and along river banks. Incorporating public recreation, access and other green infrastructure into the design of the proposed flood defence walls can allow for improvements in the setting as well as protection from flooding of architectural features of interest along the riverside.

The proposed flood defences do not take land from, or encroach into the rivers or Natura 2000 sites and so only minor negative impacts are likely for objectives 4a to 4d (WFD, Habitats Directive, national biodiversity and fisheries), see section 4.9 for discussion on flood risk management objectives. This impact is mainly due to the need for access from the river to maintain the flood defence structures and can be mitigated with proper planning.

There is the potential for spread of Invasive Species during maintenance work. Protection of Southpark (“The Swamp”) from flooding and associated erosion will reduce the risk of leachate from contaminated land discharging to surface water bodies or groundwater.

Proposed methods will have no impact upon hydromorphology. They will also have no impact upon the flow regime of the River Corrib from Lough Corrib to Galway Bay or on any of the waterways through Galway City. There is no impact from the option on the brackish mix of fresh

and saline water in Lough Atalia or on tidal flows. The tidal barrage option has been screened out as it is not technically viable. There will be no change in water quality, or pressures and risks to achieving good water quality.

Ongoing maintenance of the Dyke Road, which acts as a flood defence will continue to minimise pollution risk to water supply abstractions during flooding. There are no permanent impacts of the proposed works in Salthill on environmental receptors

4.4 Operational Requirements

Operational requirements of flood defences include an inspection regime to ensure that there is no deterioration in the structural integrity of the defences. The OPW has a statutory responsibility to maintain the defences. The flood defence walls will require regular inspection and over time maintenance work will be required.

Regular culvert and structure inspections on top of the ongoing Arterial Drainage Maintenance will be necessary to ensure the scheme operates to the design standard. At a detailed design stage it may be necessary to carry out a geomorphological study to assess the degree of deposition and its impacts on the option.

Part of the preferred option is the use of demountable gates and barriers to maintain access to the piers. These barriers and gates will need to be stored and require regular inspection. During flood events following issue of warnings they will need to be erected or put in place.

4.5 Health and Safety

A design risk health and safety has been completed and is included in Appendix F.

Construction stage

It is imperative that robust site investigations are carried out in advance to mitigate risks associated with the works and risk levels can be kept to a manageable level through the completion of a risk assessment and implementation of mitigation. Construction of some methods will be within the river channels and will require de-watering of sections of channel and full awareness of contractors of the risks. To enable large proportions of the methods to be constructed part of the road and footpath may need to be closed. Traffic management and access to properties will need to be considered to ensure safe construction. Health and Safety risks can be kept at a manageable level provided standard mitigation methods are put in place.

Operation stage

Regular maintenance is required to ensure the design standard is maintained. Risk assessments for condition inspection and maintenance activity needs to be considered. The detailed design of the scheme elements should allow for safe access to inspection and maintenance of structures and channels.

A design health and safety risk assessment has been completed for the project which has been included in the project safety file.

Residual risks and failure of walls, structures and systems

Asset inspection and maintenance is critical to managing the risk of failure of structures and walls. Detailed design of the preferred option should include modelling of flood defence wall breaches and structure failure and blockage and exceedence scenarios (such as flood probabilities with greater magnitude than the design standard or climate change scenarios). Complimentary methods will be necessary to manage exposure and flood hazard levels such as flood warning systems and designated overflow paths when defences are exceeded or fail. It is essential to consider flood defence failure and exceedence likelihood together with the possible range of flood depths to properties and access routes. Flood response plans may need to consider evacuation of properties and restricting access to defenced areas during flooding. The cost of flood forecasting and warning to alert for defence failure and overtopping has not been included in the option costs.

4.6 Cost Estimate

Costs are estimated based on unit rates for flood defences. The scheme cost estimation has used the following assumptions:

- Normal firm glacial tills with ground water levels below formation level. Only when site investigations are carried out at detailed design stage will this be confirmed. There may be the need for piled foundation or temporary pumping which would significantly increase the cost.
- The construction management plan for all flood defences will need to consider avoidance and mitigation to manage the potential impacts upon the Natura 2000 designated sites, protected habitats and species present. This includes works on the River Corrib where sediment could be transported downstream. This complexity has been factored into the cost estimates through the method factor.
- Surface water drainage will need to be considered in the detailed design of the embankments and pumping stations. This additional cost has been accounted for in the method factor.

Maintenance costs were also estimated and the NPV of the maintenance costs over 50 years discounted at 4% was calculated.

Total costs were estimated by adding allowances such as construction preliminaries, compensation, land acquisition, engineering fees, specialists etc. to the construction costs. These costs along with the applicable percentage rates are included in Table 3-16. An allowance for optimum bias was taken to be 50%. A 15% allowance for archaeology and environmental mitigation has been included to account for the environmental sensitivity of the site.

The proximity to Natura 2000 designated sites adds to the complexity of site investigations resulting in the high estimate. An art allowance has been included following the OPW per cent for art scheme formulas and capped at the maximum for the value of the project.

The Land and acquisition allowance has been reduced from the recommended 8% to 5%. This accounts for the fact that majority of the defences are to be situated along existing lines of defences and in public land.

Table 4-1: Option Costs

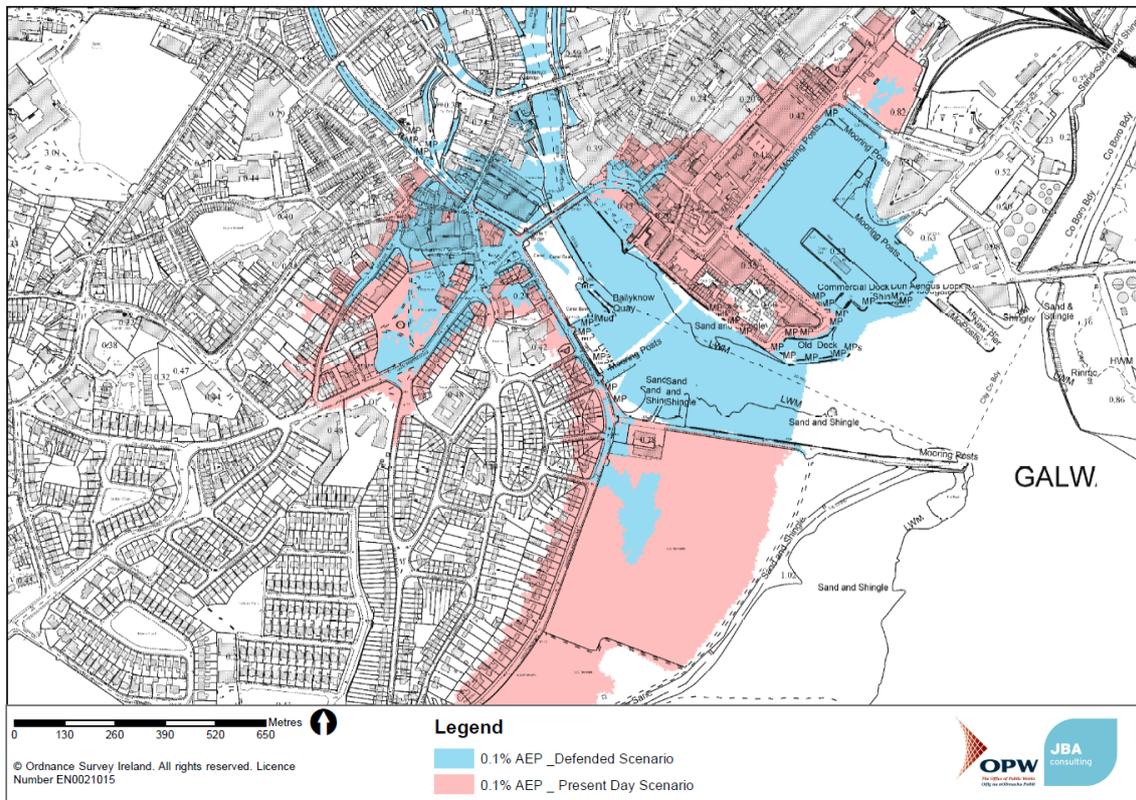
Option 2 Flood containment to 1% AEP for fluvial risk and 0.5% AEP for tidal risk design standard.		€
Construction costs		
Nimmo's Pier		346,481
Claddagh Quay		898,458
Raven Place and Eglinton Canal		849,929
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Wolfe Tone Bridge		60,479
Long Walk and New Dock		1,520,800
Salthill Area 1		120,000
Salthill Area 2		106,151

Construction costs - Subtotal		4,267,969
Preliminaries	7%	298,758
Capital costs - Subtotal		4,566,727
Optimism Bias	50%	2,283,364
Construction costs (Excl VAT)		6,850,091
Design Team Fees and Expenses (Including Site Supervision and Environmental Fees)	13%	890,511
Capital costs - Total (construction costs and fees)		7,740,602
<i>Other Items</i>		
Allowance for Archaeology & Environmental Mitigation	15%	1,161,090
Allowance for compensation and land acquisition	5%	387,030
Site investigation		25,000
Art Allowance		51,000
Other costs - Subtotal		1,624,120
Operation, Maintenance and Event Costs		117,128
Optimism Bias (O+M)	50%	58,564
Option Cost for Cost Benefit Analysis		9,540,414
BCR		0.86

4.7 Defending to a Higher Standard

The design defence standard of the scheme is the 0.5% AEP in coastal areas. Within Galway City the guarding height due to health and safety considerations dictates that in the majority of the locations that defence heights are significantly higher than the required height to protect to the defence standard. Figure 4-20 shows the present day 0.1% AEP and the 0.1% AEP defended run minus freeboard allowance. This run of the model includes the actual (minimum height) defence level, with the higher design standard. This will identify whether additional benefits can be accrued by the scheme, and assist in the delivery of a benefit cost ratio over unity.

Figure 4-20: Increased benefiting lands in the 0.1% AEP due to guarding height



It can be seen that the extent of the 0.1% AEP reduces considerably due the current proposed defences put in place. Benefit analysis of the extent area that is protected (shown in red) leads to an increase in benefits of €1.36 million. This results in the **BCR of 1.0**. The minimum design heights of the walls as shown in the schematics in Section 4.2 will also defend to a height above the MRFS. Damages in the MRFS are equate to €99.3million. Though the entire of Galway will not be defended to MRFS a significant portion of the damages can be negated by providing the current defence levels. Further improvement in the benefit cost ratio is likely in a more detailed feasibility assessment and again it should be noted that traffic disruption costs have at this time being discluded.

4.8 Climate Change Adaption

Currently the nationally consistent economic analysis of available options for Galway are close to unity. This underplays the non monetary benefits of protecting the historic core of one of Ireland's major cities. As discussed in Section 1 the extent and expected depth of flooding increases significantly in the median range future climate change scenario with capped damages increasing from €8.15m to €99.3m.

Where a community is highly vulnerable to the potential impacts of climate as the case in Galway City, then adaptation of any flood relief scheme and future interventions are likely to be required to avoid significant increases in risk in the future. This may alter the current type of methods adopted for that community. Options can be categorised into precautionary and managed adaptive approaches. Both approaches assume climate change increases the exposure to hazard. The precautionary approach (e.g. tidal barrage or flood walls to MRFS standard) is to design flood defences to protect to the maximum possible standard for the future. The managed adaptive approach (defences to current standards and redevelopment of a more resilient city fabric) is to put in place methods to address current levels of risk, which can be adapted to protect from future risk. The managed adaptive approach allows for adaptation of design standards as the uncertainty in climate change impacts reduces.

Of particular note, is that considering climate change adaptation, resilience and future risks may result in currently unviable methods and options becoming justifiable. This is not only on economic

grounds, but also environmentally as increased future risk may outweigh other environmental considerations.

4.8.1 Future Adaptability

Current medium range future predictions estimate a 20% increase in design flows and 0.5m increase in extreme sea levels. This increase in flow and sea levels has been tested and would require an additional 0.5m height on top of the proposed quay walls.

Following the review of potential methods to reduce the flood risk in Galway, it is clear that the strategic response to climate change is limited to increasing the height of defences. There are small pockets of flood risk, where a managed set back or redevelopment of these areas to flood resilient construction and operation could be considered. Therefore, the focus on any adaptive approach is about managing the height of the walls and defences, given the cultural and heritage issues that could arise in the centre of Galway. The challenge of providing a climate change suite of defences should not be underestimated, and it is recommended that the scale of the methods needed to defend against climate change are assessed as part of the actions arising from the FRMP. Public acceptance of a defended approach is essential.

The preferred option may be adaptable by adding demountable defences in areas where the guarding height does not protect to MRFS levels. Stronger foundations can be provided, to extend height in time but these would result in Quay wall heights of greater than 1.8m, which would not be aesthetically pleasing and would not be socially acceptable. Floating walls that could extend to required height at times of risk and maintain the risking views should be assessed.

The adaptability of options has been assessed and is summarised in Table 4-2. Figures under the discussion of the technical viability in Section 4.2 shows indicative heights of flood defence walls to address future flood projections.

Table 4-2: Adaptability to Climate Change

Option	Scenario	Implications for scheme
Option 2	MRFS	With MRFS predictions, Quay walls may need to be 1.8m above ground level in places. The option to increase wall heights or top with demountable sections impact the visual aesthetics or stretch local authority resources during events.
	HEFS	Increasing walls from the current estimates to the HEFS flood levels would not be an acceptable option. Sea and river views would not be visible. To manage to the HEFS projection more radical solutions may be required, such as land raising, relocation of properties or flood resilient redevelopment, tidal barrage or employing floating walls. All of which would require development planning and flood policy changes.

4.8.2 Climate change strategy for the proposed methods

Long lengths of the proposed defences will have a minimum height driven by health and safety considerations of structures adjacent to the quay wall. Where these guarding heights exceed the predicted MRFS levels there is a real opportunity to take a precautionary approach to climate change, and from the economic analysis undertaken in the option development would be cost beneficial. There are a few areas, where flood defences would have to be raised to contain the climate change levels. These could create significant visual impacts, and in these areas consideration of demountable solutions could be explored at detailed design stage. In the design of the proposed scheme it is recommended that a MRFS design standard is adopted, and optioneering of how that can be delivered in the West End/Canal network should be undertaken.

An adaptive approach should be applied to the fluvial risks associated with climate change, but when the tidal scheme is being detailed, a further check should be made to see whether in the shared tidal/fluvial flood cells additional defences could be added for modest increase in capital budget.

4.9 Multi-Criteria Analysis

The effectiveness of this option against the flood risk management objectives and the results are shown in Table 4-3. Further details are provided in Appendix E.

Table 4-3: Multi Criteria Analysis

Number	Criteria	Sub- objective	Score Option A
1a	Technical	Ensure flood risk management options are operationally robust	100
1b		Minimise health and safety risks associated with the construction and operation of flood risk management options	100
1c		Ensure flood risk management options are adaptable to future flood risk	200
TECHNICAL SCORE			400
2a	Economic	Minimise economic risk	600
2b		Minimise risk to transport infrastructure	238.25
2c		Minimise risk to utility infrastructure	0
2d		Minimise risk to agriculture	0
ECONOMIC SCORE			838.25
3a (i)	Social	Minimise risk to human health and life of residents	148.09
3a (ii)		Minimise risk to high vulnerability properties	0
3b (i)		Minimise risk to social infrastructure and amenity	93.375
3b (ii)		Minimise risk to local employment	29.785
SOCIAL SCORE			271.25
4a	Environmental	Provide no impediment to the achievement of water body objectives and, if possible, contribute to the achievement of water body objectives.	-80
4b		Avoid detrimental effects to, and where possible enhance, Natura 2000 network, protected species and their key habitats, recognising relevant landscape features and stepping stones.	-50
4c		Avoid damage to or loss of, and where possible enhance, nature conservation sites and protected species or other know species of conservation concern.	-25
4d		Maintain existing, and where possible create new, fisheries habitat including the maintenance or improvement of conditions that allow upstream migration for fish species.	-65
4e		Protect, and where possible enhance, visual amenity, landscape protection zones and views into / from designated scenic areas within the river corridor.	-128
4f (i)		Avoid damage to or loss of features of architectural value and their setting.	-48
4f (ii)		Avoid damage to or loss of features of archaeological value and their setting.	-48
ENVIRONMENTAL SCORE			-444
MCA OPTION SELECTION SCORE			1066
MCA BENEFIT SCORE			666

4.9.1 MCA Outcomes

Following the completion of the multi criteria analysis the following outcomes are available:

Criteria Scores: The MCA produces a weighted score for each objective and the sum of these within each of the criteria classifications is the Criteria Score, Table 4-4.

Table 4-4: Criteria Scores

Criteria	Score Option A
Technical	400
Economic	838.25
Social	271.25
Environmental	-444

MCA Benefit Score: The sum of the scores for the economic, social and environmental criteria. It excludes the technical criteria score. This score represents the net benefits of the option.

Option Selection MCA Score: The sum of the scores for all four of the criteria. This score compliments the MCA Benefit Score with the Technical Criteria Score, and hence includes all of the aspects that should be taken into account in considering the preferred option for a given location.

MCA Benefit – Cost Ratio (BCR): The MCA Benefit Score divided by the cost of the option to provide a numerical, but non-monetarised, MCA Benefit - Cost Ratio that provides an indication of the overall benefits that can be delivered per Euro invested.

The Economic Benefit – Cost Ratio (BCR) has also been calculated as discussed in Section 4.6. This was found to be 0.83. The Outcomes of the MCA process can be used to guide the decision making process in combination with consultation with the steering group meeting.

4.10 Stakeholder Engagement

Throughout this process OPW regional engineers and local authority engineers have been consulted in the form of steering group, progress group and engineer meetings and their input has feed into the preliminary option stage.

Public Consultation Day (PCD) - 22nd of September 2015

On September 22nd, 2015, a public consultation was held at the Harbour Hotel to outline possible methods for the town.

This PCD was attended by 20 people. At the PCD attendees were invited to leave feedback, in the form of a questionnaire and through notes taken by the event facilitators from JBA and the OPW. The questionnaire sought opinion on the public's attitude to some of the types of methods being explored for the town. A detailed report on the PCD has been prepared. This report details all responses received on the day.

A range of well-informed opinions and ideas was raised at the PCD event. It is clear the local community understand the risks and are in need of some certainty. Some of the ideas and opinions raised conflict, but all have been used to inform the preliminary options development. The screening of methods was revisited following the PCD to address comments from the community.

Table 4-5 summarises the opinions on the returned questionnaires on the initial options presented at the PCD. These opinions have been used to inform the options proposed in this report. Table 4-6 outlines the main concerns and how they have been incorporated into the POR stage by the study team.

Table 4-5: Summary of opinion on options presented at the PCD

Option		Summary of comments	
All areas	All areas - Existing Approach	Against - 1 Neither against or support - 0 Support - 0 Unsure - 0 No answer - 7	Action needed. Not viable as inadequate for level of flooding
Nimmo Pier	1 - Wall along Quay	Against - 0 Neither against or support - 0 Support - 2 Unsure - 0 No answer - 6	Support but concern about effect on visual amenity.
	2 – Embankment plus road ramp	Against - 0 Neither against or support - 0 Support - 0 Unsure - 0 No answer - 7	Most cost effective approach, no opposition to option.

Claddagh Basin	1 – Claddagh Quay defence wall	Against - 0 Neither against or support - 0 Support - 0 Unsure - 0 No answer - 7	Most cost effective approach, no opposition to option.
	2 - Defence at Claddagh Basin with storm gates	Against - 0 Neither against or support - 0 Support - 0 Unsure - 1 No answer - 7	Some respondents were concerned about the impact of this option.
Eglington Canal & Raven Place	Defence walls with demountable	Against - 0 Neither against or support - 0 Support - 2 Unsure - 0 No answer - 6	Good support for this option. Residents saw this area as a source of flood risk.
Wolfe Tone Bridge	Upgrade bridge parapet with demountables	Against - 0 Neither against or support - 0 Support - 0 Unsure - 0 No answer - 7	No opposition to this option.
Spanish Arch	1 - Quay wall defences	Against - 0 Neither against or support - 0 Support - 2 Unsure - 0 No answer - 6	Visual aspects of this option are important.
	2 - Wall set back from quay to tie in with buildings	Against - 0 Neither against or support - 0 Support - 1 Unsure - 0 No answer - 7	Visual aspects of this option are important. Respondents were keen on some public realm work.
Long Walk & New Dock	1 - Defence along front of Dock	Against - 0 Neither against or support - 0 Support - 2 Unsure - 0 No answer - 6	Support for option.
	2 - Wall along Long Walk, embankment and wall set back from existing quay wall at the dock	Against - 0 Neither against or support - 0 Support - 1 Unsure - 0 No answer - 7	Support for option.
Salthill Area 1	Defence walls with flood gates	Against - 0 Neither against or support - 0 Support - 0 Unsure - 0 No answer - 7	No opposition to option. However, the stakeholders most concerned with this option were not present.
Salthill Area 2	Landscaped embankment to tie into raised road ramps	Against - 1 Neither against or support - 0 Support - 2 Unsure - 0 No answer - 5	Business residents want to install tennis court and basketball court in this area. Embankment could run along front in location where gates installed. The area can be landscaped to both provided protection and an enhanced amenity area. Support for option.

Respondees answered no "no answer" where the options did not directly affect them.

Table 4-6: PCD Feedback

Comment Received	Study Response
No wall at Raven Place, water ingress at Raven Terrace. 2003 wall taken away.	Defence wall have been recommended here.
Spanish Parade - Kumar's taste of Asia Restaurant - flooding because of gullies blocking during periods of heavy rain and high tide levels. Improved maintenance to clear leaves will reduce risk. Comes in through front door. Also there is a gully inside the property and this can back up.	Surface water flooding and drainage outside of the CFRAM scope, however needs to be considered in scheme development.
Flooding to Spanish Dock comes from Dock area along Spanish Parade. Also sewer system in the area doesn't have enough capacity and requires upgrading	Surface water flooding and drainage outside of the CFRAM scope, however needs to be considered in scheme development.
Flooding reaches 4ft high in basements at times in lower. Salthill and is getting worse. The tide came down the lower Salthill road in Jan '95 for the first time and has done so since on at least 4 occasions	Surface water flooding and drainage outside of the CFRAM scope, however needs to be considered in scheme development.
Very important that defences are visually acceptable in a tourist hot spot. Protection from flooding of utmost importance.	JBA to consider finish in important areas.

5 Non Structural Methods

Non-structural flood risk management methods are proven methods and techniques for reducing flood risk and flood damages incurred within towns. Besides being very effective for both short and long term flood risk and flood damage reduction, non-structural methods can be very cost effective when compared to structural methods. A particular advantage of non-structural methods when compared to structural methods is the ability of non-structural methods to be sustainable over the long term with minimal costs for operation, maintenance, repair, rehabilitation, and replacement.

At the screening stage non-structural methods and how they could benefit Galway City were considered (see Table 3-1). Full discussions on non-structural methods has been discussed in the overarching UoM preliminary options report. This section provides a bit more detail on these methods and how they could be implemented, either as standalone or in conjunction with a structural flood relief scheme in Galway City.

Non-Structural Methods
Planning Development and Control
<p>Spatial Planning and Impacts on Development</p> <p>There is a significant opportunity for planning and development management policies to improve the resilience of Galway City to flooding. The challenge is to maintain sustainable communities into the future. Development plan zoning objectives and development management policies should be amended to reflect flood risk, climate change adaptation and resilience and the overall vision for Galway City. Until development plans are updated the CFRAM flood maps should be used to inform planning decisions.</p> <p>Non-resilient development should not be permitted in defended areas as this will expose an increased population to residual flood risks.</p> <p>Further detail on flood risk and land zoning objectives under both current and future scenarios is provided in Section 5 of the UoM30 Overarching Report.</p>
<p>Sustainable Drainage Systems</p> <p>Having reviewed the potential for various types of SuDS in Galway City, it is likely that there is a low to moderate chance of successfully implementing infiltration techniques so storage and attenuation with controlled discharges will also need to be considered.</p> <p>There are opportunities to retrofit Green Infrastructure in Galway City on a local level to reduce the rate at which runoff discharges into storm sewers and watercourses.</p> <p>SuDs and Green Infrastructure should be used as overflow paths to manage residual risks when defences are exceeded or fail.</p> <p>More detail on the applicability of SuDS in Galway City, and indicative storage volumes, are provided in Section 6 of the UoM30 Overarching Report.</p>

Flood Preparedness Methods

Flood forecasting and warning systems

A fluvial flood warning based on a trigger alone is feasible as it gives adequate warning time to reduce risk from fluvial flooding. A gauge on Lough Corrib will provide sufficient warning times. Potentially the gauging station upstream at Corrofin / Claregalway could be utilised also. Minor works will need to be undertaken to install telemetry capabilities, warning system and calibration. A flood warning system for the entire catchment can provide warning to residents in Galway from fluvial flooding. However, this system is currently unviable with a BCR of 0.52, as the benefits of protecting the fluvially affected areas are limited in the current scenario. It should also be noted that any containment scheme to protect the tidal risk areas, would also remove the fluvially impacted areas downstream of the Salmon weir

In terms of Coastal flooding, Galway City itself can tie into the national tide and storm surge model to provide sufficient warnings, but for Salthill an overtopping model is required which is currently not economically viable.

More detail of the potential for flood forecasting in Galway is provided in Section 7 of the UoM 30 Overarching Report.

Emergency Response Planning

Until such time as a scheme is built in Galway City, the existing risk to life will remain unless a flood response plan can ensure necessary actions are taken and all vulnerable residents can be safely evacuated and accommodated, if necessary. Well prepared and executed emergency plans can significantly reduce the impact of flood events. Galway City Council has produced a Major Emergency Plan, which incorporates a "Flooding Sub Plan and should be implemented by Galway City Council in times of flood emergency.

Even with flood protection, a response plan is necessary to ensure asset condition is monitored during a flood event and local communities are not exposed to flood risk. The high tourist population also increases the risk as people are not aware of their surroundings.

Targeted Public Awareness

Individuals and communities that are aware of any prevalent flood risk are able to prepare for flood events when such events occur. People are able to take appropriate actions in advance of, during and after a flood to reduce the harm and damages a flood can cause. There has been good attendance to both the flood mapping and POR Public Consultation Days (PCD) in the town. Salthill and much of the centre of Galway City has a high tourist population and many will be unaware of the risks. Signage indicating high tide advisories could be utilised.

Individual Property Resilience

Resilience may be suitable for properties vulnerable to repeated flooding where the depth of flooding exceeds 600 mm (CIRIA 2007). When floodwater exceeds this level, it may be more appropriate to allow water into a property, preventing possible structural damage to walls in a way that limits the potential damage, cost, disruption and ultimately the time that a property is uninhabitable.

Individual Property Protection

Flood resistance, or dry proofing, techniques prevent floodwater from entering a building. This approach includes, for example, using flood barriers across doorways, airbricks and raised floor levels. Household flood resistance aims to prevent floodwaters from entering a building structure. Such methods are appropriate in areas that frequently flood to shallow depths, and where community-scale defences are unlikely to be a viable option. However, with the number of houses in Galway City and with the depth of flooding this option of protection is limited. Also with climate change the expected flood depths exceed the level at which individual property protection is effective.

Relocation or Redevelopment

Rebuilding and relocation of properties at risk is an option the OPW and National Government are considering. Rebuilding properties at risk to a higher level in the same location or on the same site may be applicable to rural properties where parts of the land are outside of flood zones. In urban areas there is unlikely to be sufficient space for such a policy. Access to and from properties above flood levels will need to be safe from flooding.

For Galway City such a policy would need to be comprehensive across the city affecting much the core business areas. Therefore, this option is unlikely to be implemented.

Maintenance

The River Corrib is part of the Corrib Arterial Drainage Scheme and so maintained under the Arterial Drainage Acts. Further enhanced structure maintenance to the culverts and culvert inlets could potentially increase the structure capacity through the removal of fine sediment deposits.

The hydromorphic audit has identified that of the Castlegar River which is a tributary of the main River Corrib river is susceptible to reach scale sedimentation processes. Seven structures have been identified on this watercourse. The dyke road embankment is a vital defence to many areas and this should be maintained effectively going forward. It is recommended that all formal effective defences along the River Corrib be maintained to ensure the current standard of protection.

The OPW, Lough Corrib Trustees, Galway Port and Galway City Council have all responsibility in some part of Galway City. Engagement between these groups is important for maintenance regimes to be effective. The dyke road embankment is a vital defence to many areas and this should be maintained effectively going forward.

A full asset and maintenance plan for the canals would improve the risk of structure failure and maintain or improve the current flood risk

6 Conclusion

The Preliminary Options Appraisal has concluded that there is a viable but not cost beneficial option to protect the full AFA to the 1% AEP fluvial and 0.5% AEP tidal design standard.

The preferred option has a benefit cost ratio of 1.0 and a Multi-Criteria Analysis score of MCA option selection score of 1066.

Long lengths of the proposed defences will have a minimum height driven by health and safety considerations of structures adjacent to the quay wall. Where these guarding heights exceed the predicted MRFS levels which will provide benefits to the majority of areas in the future as well as the current scenario. There are a few areas, where flood defences would have to be raised to contain the climate change levels. These could create significant visual impacts, and in these areas consideration of demountable solutions could be explored at detailed design stage. In the design of the proposed scheme it is recommended that a MRFS design standard is adopted, and optioneering of how that can be delivered in the West End/Canal network should be undertaken.

In terms of Environmental impact, the proposed flood defences do not take land from, or encroach into the rivers or Natura 2000 sites and so only minor negative impacts are likely for objectives 4a to 4d (WFD, Habitats Directive, national biodiversity and fisheries). This impact is mainly due to the need for access from the river to maintain the flood defence structures and can be mitigated with proper planning.

From a social aspect, the proposed scheme will reduce the risk of flooding to important landmarks, views, architecture and archaeology. However, there is potential for significant permanent negative impacts and consultation should be sought with relevant stakeholders and bodies to reduce these negative impacts.

The residual risk and exposure to flooding needs to be managed as climate change flood hazard is predicted to increase significantly. Failure or overtopping of tidal defences in climate change scenarios will pose a significant risk to life. Non-structural methods must complement the preferred option to manage the residual risks both now and in the future.

Appendices

A Economic Appraisal of Technically Viable Options

A.1 Overview

The economic appraisal of a method or option is based on the assumption that the cost of implementing a method should not exceed the benefit associated with the reduction in flood risk following the implementation of that method. The cost of implementing a method reflects the costs of construction and whole life costs arising from maintenance. The benefits associated with the reduction in flood risk as a result of a method are discussed in detail in this Section.

For each AFA with a technically viable method or set of methods, the following economic appraisal has been carried out. Where there are no technically viable methods, economic appraisal has not been undertaken. The starting point for determining the benefits of a flood relief scheme is to identify the tangible costs associated with a flood event, or those costs which would be removed if a flood relief scheme were put in place. The tangible costs are those factors for which there is a clear monetary cost resulting from a flood. These costs can be split in to direct and indirect costs. Direct costs are the damages incurred to property as a result of a flood. Indirect costs are costs incurred as a result of a flood other than direct damages, for example the rental costs of temporary accommodation or the costs associated with a flood event response by the emergency services.

There are also intangible costs associated with a flood event. These represent the human impacts on an event such as anxiety, stress and ill health. The total economic costs associated with a flood event are assumed to equal the total of the tangible and intangible costs. The methodology for calculating these costs is set out in the following sections.

Having established the potential benefits of a method or option, the viability of selected methods is dependent on the likely costs of construction and long term maintenance compared to the benefits.

Indicative costs have been calculated as part of the screening assessment where the screening assessment confirmed an economically viable option was available, the costs have been refined as part of the full scheme development costings. In both cases, costs have been determined using the unit cost database.

The unit cost database has been used to maintain consistency in estimated costs of construction and maintenance of methods nationwide under the CFRAM project.

The screening cost estimate consists of construction costs, associated preliminaries, operation and maintenance costs and an allowance for optimism bias. The final option costs also include additional allowances detailed design, archaeology, land compensation and art.

The following section step through the process of calculating benefits (Sections A.2 to A.5) and costs (Section A.6). The costing summary sheet for all technically viable options is provided in Appendix B.

A.2 Direct Flood Damages

A.2.1 Source Data

Economic flood damages have been estimated using the data and general methodologies outlined in 'The Benefits of Flood and Coastal Risk Management: A Handbook of Assessment Techniques 2010), which is often referred to as the 'Multi-Coloured Manual' (MCM). This manual provides depth damage curves for different types of residential and commercial properties compiled from historical data of damages incurred in past flood events. By extracting the flood depths for affected properties from WCFRAM hydraulic modelling outputs the total damages in a given flood event can be determined.

Property types have been derived from the An Post geodirectory. The An Post directory assigns one of four codes to each of the property points to indicate the property type. These are R – residential, C – commercial, B – both and U – Unknown. A review of property points assigned a B

code confirms it is generally the commercial property on the ground floor and so, subject to flood risk, residential costs in these instances have been removed. A-3

Residential properties are further categorised in the geodirectory into detached, semi-detached, terraced, duplex and bungalow. Unknown (U code) properties were found to include a description of the property type (detached, semi-detached etc.) and so were assumed to be residential.

Commercial properties in the geodirectory have a NACE code assigned; this is a European equivalent to the MCM codes but not directly comparable. To facilitate the analysis, each NACE code has been attributed an equivalent MCM code and so each commercial property attributed an appropriate MCM code. Where a NACE code was not available an appropriate MCM code has been determined based on knowledge of the town.

Property floor areas were extracted from OSi data and geographically linked to the An Post data. Where multiple An Post points existed within the same building polygon it was assumed the building footprint was divided equally between points. Where An Post data did not coincide with a building polygon a footprint area of zero was applied and hence no damages will be calculated for these points.

Property threshold levels are assumed to be equivalent to the mean LiDAR level over the buildings' footprint polygon plus a typical observed threshold level for the area.

A.2.2 Methodology

The depth damage curves used in the analysis for residential properties are based on the type of property described above only, i.e. detached, semi-detached etc. Where this data was not available a residential average was applied. Damage curves has been further selected based on local conditions such as whether the event had a short or long duration, defined as less than or greater than 12 hours, or whether salt water damage should be considered, as would be the case for tidal flooding. For residential properties damages begin at -0.3m to allow for damage to foundations.

In some AFAs, properties are affected by both fluvial and coastal flooding. However, hydraulic modelling has demonstrated that there is no joint probability risk from the two sources, so damages from each source can be treated independently. Once calculated for each individual source the total direct damage to an individual property is the sum of the damages from the two sources.

Prices (damage costs) in the data provided by FHRC 2010 have been converted to euro rates applicable to Ireland in 2013 (the reference date set by the OPW to allow a consistent comparison of findings across all CFRAMs) by:

- Applying a 'PPP' multiplication factor of 1.279. This is derived from the relative OECD Purchasing Price Parity values for the UK and for Ireland for 2010. The 'PPP' factor is net of currency conversion (i.e., already includes for exchange rates as well as price differences, and so no currency conversion rate should be applied in addition to this factor)
- Applying an inflation multiplication factor of 1.051. This is derived from inflation rates based on the CPI in Ireland for the period 2010 - 2013

Economic damages to infrastructural utility assets (e.g. electrical sub-stations, gas installations and pipe-work, telecommunications assets, etc.) are assumed to be 20% of total direct damages to properties for the AFA.

A.3 Intangible and Indirect Damages

Flood events can cause significant stress, anxiety and ill health to potentially affected people, during and then after a flood. Individuals generally also incur some costs due to their properties flooding that are not directly related to damage, such as evacuation, temporary accommodation, loss of earnings, increased travel and shopping costs, etc.

For residential properties the intangible and indirect flood damages shall together be set equal to the total direct property damages as calculated above.

Costs attributable to emergency services (which includes evacuation costs) are assumed to be equivalent to 8.1% of the total direct property damages. This value was derived as an average of the measured emergency services costs for the 2000 and 2007 floods in the UK.

Traffic disruption has not been included in the assessment of damages. Traffic disruption historically makes up a small percentage of damages and was not included at this strategic level.

A.4 Calculation of Annual Average Damage (AAD) and Present Value of damages

A.4.3 Discount rate and project horizon

Given a choice between receiving a specific sum now and the same amount sometime later, most people will express a preference for the present sum. The tangible benefits accruing from a flood alleviation scheme will not provide cash sums to the beneficiaries; however, they will prevent a negative cash flow (avoidance of associated flooding costs) from the individuals.

The avoidance of fixed negative cash flow now is also preferable to avoidance sometime in the future. The “social time preference” (STP) can be measured by an appropriate Discount Rate (STPDR) and is taken as the compound rate of interest ‘r’ (% per annum) by which ‘y’ Euros in ‘x’ years’ time is equal to one euro now.

The benefits arising from a flood relief scheme commence on the completion of the scheme and exist for the life of the works. To obtain a method of the overall benefit in present day monetary values, it is necessary to:

- a. Estimate the benefit arising each year of the project life, termed the Average Annual Damages (AAD)
- b. Discount the AAD to present values using the appropriate discount rate.
- c. Total the present values to obtain the overall benefit.

The Department of Finance’s discount rate for public investment is 4%. The lifetime over which the benefits are discounted is taken as 50 years. For computation purposes, it is assumed that the residual value of the scheme at the end of the period is nil. This may be regarded as somewhat conservative, since works typically have a design life of 100 years.

A.4.4 Property capping assumptions

The present value damages for any given property should not exceed its current valuation. This is to prevent justification for a flood mitigation scheme being based on the repeated flooding of a property over the project life when it would be more cost beneficial to simply buy out the property. Estimated property values have been determined for both residential and commercial properties.

Residential Properties

Average prices for apartments, bungalows, detached, semi-detached and terrace properties were derived for each AFA as there was considerable difference in property values across all AFAs. The data was extracted from www.lpt.revenue.ie. The final capping value was set at twice the market value to allow for intangible damages.

Figure A-1: Residential capping assumptions

Area of further assessment (AFA)	Property type					Electoral district
	Apartment/Flat	Bungalow	Detached	Semi-Detached	Terraced	
Corrofin	150,000.00	150,000.00	150,000.00	150,000.00	100,000.00	Corrofin
Galway City (1)	150,000.00	200,000.00	250,000.00	200,000.00	150,000.00	Menlough
Galway City (2)	200,000.00	200,000.00	250,000.00	200,000.00	200,000.00	Dangan
Galway City (3)	150,000.00	150,000.00	150,000.00	150,000.00	150,000.00	St. Nicholas
Galway City (4)	150,000.00	200,000.00	200,000.00	200,000.00	200,000.00	Nun’s Island
Galway City (5)	200,000.00	250,000.00	300,000.00	250,000.00	200,000.00	Claddagh
Galway City (6)	150,000.00	150,000.00	250,000.00	250,000.00	200,000.00	Eyre Square
Galway City (7)	150,000.00	150,000.00	200,000.00	150,000.00	150,000.00	Castlegar
Galway City (8)	150,000.00	200,000.00	250,000.00	200,000.00	200,000.00	Lough Atalia
Galway City (9)	200,000.00	200,000.00	250,000.00	250,000.00	200,000.00	Salthill
Dughterard	150,000.00	150,000.00	200,000.00	150,000.00	150,000.00	Dughterard
Ballyhaunis	100,000.00	150,000.00	150,000.00	150,000.00	100,000.00	Ballyhaunis
Tuam	150,000.00	150,000.00	150,000.00	150,000.00	100,000.00	Tuam Urban

Non Residential Properties

Average commercial property values have proved to be difficult to pinpoint. The high level approach outlined within the MCM is to estimate values as a factor of 10 greater than the rateable value, broadly defined as the annual rental value of the property. However, average commercial rental values are not widely available. Commercial rateable values were provided by the relevant county councils but these values are not equivalent to the rental value of the property and are not suitable for determining capping values. The Ireland Valuation Office is currently going through a revaluation process owing to the poor correlation between the rental value of properties and the rateable value but this information is not available for the west of Ireland.

Rateable values for all properties have been obtained from the April 2008 values for South West England from 'Commercial and Industrial Floor space and Rateable Value Statistics' (<https://www.gov.uk/government/statistical-data-sets/live-tables-on-commercial-and-industrialfloorspace-and-rateable-value-statistics>) as instructed by the OPW. These UK rateable values have been multiplied by the "PPP" multiplication factor of 1.279 and uplifted by the inflation multiplication factor of 1.051 resulting in the following euro rates. Non-residential properties were capped at 10 times the below rateable income.

Table A-1: Rateable incomes for non-residential properties

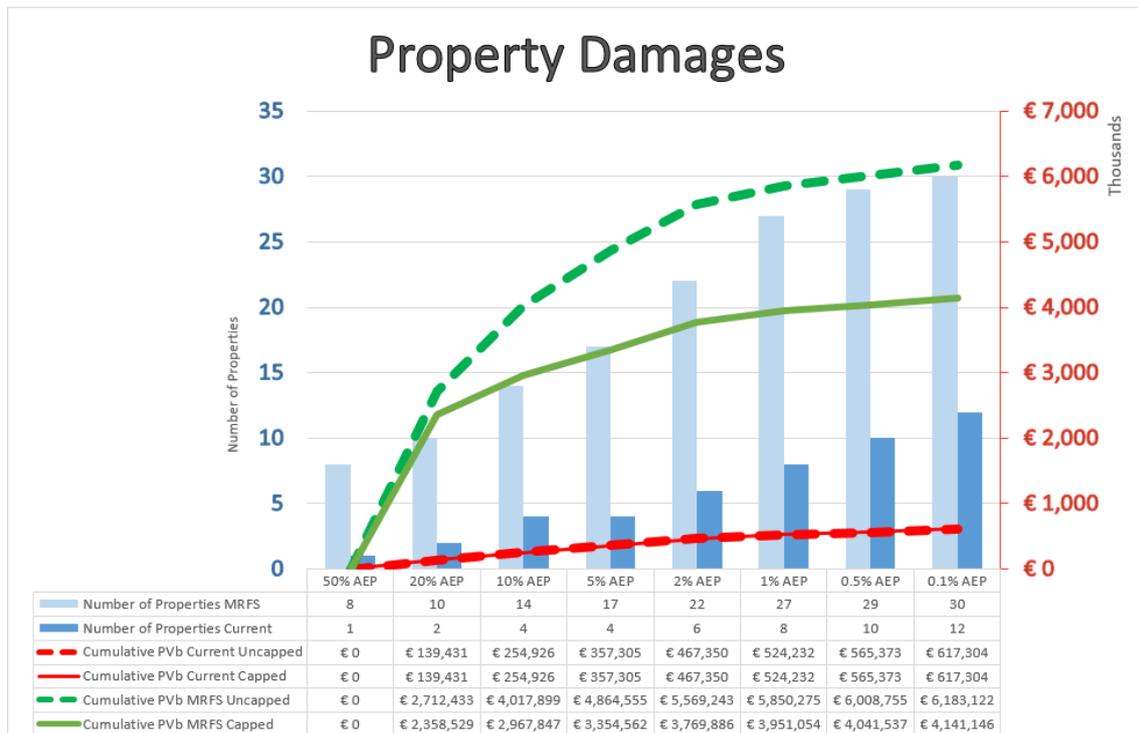
Property type	Rateable value per m ² (€)
Retail	161
Office	115
Warehouse	51
Leisure & Public	37
Industry	41

A.5 Benefit analysis

Using JBA's custom software package, FRISM, flood depths have been extracted and damages determined for each property for each of the eight defined design event probabilities. The Annual Average Damage (AAD) has then been calculated as the probability weighted sum of the damage values of each event up to and including the 0.1% AEP event. The Average Annual Damage, discounted at a rate of 4% per annum over a time-horizon of 50 years, produces the Net Present Value of the potential flood damage. An example of calculated damages is shown in Figure A-2.

It should be noted that, in the example shown in Figure A-2, the current and MRFS damages are both less than the equivalent capped damages, indicating that the value of residential and commercial properties has not impacted on the damages attributable to flood events.

Figure A-2: Damage calculation result



The damages calculated using this method have been applied at for both the verification screening and detailed options development stages of assessment.

A.6 Screening cost estimates

For each technically viable method identified as part of the screening assessment a cost estimate is provided in the relevant AFA report. An example breakdown of estimated costs for the screening assessment is shown in Table A-2 and details of the constituent parts provided in the following sections.

Table A-2: Screening costs

Option 2			
Construction of retaining wall at Botharnsup Road Property and embankments to protect main street and Renville property			
Retaining wall at Botharnsup Road		€	78,175
Embankment to the rear of properties on main street			7,626
Embankment at Renville Property			15,253
Preliminaries	32%		32,337
Sub - Total			133,391
Optimism Bias	50%		66,696
Construction costs (Excl VAT)			200,087
Est. NPV Operation and Maintenance (Walls)		214	
Est. NPV Operation and Maintenance (Embankment Main Street)		5,864	
Est. NPV Operation and Maintenance (Embankment - Renville)		5,864	
Optimism Bias	32%	3,821	15,763
Indicative Screening Cost			215,850

A.6.5 Construction costs

Construction costs were estimated based on typical unit and item costs (e.g. cost per metre length of reinforced concrete wall of given height, or cost of a pump of certain capacity) as set out by the unit cost database. Details of which unit and option cost have been applied are provided within the relevant AFAs reports. Summing the construction unit cost of the methods gives the Gross Capital Construction Cost.

A.6.6 Preliminaries

Preliminaries and other construction costs include the following items:

- Compound
- Site cabins and services
- Temporary power and generators
- Protection to overhead services
- Protection to underground services
- Road sweeping of public roads
- Preparation of as constructed drawings
- Health and safety
- Security
- Wheel wash provision at exits to public roads
- Manual washing prior to vehicles existing to public roads
- Supervision
- Setting out
- Mobilisation and demobilise
- Insurance

A relationship between the cost of preliminaries and the construction costs of a given scheme has been determined and is shown in Table A-3.

Table A-3: Preliminaries cost curve

Construction cost:	€100k	€250k	€1m	€2m	€5m	€10m	€15m
Total Preliminaries	€32k	€89k	€199k	€330k	€512k	€743k	€932k
Preliminaries as a % of total	32%	20%	18%	16%	10%	7%	6%

In addition to the above, each of the separate unit costs includes an estimate of some of the additional preliminaries, such as temporary works, environmental mitigation and temporary flow controls. The temporary works costs are based on what would be required on all sites but are not intended to be definitive for all possible eventualities. Where non-standard, difficult or additional temporary works are deemed likely to apply the allowance for preliminaries in the individual method cost may be increased.

A.6.7 Operation and maintenance

Whole life cost estimation needs to identify all activities that constitute flood defence management practice e.g. inspection, vegetation management, repair, operations, incident management, general administration and regulatory activities. Operational costs may include annual maintenance as well as intermittent costs if relevant and proportional and data is available.

Operational costs are assumed to continue for the design life of the scheme. Present value costs for operation and maintenance have been determined using the same methodology set out in Section A.4.3, which is assuming a design life of the scheme of 50 years and a discount rate of 4%.

A.6.8 Optimism bias tool

There is a demonstrated, systematic, tendency for project appraisers to be overly optimistic when developing costs estimates for capital works. The aim of adding an optimism bias is to allow a contingency on these estimates to cater for unknowns and help ensure project promoters retain adequate project budget.

Different magnitudes of uplift or optimism bias are applied at different stages of the appraisal process. For example, a higher optimism bias is expected at the start of a project where there are a lot of unknowns, this optimism bias would expect to be reduced once detailed design has been completed and site conditions are better understood and approaches to manage risks have been identified or the additional costs associated the construction have been priced explicitly.

The proposed optimism bias has been determined from a Review of Large Public Procurement in the UK1. This study reviewed cost estimates and resulting capital expenditure from public procurement projects over a period of 20 years. The findings of this review highlighted that an appropriate optimism bias for standard civil engineering projects at the outline business case stage, which broadly reflects the level of assessment in the CFRAM, is 44%. On this basis an optimism bias of 50% has been applied for all cost estimates in the WCFRAM.

B Screening Costs

B.1 Nimmo's Pier

Nimmo's Pier Option A

Wall (311m Quay Wall @ 1.2m high)

Single Method Capital Cost Tool	
Wall type	Quay Wall
Wall height (m) equivalent for unit cost rate	1.2
Wall length (m)	311
Wall unit rate (€/m)	€ 2,370
Over-ride unit rate (€/m)	
Total costs (€)	€ 737,070
Apply update to unit rate (CPI) if appropriate (€) (1.0)	€ 737,070
Enter other applicable costs (€)	-
Total capital cost (€)	€ 737,070
Consider amendments based on site issues/constraints (€) (Method factor 25%)	€ 921,337
Preliminaries (7%)	€ 64,493
Total capital cost (€)	€ 985,831

Operation and Maintenance Cost Tool	
Wall length total (m)	311
Wall O&M costs (€/m/yr)	Higher estimates €0.325
Over-ride unit rate (€/m/year)	-
Total annual O&M costs (€)	€101
Present value O&M costs (€)	€2,258

Gate (1No @ 4m wide access for car)

Single Method Capital Cost Tool	
Simple swing or Lift Hinge Gate	Simple Swing Gate
No of Gate (unit)	1
Gate width (m)	4
Gate height (m)	1.2
Gate unit rate (€/m)	€ 16,800
Over-ride unit rate (€/m)	
Total costs (€)	€ 16,800
Apply update to unit rate (CPI) if appropriate (€) (1.0)	€ 16,800
Enter other applicable costs (€)	-
Total capital cost (€)	€ 16,800
Consider amendments based on site issues/constraints (€) (Method factor 10%)	€18,480
Preliminaries (7%)	€ 1,293
Total capital cost (€)	€ 19,773

Operation and Maintenance Cost Tool	
No of Gates	1
Total annual O&M costs (€)	€50.6
Present value O&M costs (€)	€1,129

Event Costs	
No of Gates	1
Total annual O&M costs (€)	€27
Present value O&M costs (€)	€602

Gate (1No @ 2m wide pedestrian access)

Single Method Capital Cost Tool	
Simple swing or Lift Hinge Gate	Simple Swing Gate
No of Gate (unit)	1
Gate width (m)	2
Gate height (m)	1.2
Gate unit rate (€/m)	€ 5,350
Over-ride unit rate (€/m)	
Total costs (€)	€ 5,350
Apply update to unit rate (CPI) if appropriate (€) (1.0)	€ 5,350
Enter other applicable costs (€)	-
Total capital cost (€)	€ 5,350
Consider amendments based on site issues/constraints (€) (Method factor 10%)	€5,885
Preliminaries (7%)	€ 441
Total capital cost (€)	€ 6,296

Operation and Maintenance Cost Tool	
No of Gates	1
Total annual O&M costs (€)	€50.6
Present value O&M costs (€)	€1,129
Event Costs	
No of Gates	1
Total annual O&M costs (€)	€27
Present value O&M costs (€)	€602

Summary

Total PV Cost	
Total capital costs (€)	€ 1,011,900
Total Operation and Maintenance (€)	€2,258
Total Event Costs (€)	€1,204
Total Pvc costs (€)	€ 1,015,363
Optimism bias rate (%)	50%
Total Cost including Optimism Bias (€)	€ 1,523,044

Nimmo's Pier - Option B

Wall (98m Quay Wall @ 1.2m high)

Single Method Capital Cost Tool	
Wall type	Quay Wall
Wall height (m) equivalent for unit cost rate	1.2
Wall length (m)	98
Wall unit rate (€/m)	€ 2,370
Over-ride unit rate (€/m)	

Total costs (€)	€ 232,221
Apply update to unit rate (CPI) if appropriate (€) (1.0)	€ 232,221
Enter other applicable costs (€)	-
Total capital cost (€)	€ 232,221
Consider amendments based on site issues/constraints (€) (Method factor 25%)	€ 290,276
Preliminaries (7%)	€ 20,319
Total capital cost (€)	€ 310,595

Operation and Maintenance Cost Tool		
Wall length total (m)		98
Wall O&M costs (€/m/yr)	Higher estimates	€0.325
Over-ride unit rate (€/m/year)		-
Total annual O&M costs (€)		€32
Present value O&M costs (€)		€714

Embankment (23m @ 1m high)

Single Method Capital Cost Tool	
Embankment type	Rural clay embankment
Material	Imported
Embankment height (m) equivalent for unit cost rate	1
Embankment length (m)	230
Embankment unit rate (€/m)	€ 128
Over-ride unit rate (€/m)	
Total costs (€)	€ 29,405
Apply update to unit rate (CPI) if appropriate (€) (1.0)	€ 29,405
Enter other applicable costs (€)	-
Total capital cost (€)	€ 29,405
Consider amendments based on site issues/constraints (€) (Method factor 25%)	€ 36,756
Preliminaries (7%)	€ 2,572
Total capital cost (€)	€ 39,329

Operation and Maintenance Cost Tool		
Embankment length total (m)		230
Embankment O&M costs (€/m/yr)	Average Estimates	€2.73
Over-ride unit rate (€/m/year)		-
Total annual O&M costs (€)		€627
Present value O&M costs (€)		€13,985

Road Rising (20m)

Single Method Capital Cost Tool	
Length of road to be raised (m)	20
unit rate (€/m)	€ 778
Over-ride unit rate (€/m)	
Total costs (€)	€ 15,560
Apply update to unit rate (CPI) if appropriate (€) (1.0)	€ 15,560
Enter other applicable costs (€)	-
Total capital cost (€)	€ 15,560
Consider amendments based on site issues/constraints (€) (Method factor 30%)	€ 19,450

Preliminaries (7%)	€ 1,361
Total capital cost (€)	€ 20,811

Summary

Total PV Cost	
Total capital costs (€)	€ 370,735
Total Operation and Maintenance (€)	, €14,699
Total Event Costs (€)	
Total PVC costs (€)	€ 385,434
Optimism bias rate (%)	50%
Total Cost including Optimism Bias (€)	€ 578,151

B.2 Claddagh Quay

Claddagh Quay Option A

Wall (269m Quay Wall @ 1.2m high)

Single Method Capital Cost Tool	
Wall type	Quay Wall
Wall height (m) equivalent for unit cost rate	1.2
Wall length (m)	269
Wall unit rate (€/m)	€ 2,370
Over-ride unit rate (€/m)	
Total costs (€)	€ 637,423
Apply update to unit rate (CPI) if appropriate (€) (1.0)	€ 637,423
Enter other applicable costs (€)	-
Total capital cost (€)	€ 637,423
Consider amendments based on site issues/constraints (€) (Method factor 25%)	€796,779
Preliminaries (7%)	€ 53,744
Total capital cost (€)	€ 821,523

Operation and Maintenance Cost Tool	
Wall length total (m)	269
Wall O&M costs (€/m/yr)	Higher estimates €0.325
Over-ride unit rate (€/m/year)	-
Total annual O&M costs (€)	€87
Present value O&M costs (€)	€1,941

Gate (2 No @ 4m wide access for car)

Single Method Capital Cost Tool	
Simple swing or Lift Hinge Gate	Simple Swing Gate
No of Gate (unit)	2
Gate width (m)	4
Gate height (m)	1.2
Gate unit rate (€/m)	€ 16,800
Over-ride unit rate (€/m)	
Total costs (€)	€ 33,600

Apply update to unit rate (CPI) if appropriate (€) (1.0)	€ 33,600
Enter other applicable costs (€)	-
Total capital cost (€)	€33,600
Consider amendments based on site issues/constraints (€) (Method factor 10%)	€36,960
Preliminaries (7%)	€ 2,587
Total capital cost (€)	€ 39,547

Operation and Maintenance Cost Tool	
No of Gates	2
Total annual O&M costs (€)	€101
Present value O&M costs (€)	€2,260
Event Costs	
No of Gates	2
Total annual O&M costs (€)	€54
Present value O&M costs (€)	€1,204

Gate (6No @ 2m pedestrian access)

Single Method Capital Cost Tool	
Simple swing or Lift Hinge Gate	Simple Swing Gate
No of Gate (unit)	6
Gate width (m)	2
Gate height (m)	0.6
Gate unit rate (€/m)	€ 14,200
Over-ride unit rate (€/m)	
Total costs (€)	€ 85,200
Apply update to unit rate (CPI) if appropriate (€) (1.0)	€ 85,200
Enter other applicable costs (€)	-
Total capital cost (€)	€85,200
Consider amendments based on site issues/constraints (€) (Method factor 10%)	€93,720
Preliminaries (7%)	€ 6,560
Total capital cost (€)	€ 100,280

Operation and Maintenance Cost Tool	
No of Gates	6
Total annual O&M costs (€)	€303
Present value O&M costs (€)	€6,778
Event Costs	
No of Gates	6
Total annual O&M costs (€)	€162
Present value O&M costs (€)	€3,614

Summary

Total PV Cost	
Total capital costs (€)	€ 961,350
Total Operation and Maintenance (€)	, €10,979
Total Event Costs (€)	€4,818
Total PVc costs (€)	€ 977,147

Optimism bias rate (%)	50%
Total Cost including Optimism Bias (€)	€ 1,465,720

B.3 Raven Place and Eglington Canal

Raven Place and Eglington Canal Option A

Wall (259m Quay Wall @ 1.2m high)

Single Method Capital Cost Tool	
Wall type	Quay Wall
Wall height (m) equivalent for unit cost rate	1.2
Wall length (m)	259
Wall unit rate (€/m)	€ 2,370
Over-ride unit rate (€/m)	
Total costs (€)	€ 613,727
Apply update to unit rate (CPI) if appropriate (€) (1.0)	€ 613,727
Enter other applicable costs (€)	-
Total capital cost (€)	€ 613,727
Consider amendments based on site issues/constraints (€) (Method factor 25%)	€767,159
Preliminaries (7%)	€ 53,701
Total capital cost (€)	€ 820,860

Operation and Maintenance Cost Tool	
Wall length total (m)	259
Wall O&M costs (€/m/yr)	Average Estimate €0.325
Over-ride unit rate (€/m/year)	-
Total annual O&M costs (€)	€84
Present value O&M costs (€)	€1,874

Gate (3No @ 2m pedestrian access)

Single Method Capital Cost Tool	
Simple swing or Lift Hinge Gate	Simple Swing Gate
No of Gate (unit)	3
Gate width (m)	2
Gate height (m)	1.2
Gate unit rate (€/m)	€ 14,200
Over-ride unit rate (€/m)	
Total costs (€)	€ 42,600
Apply update to unit rate (CPI) if appropriate (€) (1.0)	€ 42,600
Enter other applicable costs (€)	-
Total capital cost (€)	€42,600
Consider amendments based on site issues/constraints (€) (Method factor 25%)	€53,250
Preliminaries (7%)	€ 3,728
Total capital cost (€)	€ 56,978

Operation and Maintenance Cost Tool	
No of Gates	3
Total annual O&M costs (€)	€151

Present value O&M costs (€)	€3,369
Event Costs	
No of Gates	3
Total annual O&M costs (€)	€81
Present value O&M costs (€)	€1,809

Property Line Defences (4 Houses and 1 Office)

	Detached	Semi-Detached	Terraced	Flat	Shop	Office
Number of properties of each type (no.)			4			1
Individual cost (€/unit)						
Over-ride unit rate (€/property)			€3,800			€9,400
Individual cost (€)	€0	€0	€15,200	€0	€0	€9,400
Select manual or automatic						Manual
Total costs (€)						€24,600
Apply update to unit rate (CPI) if appropriate (cell M16) (€)						€24,600
Other applicable costs (€)						
Total capital cost (€)						€24,600
Consider amendments based on site issues/constraints (€) (Method Factor 1.2)						€29,520
Preliminaries (7%)						€ 2,067
Total capital cost (€)						€31,586

Operation and Maintenance Cost Tool	
Number of residential (no.)	4
Costs (€/property)	€88
Over-ride unit rate (€/property)	
Costs of residential (€)	€350
Number of shop/office (no.)	1
Costs (€/property)	€177
Over-ride unit rate (€/property)	
Costs of shop/office (€)	€177
Total annual O&M costs (€)	€527
Present Value O&M costs (€)	€11,729

Summary

Total PV Cost	
Total capital costs (€)	€ 909,424
Total Operation and Maintenance (€)	€16,972
Total Event Costs (€)	€1,809
Total PVc costs (€)	€ 928,205

Optimism bias rate (%)	50%
Total Cost including Optimism Bias (€)	€ 1,392,307

B.4 Wolf Tone Bridge

Wolf Tone Bridge Option A

Gate (3 No @ 4m pedestrian access)

Single Method Capital Cost Tool	
Simple swing or Lift Hinge Gate	Simple Swing Gate
No of Gate (unit)	3
Gate width (m)	4
Gate height (m)	1.2
Gate unit rate (€/m)	€ 16,800
Over-ride unit rate (€/m)	
Total costs (€)	€ 50,400
Apply update to unit rate (CPI) if appropriate (€) (1.0)	€ 50,400
Enter other applicable costs (€)	-
Total capital cost (€)	€50,400
Consider amendments based on site issues/constraints (€) (Method factor 25%)	€60,480
Preliminaries (7%)	€ 4,233
Total capital cost (€)	€ 64,713

Operation and Maintenance Cost Tool	
No of Gates	3
Total annual O&M costs (€)	€151
Present value O&M costs (€)	€3,369
Event Costs	
No of Gates	3
Total annual O&M costs (€)	€81
Present value O&M costs (€)	€1,809

Summary

Total PV Cost	
Total capital costs (€)	€ 64,713
Total Operation and Maintenance (€)	€3,369
Total Event Costs (€)	€1,809
Total Pvc costs (€)	€ 69,891
Optimism bias rate (%)	50%
Total Cost including Optimism Bias (€)	€ 104,836

B.5 Spanish Arch/Merchant's Quay

Spanish Arch/Merchant's Quay Option A

Wall (113m Quay Wall @ 1.2m high)

Single Method Capital Cost Tool	
Wall type	Quay Wall
Wall height (m) equivalent for unit cost rate	1.2

Wall length (m)	113
Wall unit rate (€/m)	€ 2,370
Over-ride unit rate (€/m)	€3,000
Total costs (€)	€ 339,000
Apply update to unit rate (CPI) if appropriate (€) (1.0)	€ 339,000
Enter other applicable costs (€)	-
Total capital cost (€)	€ 339,000
Consider amendments based on site issues/constraints (€) (Method factor 25%)	€423,750
Preliminaries (7%)	€ 29,662
Total capital cost (€)	€ 453,412

Operation and Maintenance Cost Tool		
Wall length total (m)		113
Wall O&M costs (€/m/yr)	Average Estimate	€0.325
Over-ride unit rate (€/m/year)		-
Total annual O&M costs (€)		€37
Present value O&M costs (€)		€825

Gate (1 No @ 3.5m access gate)

Single Method Capital Cost Tool	
Simple swing or Lift Hinge Gate	Simple Swing Gate
No of Gate (unit)	1
Gate width (m)	4
Gate height (m)	1.2
Gate unit rate (€/m)	€ 16,800
Over-ride unit rate (€/m)	
Total costs (€)	€ 16,800
Apply update to unit rate (CPI) if appropriate (€) (1.0)	€ 16,800
Enter other applicable costs (€)	-
Total capital cost (€)	€16,800
Consider amendments based on site issues/constraints (€) (Method factor 20%)	€20,160
Preliminaries (7%)	€ 1,411
Total capital cost (€)	€ 21,571

Operation and Maintenance Cost Tool	
No of Gates	1
Total annual O&M costs (€)	€50.6
Present value O&M costs (€)	€1,129
Event Costs	
No of Gates	1
Total annual O&M costs (€)	€27
Present value O&M costs (€)	€602

Property line Defences (4 Houses and 1 Office)

	Detached	Semi-Detached	Terraced	Flat	Shop	Office
Number of properties of each type (no.)					1	
Individual cost (€/unit)					€8,300	
Over-ride unit rate (€/property)						
Individual cost (€)	€0	€0	€0	€0	€8,300	€0
Select manual or automatic						Manual
Total costs (€)						€8,300
Apply update to unit rate (CPI) if appropriate (€)						€8,300
Other applicable costs (€)						
Total capital cost (€)						€8,300
Consider amendments based on site issues/constraints (20%)						€9,960
Preliminaries (7%)						€697
Total Capital Costs						€10,657

Operation and Maintenance Cost Tool	
Number of shop/office (no.)	1
Costs (€/property)	€177
Over-ride unit rate (€/property)	
Costs of shop/office (€)	€177
Total annual O&M costs (€)	€177
Present Value O&M costs (€)	€3,949

Summary

Total PV Cost	
Total capital costs (€)	€ 485,641
Total Operation and Maintenance (€)	€5,903
Total Event Costs (€)	€602
Total PVc costs (€)	€ 492,146
Optimism bias rate (%)	50%
Total Cost including Optimism Bias (€)	€ 738,219

Spanish Arch/Merchant's Quay Option B

Wall (113m Quay Wall @ 1.2m high)

Single Method Capital Cost Tool	
Wall type	Quay Wall
Wall height (m) equivalent for unit cost rate	1.2
Wall length (m)	5
Wall unit rate (€/m)	€ 2,370
Over-ride unit rate (€/m)	€3,000
Total costs (€)	€ 15,000

Apply update to unit rate (CPI) if appropriate (€) (1.0)	€ 15,000
Enter other applicable costs (€)	-
Total capital cost (€)	€ 15,000
Consider amendments based on site issues/constraints (€) (Method factor 25%)	€18,750
Preliminaries (7%)	€ 1,313
Total capital cost (€)	€ 20,063

Operation and Maintenance Cost Tool	
Wall length total (m)	5
Wall O&M costs (€/m/yr)	Average Estimate €0.325
Over-ride unit rate (€/m/year)	-
Total annual O&M costs (€)	€1.63
Present value O&M costs (€)	€36

Gate (2 No @ 3.5m access gate)

Single Method Capital Cost Tool	
Simple swing or Lift Hinge Gate	Simple Swing Gate
No of Gate (unit)	1
Gate width (m)	4
Gate height (m)	1.2
Gate unit rate (€/m)	€ 16,800
Over-ride unit rate (€/m)	
Total costs (€)	€ 33,600
Apply update to unit rate (CPI) if appropriate (€) (1.0)	€ 33,600
Enter other applicable costs (€)	-
Total capital cost (€)	€33,600
Consider amendments based on site issues/constraints (€) (Method factor 20%)	€36,960
Preliminaries (7%)	€2,587
Total capital cost (€)	€ 39,547

Operation and Maintenance Cost Tool	
No of Gates	2
Total annual O&M costs (€)	€101.3
Present value O&M costs (€)	€2,260
Event Costs	
No of Gates	2
Total annual O&M costs (€)	€54
Present value O&M costs (€)	€1,204

Property Line Defences (4 Houses and 1 Office)

	Detached	Semi-Detached	Terraced	Flat	Shop	Office
Number of properties of each type (no.)					1	
Individual cost (€/unit)					€8,300	
Over-ride unit rate (€/property)						
Individual cost (€)	€0	€0	€0	€0	€8,300	€0
Select manual or automatic						Manual
Total costs (€)						€8,300
Apply update to unit rate (CPI) if appropriate (€)						€8,300
Other applicable costs (€)						
Total capital cost (€)						€8,300
Consider amendments based on site issues/constraints (20%)						€9,960
Preliminaries (7%)						€697
Total Capital Costs						€10,657

Operation and Maintenance Cost Tool	
Number of shop/office (no.)	1
Costs (€/property)	€177
Over-ride unit rate (€/property)	
Costs of shop/office (€)	€177
Total annual O&M costs (€)	€177
Present Value O&M costs (€)	€3,949

Public Realm

Single Method Capital Cost Tool	
Public Realm (nominal cost)	300,000
Preliminaries (7%)	€ 21,000
Total capital cost (€)	€ 321,000

Summary

Total PV Cost	
Total capital costs (€)	€ 391,267
Total Operation and Maintenance (€)	€6,245
Total Event Costs (€)	€1,204
Total PVc costs (€)	€ 398,716
Optimism bias rate (%)	50%
Total Cost including Optimism Bias (€)	€ 598,074

B.6 Long Mile Walk

Long Mile Walk Option A

Wall (409m Quay Wall @ 1.2m high)

Single Method Capital Cost Tool	
Wall type	Quay Wall
Wall height (m) equivalent for unit cost rate	1.2
Wall length (m)	409
Wall unit rate (€/m)	€ 2,370
Over-ride unit rate (€/m)	
Total costs (€)	€ 969,168
Apply update to unit rate (CPI) if appropriate (€) (1.0)	€ 969,168
Enter other applicable costs (€)	-
Total capital cost (€)	€ 969,168
Consider amendments based on site issues/constraints (€) (Method factor 25%)	€1,211,460
Preliminaries (7%)	€ 84,802
Total capital cost (€)	€ 1,296,262

Operation and Maintenance Cost Tool		
Wall length total (m)		409
Wall O&M costs (€/m/yr)	Average Estimate	€0.325
Over-ride unit rate (€/m/year)		-
Total annual O&M costs (€)		€133
Present value O&M costs (€)		€2,966

Gate (2 No @ 2m access gate)

Single Method Capital Cost Tool	
Simple swing or Lift Hinge Gate	Simple Swing Gate
No of Gate (unit)	1
Gate width (m)	2
Gate height (m)	1.2
Gate unit rate (€/m)	€ 14,200
Over-ride unit rate (€/m)	
Total costs (€)	€ 28,400
Apply update to unit rate (CPI) if appropriate (€) (1.0)	€ 28,400
Enter other applicable costs (€)	-
Total capital cost (€)	€28,400
Consider amendments based on site issues/constraints (€) (Method factor 20%)	€34,080
Preliminaries (7%)	€2,385
Total capital cost (€)	€ 39,547

Operation and Maintenance Cost Tool	
No of Gates	2
Total annual O&M costs (€)	€101.3
Present value O&M costs (€)	€2,260
Event Costs	
No of Gates	2

Total annual O&M costs (€)	€54
Present value O&M costs (€)	€1,204

Embankment (105m @ 2m high)

Single Method Capital Cost Tool	
Embankment type	Rural clay embankment
Material	Imported
Embankment height (m) equivalent for unit cost rate	2
Embankment length (m)	105
Embankment unit rate (€/m)	€ 285
Over-ride unit rate (€/m)	
Total costs (€)	€ 29,876
Apply update to unit rate (CPI) if appropriate (€) (1.0)	€ 29,876
Enter other applicable costs (€)	-
Total capital cost (€)	€ 29,876
Consider amendments based on site issues/constraints (€) (Method factor 20%)	€ 35,851
Preliminaries (7%)	€ 2,753
Total capital cost (€)	€ 42,082

Operation and Maintenance Cost Tool	
Embankment length total (m)	105
Embankment O&M costs (€/m/yr)	Average Estimates €2.73
Over-ride unit rate (€/m/year)	-
Total annual O&M costs (€)	€286
Present value O&M costs (€)	€6,384

Retrofit Existing Gate

Single Method Capital Cost Tool	
Public Realm (nominal cost)	3,000,000
Preliminaries (7%)	€ 210,000
Total capital cost (€)	€ 3,210,000

Summary

Total PV Cost	
Total capital costs (€)	€ 4,581,088
Total Operation and Maintenance (€)	€11,610
Total Event Costs (€)	€1,204
Total PVc costs (€)	€ 4,582,292
Optimism bias rate (%)	50%
Total Cost including Optimism Bias (€)	€ 6,889,047

Long Mile Walk Option B

Wall (239m Quay Wall @ 1.2m high)

Single Method Capital Cost Tool	
Wall type	Quay Wall
Wall height (m) equivalent for unit cost rate	1.2
Wall length (m)	239

Wall unit rate (€/m)	€ 2,370
Over-ride unit rate (€/m)	
Total costs (€)	€ 565,335
Apply update to unit rate (CPI) if appropriate (€) (1.0)	€ 565,335
Enter other applicable costs (€)	-
Total capital cost (€)	€ 565,335
Consider amendments based on site issues/constraints (€) (Method factor 20%)	€679,602
Preliminaries (7%)	€ 47,572
Total capital cost (€)	€ 727,174

Operation and Maintenance Cost Tool		
Wall length total (m)		239
Wall O&M costs (€/m/yr)	Average Estimate	€0.325
Over-ride unit rate (€/m/year)		-
Total annual O&M costs (€)		€78
Present value O&M costs (€)		€1,740

Wall (435m Retaining Wall @ 1.2m high)

Single Method Capital Cost Tool	
Wall type	Retaining Wall
Wall height (m) equivalent for unit cost rate	1.2
Wall length (m)	435
Wall unit rate (€/m)	€ 1,325
Over-ride unit rate (€/m)	
Total costs (€)	€ 576,375
Apply update to unit rate (CPI) if appropriate (€) (1.0)	€ 576,375
Enter other applicable costs (€)	-
Total capital cost (€)	€ 576,375
Consider amendments based on site issues/constraints (€) (Method factor 20%)	€691,650
Preliminaries (7%)	€ 48,415
Total capital cost (€)	€ 740,065

Operation and Maintenance Cost Tool		
Wall length total (m)		435
Wall O&M costs (€/m/yr)	Average Estimate	€0.325
Over-ride unit rate (€/m/year)		-
Total annual O&M costs (€)		€141
Present value O&M costs (€)		€3,146

Gate (3 No @ 2m access gate)

Single Method Capital Cost Tool	
Simple swing or Lift Hinge Gate	Simple Swing Gate
No of Gate (unit)	1
Gate width (m)	2
Gate height (m)	1.2
Gate unit rate (€/m)	€ 14,200
Over-ride unit rate (€/m)	
Total costs (€)	€ 42,600

Apply update to unit rate (CPI) if appropriate (€) (1.0)	€ 42,600
Enter other applicable costs (€)	-
Total capital cost (€)	€42,600
Consider amendments based on site issues/constraints (€) (Method factor 20%)	€51,120
Preliminaries (7%)	€3,579
Total capital cost (€)	€ 54,698

Operation and Maintenance Cost Tool	
No of Gates	3
Total annual O&M costs (€)	€151
Present value O&M costs (€)	€3,389
Event Costs	
No of Gates	3
Total annual O&M costs (€)	€81
Present value O&M costs (€)	€1,807

Gate (2 No @ 2m access gate)

Single Method Capital Cost Tool	
Simple swing or Lift Hinge Gate	Simple Swing Gate
No of Gate (unit)	1
Gate width (m)	2
Gate height (m)	1.2
Gate unit rate (€/m)	€ 16,800
Over-ride unit rate (€/m)	
Total costs (€)	€ 33,600
Apply update to unit rate (CPI) if appropriate (€) (1.0)	€ 33,600
Enter other applicable costs (€)	-
Total capital cost (€)	€33,600
Consider amendments based on site issues/constraints (€) (Method factor 20%)	€40,320
Preliminaries (7%)	€2,822
Total capital cost (€)	€ 43,142

Operation and Maintenance Cost Tool	
No of Gates	2
Total annual O&M costs (€)	€101.3
Present value O&M costs (€)	€2,260
Event Costs	
No of Gates	2
Total annual O&M costs (€)	€54
Present value O&M costs (€)	€1,204

Embankment (105m @ 2m high)

Single Method Capital Cost Tool	
Embankment type	Rural clay embankment
Material	Imported
Embankment height (m) equivalent for unit cost rate	2
Embankment length (m)	105

Embankment unit rate (€/m)	€ 285
Over-ride unit rate (€/m)	
Total costs (€)	€ 29,876
Apply update to unit rate (CPI) if appropriate (€) (1.0)	€ 29,876
Enter other applicable costs (€)	-
Total capital cost (€)	€ 29,876
Consider amendments based on site issues/constraints (€) (Method factor 20%)	€ 35,851
Preliminaries (7%)	€ 2,753
Total capital cost (€)	€ 42,082

Operation and Maintenance Cost Tool		
Embankment length total (m)		105
Embankment O&M costs (€/m/yr)	Average Estimates	€2.73
Over-ride unit rate (€/m/year)		-
Total annual O&M costs (€)		€286
Present value O&M costs (€)		€6,384

Road Rising (20m)

Single Method Capital Cost Tool		
Length of road to be raised (m)		20
unit rate (€/m)		€ 778
Over-ride unit rate (€/m)		
Total costs (€)		€ 15,560
Apply update to unit rate (CPI) if appropriate (€) (1.0)		€ 15,560
Enter other applicable costs (€)		-
Total capital cost (€)		€ 15,560
Consider amendments based on site issues/constraints (€) (Method factor 20%)		€ 18,672
Preliminaries (7%)		€1,307
Total capital cost (€)		€ 19,979

Summary

Total PV Cost		
Total capital costs (€)		€ 1,627,256
Total Operation and Maintenance (€)		€16,914
Total Event Costs (€)		€3,011
Total PVc costs (€)		€ 1,646,451
Optimism bias rate (%)		50%
Total Cost including Optimism Bias (€)		€ 2,469,676

B.7 Salthill Area 1

Salthill Area 1 - Option A

Gate (2 No @ 4m access gate)

Single Method Capital Cost Tool		
Simple swing or Lift Hinge Gate		Simple Swing Gate
No of Gate (unit)		1
Gate width (m)		4

Gate height (m)	1.2
Gate unit rate (€/m)	€ 16,800
Over-ride unit rate (€/m)	
Total costs (€)	€ 33,600
Apply update to unit rate (CPI) if appropriate (€) (1.0)	€ 33,600
Enter other applicable costs (€)	-
Total capital cost (€)	€33,600
Consider amendments based on site issues/constraints (€) (Method factor 20%)	€40,320
Preliminaries (7%)	€2,822
Total capital cost (€)	€ 43,142

Operation and Maintenance Cost Tool	
No of Gates	2
Total annual O&M costs (€)	€101.3
Present value O&M costs (€)	€2,260
Event Costs	
No of Gates	2
Total annual O&M costs (€)	€54
Present value O&M costs (€)	€1,204

Property Line Defences (6 Shop Fronts)

	Detached	Semi-Detached	Terraced	Flat	Shop	Office
Number of properties of each type (no.)					6	
Individual cost (€/unit)					€8,300	
Over-ride unit rate (€/property)						
Individual cost (€)	€0	€0	€0	€0	49,800	€0
Select manual or automatic						Manual
Total costs (€)						€49,800
Apply update to unit rate (CPI) if appropriate (€)						€49,800
Other applicable costs (€)						
Total capital cost (€)						€49,800
Consider amendments based on site issues/constraints (60%)						€79,680
Preliminaries (7%)						€5,577
Total Capital Costs						€85,257

Operation and Maintenance Cost Tool	
Number of shop/office (no.)	6
Costs (€/property)	€177
Over-ride unit rate (€/property)	
Costs of shop/office (€)	€1,062
Total annual O&M costs (€)	€1,062
Present Value O&M costs (€)	€23,697

Summary

Total PV Cost	
Total capital costs (€)	€ 128,400
Total Operation and Maintenance (€)	€25,953
Total Event Costs (€)	€1,204
Total PVc costs (€)	€ 155,557
Optimism bias rate (%)	50%
Total Cost including Optimism Bias (€)	€ 233,336

B.8 Salthill Area 2

Salthill Area 2 Option 1

Road Raising (30m x 2)

Single Method Capital Cost Tool	
Length of road to be raised (m)	60
unit rate (€/m)	€ 778
Over-ride unit rate (€/m)	
Total costs (€)	€ 46,680
Apply update to unit rate (CPI) if appropriate (€) (1.0)	€ 46,680
Enter other applicable costs (€)	-
Total capital cost (€)	€ 46,680
Consider amendments based on site issues/constraints (€) (Method factor 30%)	€ 58,350
Preliminaries (7%)	€4,085
Total capital cost (€)	€62,434

Embankment (140m @ 2m high)

Single Method Capital Cost Tool	
Embankment type	Rural clay embankment
Material	Imported
Embankment height (m) equivalent for unit cost rate	2
Embankment length (m)	140
Embankment unit rate (€/m)	€ 285
Over-ride unit rate (€/m)	
Total costs (€)	€ 39,835
Apply update to unit rate (CPI) if appropriate (€) (1.0)	€ 39,835
Enter other applicable costs (€)	-
Total capital cost (€)	€ 39,835
Consider amendments based on site issues/constraints (€) (Method factor 20%)	€ 47,802

Preliminaries (7%)	€ 3,346
Total capital cost (€)	€ 51,148

Operation and Maintenance Cost Tool		
Embankment length total (m)		140
Embankment O&M costs (€/m/yr)	Average Estimates	€2.73
Over-ride unit rate (€/m/year)		-
Total annual O&M costs (€)		€381.5
Present value O&M costs (€)		€8,142

Summary

Total PV Cost	
Total capital costs (€)	€ 113,582
Total Operation and Maintenance (€)	€8,142
Total Event Costs (€)	-
Total PVc costs (€)	€ 121,724
Optimism bias rate (%)	50%
Total Cost including Optimism Bias (€)	€ 182,238

C Environmental and Social Appraisal of Viable Options

C.1 Introduction

The environmental constraints and the scope of the Strategic Environmental Assessment (SEA) have been identified in the SEA scoping report. In the screening of methods and development of flood risk management solutions the possible constraints, environmental benefits and impacts associated with each method have been identified. The benefits and impacts have been considered in terms of quality, significance, duration and type.

C.2 Screening of Methods

Alongside the technical and economic assessment of potential methods, an assessment into the key social, cultural and environmental issues relating to flood risk in the area were considered. This work built on the key constraint listed in the SEA scoping Report. This is included in Section 2.2 for each individual AFA POR report.

At this preliminary screening stage, methods were assessed in relation to:

- Location - would the placement of the method be located near or within a Natura 200 site.
- Impact during construction or any operational requirements.
- Presence of protected species within the area.

By outlining the key constraints, potential methods that would need to follow the full IROPI (Imperative Reasons of Overriding Public Interest) process can be discounted at the viability screening stage.

C.3 Environmental Appraisal of Options

C.3.1 Assessment criteria

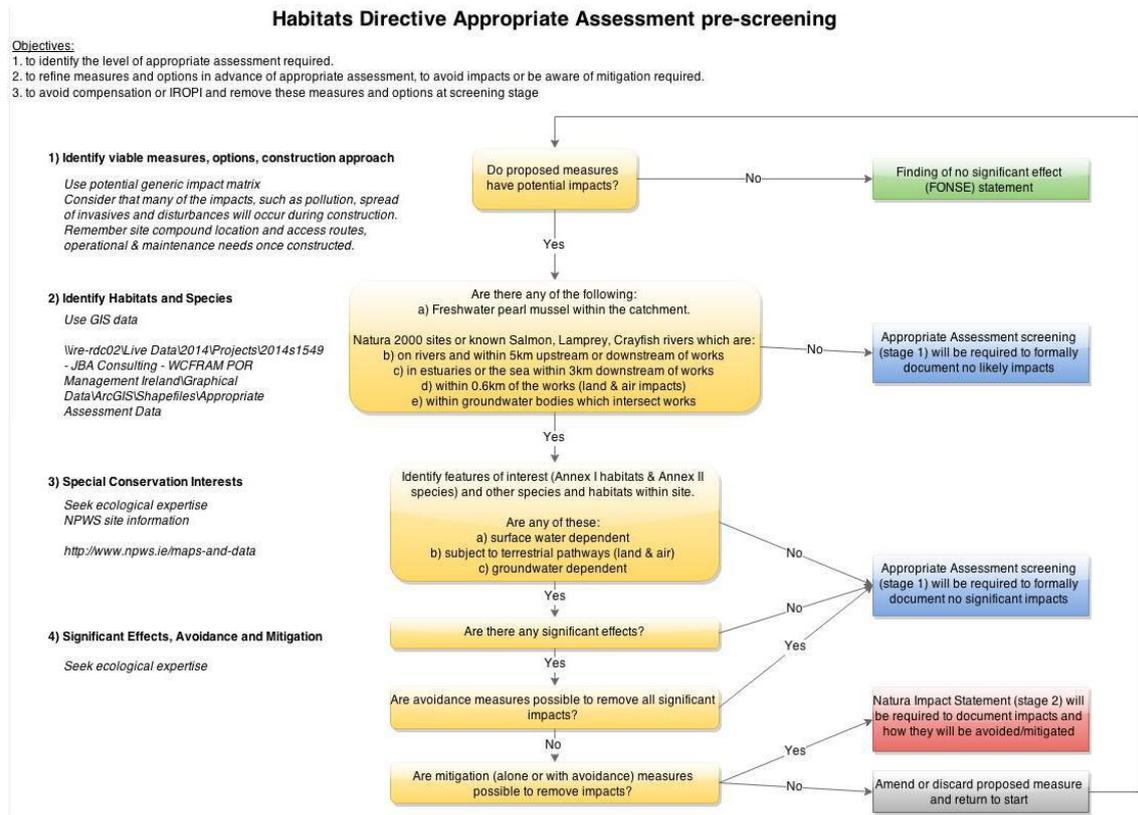
The screening determined potential viable methods and these were carried forward to full option development. In the full development of options and environmental appraisal of each viable option has been carried out and has been included in each individual POR report. The following has been considered.

C.3.2 Habitats Directive Appropriate Assessment pre-screening

Pre-screening in relation to the Habitats Directive was carried out to examine the potential impacts on Natura 2000 sites early in the design process. Where an option could potentially involve Stage 3 & 4 of the AA process, this option was re-examined and in most cases options that would require an IROPI approval process were rejected and alternative options sought. This is illustrated below in Figure C-1.

Habitat Loss	This is a permanent loss of habitat within the designated boundaries of a Natura 2000 site. For flood relief schemes this could arise from the construction of new structures within the site boundary, including provision for future maintenance. Dredging, bank alteration etc., and other activities can cause habitat loss.
Physical Damage	This includes degradation to, and modification of, habitat within the designated boundaries of a Natura 2000 site. This could arise in working areas and along access routes where construction works are undertaken.
Habitat Fragmentation	More physical damage to habitats could occur, for example, through increased recreational pressure associated with certain methods, which could result in trampling, erosion or rubbish tipping.
Species Loss	Damage may be temporary or permanent.
Change in physical regime	This is where activities result in the separation of available habitats or split extensive areas of suitable habitat. It is most likely to affect species, but can impact upon the functionality of habitats.
Changes in hydrological regime	This is a permanent loss of species such as Atlantic Salmon within the designated boundaries of a Natura 2000 site as a result of schemes e.g. removal of spawning grounds due to channel deepening and widening, loss of Otter due to damage to holts on river banks or loss of pearl mussel due to instream works. For flood relief schemes this could arise from the construction of new structures within the site boundary, dredging, channel widening, bank alterations or including provision for future maintenance. At coastal locations this may arise mainly for birds e.g. nesting terns on shingle or some rare plants. Dredging, bank alterations etc., and other activities can cause habitat loss
Disturbance (noise, visual, vibration)	These are changes to physical process that can alter the present characteristics of the Natura 2000 site (e.g. estuarine, fluvial and geomorphological processes, salinity levels, tidal regimes, erosion, deposition, sediment transport and accumulation). This could then result in degradation or loss of habitats.
Competition from non-native species	Certain activities may result in changes to the current hydrological regime. For example, a reduction or increase in the frequency, extent, duration and/or depth of flooding may affect estuarine, riverine and floodplain habitats.
Changes in water quality	Activities which may affect surface and groundwater levels, such as impoundments or defence construction, may also have adverse impacts on surface water or groundwater dependant habitats (rivers, fens, bogs, etc.) and species.
Pollution	A number of activities can result in disturbance, including visual and from noise. This is more frequently associated with construction activities, but could also be associated with the operational phases of some flood relief methods, in particular where recreational opportunities may be exploited. Disturbance can cause sensitive species, such as birds or mammals, to deviate from their normal, preferred behaviour, resulting in stress, increased energy expenditure and, in some cases, species mortality.
Landscape and Visuals	The visual impacts of the proposed options were assessed using the existing landscape ratings and status for the areas as outlined in the County Development and Local Area Plans.
Archaeology & Cultural Heritage	The potential impacts of the proposed flood management options were assessed against the archaeological and architectural features in the areas of the proposed works. Architectural Conservation Areas in town were taken into consideration during the assessments.

Figure C-1: Habitats Directive Appropriate Assessment pre-screening



D Development and Evaluation of Options

D.1 Introduction

Following the viability screening assessment, technically viable and economically beneficial options were identified and brought forward to the option development stage. The short list of methods was reviewed and developed into one or more flood risk options. Options can incorporate one, or (mostly) a combination of, the FRM methods, or elements of these methods, determined to be viable through the screening process, and include a mix of localised and broader FRM methods.

D.2 Refinement of options

The existing hydraulic model developed for each AFA was adapted to represent each option. Hydraulic modelling of the methods was used to confirm the scale and extent of the proposed methods and also to ensure any proposed methods do not have a negative impact on areas upstream and downstream of the area being considered.

The design standard for the WCFRAM (i.e., flood event probabilities that the flood risk management methods and options should address) is the 1% AEP for fluvial flooding and 0.5% AEP for tidal flooding.

Where no major structural flood protection option is viable for a particular spatial scale of assessment (SSA), localised or low-scale structural protection methods (e.g., raising existing defences, infilling gaps in defences, creating minor defences not requiring major structural works, etc.) were assessed to determine whether some protection (to a design standard that may be less than the preferred design standard), would be beneficial and viable. Such methods may compliment other non-structural methods that have been determined to be viable or may provide some alleviation in the short term prior to the completion of more significant works.

D.3 Full scheme cost estimates

Following the estimate of damage and costs for screening purposes, as detailed in Appendix B, for all AFAs with an economically viable option at screening stage, a more detailed assessment of scheme costs was calculated. The following additional allowances were incorporated into the scheme costs for economically viable options:

- Detailed Design Fees (13%)
- Allowances for archaeological and environmental mitigation methods (typically 10-15% depending on the archaeological and environmental sensitivity)
- Cost of Land Acquisition / Compensation costs (typical values 10-15% depending on the likely level of interference with private property.
- Allowance for Art (Up to €64,000 depending on the construction price of a project)

Where viable options have been identified in the respective AFA reports, a breakdown of the full scheme costs is provided. An example of this shown in Table D-1 below.

Table D-1: Full option development costs

Option 1- Storage Embankment		€
Construction costs		
Rural clay embankment; imported material; 415m long; avg 1.2m high		63,668
Controlled outfall - Orifice and headwall arrangement		10,800
Construction costs - Subtotal		74,468
Preliminaries	20%	14,894
Capital costs - Subtotal		89,362
Optimism Bias	50%	44,681
Capital costs - Total		134,042
Other items (% of construction costs where stated)		
Design team fees and expenses (inc site supervision, and environmental fees)	13%	17,426
Allowance for Archeaology & Environmental Mitigation Measures	10%	13,404
Allowance for compensation and land acquisition	10%	13,404
Site investigation		10,000
Art allowance		5,000
Other items - Total		59,234
Operation and maintenance net present value		
Embankment O&M Cost; average estimates		24,135
Outfall O&M Cost; higher estimates		11,418
Operation and maintenance - Subtotal		35,553
Optimism Bias	50%	17,777
Operation and maintenance costs - Total		53,330
Option cost for cost benefit analysis		246,606

VAT and the cost of OPW staff time has not been included in potential option costs for cost-benefit analysis calculations.

D.4 Adaptability to climate change

Climate change adaptability is included in the MCA process but should also be a guiding factor in considering the overall long-term strategy for flood risk management for an area and be an overriding criteria against which the plan should be tested. This ensures decisions are robust when climate change enhanced events manifest themselves.

To address this challenge, the OPW, as lead agency for flood risk management in Ireland, has adopted an approach that requires that the possible impacts of climate change be considered in the development of the FRMP. It requires that the FRMP, including policies, strategies and methods, must be sustainable and should adopt an adaptive or, where appropriate, an assumptive approach with respect to climate change. There are some potentially significant advantages of a managed adaptive approach including a less intense capital programme, communities starting to take more responsibility for future provision of FRM methods and those FRM methods becoming more aligned to the spatial planning cycle.

The managed adaptive process adopted within the WCFRAM starts with the climate change maps presented in the hydraulic modelling reports to inform where significant changes are possible which will then feed into the design process. Two general approaches have been followed based on the risk presented in the climate change maps:

Highly sensitive communities (those with a high vulnerability to the potential impacts of climate change):	Less sensitive communities (those with a low vulnerability to the potential impacts of climate change):
<p>These communities have a significant increase in risk presented in climate change maps.</p> <p>The design and selection of methods to address current risk should proceed on the basis of what may be required in the future. Methods should be able to be adapted to climate change or include for future risks in the current design. This may require option development for the future scenarios to be undertaken in outline form.</p> <p>Where the potential impacts of climate change are particularly complex, a detailed decision-tree analysis may be required to inform the option selection process and the appraisal.</p>	<p>These communities have little increase in risk presented in climate change maps.</p> <p>Proposed methods are less likely to need significant adaptations to accommodate climate change. The design and selection of methods has focussed on existing risk. Design for adaptation should be undertaken at the project stage (i.e., post-CFRAM).</p>

D.5 Health and safety considerations

Designers can make decisions that significantly reduce the risks to the health and safety during the construction stage and during subsequent use and maintenance. Designers must take account of the General Principles of Prevention when preparing designs. The principles of prevention are a hierarchy of risk elimination and reduction.

The General Principles of Prevention are set out in descending order of preference as follows:

- Avoid risks.
- Evaluate unavoidable risks.
- Combat risks at source.
- Adapt work to the individual, especially the design of places of work
- Adapt the place of work to technical progress.
- Replace dangerous articles, substances, or systems of work by non-dangerous or less dangerous articles, substances, or systems
- Use collective protective methods over individual methods
- Develop an adequate prevention policy
- Give appropriate training and instruction to employees.

At the screening stage identification of risks was carried out to determine if it is possible to mitigate the risks posed by a method and if not it was screened out on health and safety grounds. Where viable methods were carried forward to form part or all of the flood risk management option a design health and safety risk assessment was carried out and is included in the appendices of the relevant AFA preliminary options report and will be included in the project safety file.

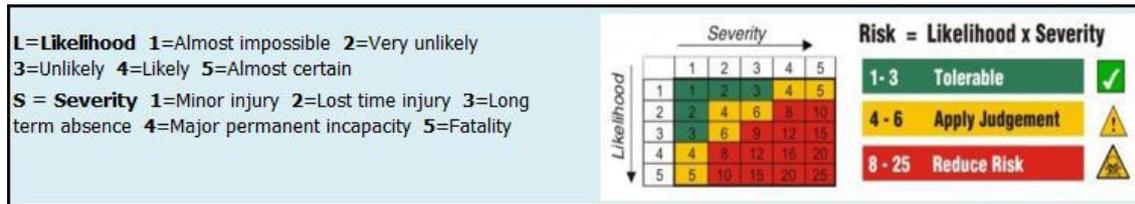
The designer has the following key duties and each assessment has been reviewed by the project PSDP

- Identify any hazards that an option design may present during construction and subsequent maintenance
- Where possible, eliminate the hazards or reduce the risk
- Communicate the necessary control methods, design assumptions or remaining risks so they can be dealt with at later stages of the project if brought forward to detailed design (Post CFRAM)

For each viable option construction and operational hazards were identified and each potential hazard was assessed under likelihood and severity. By multiplying the respective scores an appreciation of the risk was obtained. Figure D-1 shows the key principles applied. Where the risk was found to be high (red) realistic control methods were sought to reduce the risk to ensure that an option was viable on health and safety grounds. In all cases control methods were sought to reduce the perceived risk and have been detailed in the design risk assessment. The risk was again calculated with the proposed methods in place to ensure an acceptable level of risk was reached.

The Designers Risk Assessment for this AFA is included in Appendix F.

Figure D-1: Calculation of risk



D.6 Determination of freeboard

An initial assessment of appropriate freeboards allowances has been completed to provide some indication of the full height implications of the final proposals. This assessment was based on the sensitivity runs detailed in the hydraulic modelling reports. The relevant uncertainties included:

- Peak flow
- Flow volume
- Afflux at selected structures
- Increasing and decreasing channel and floodplain roughness

Figure D-2: Freeboard flow chart

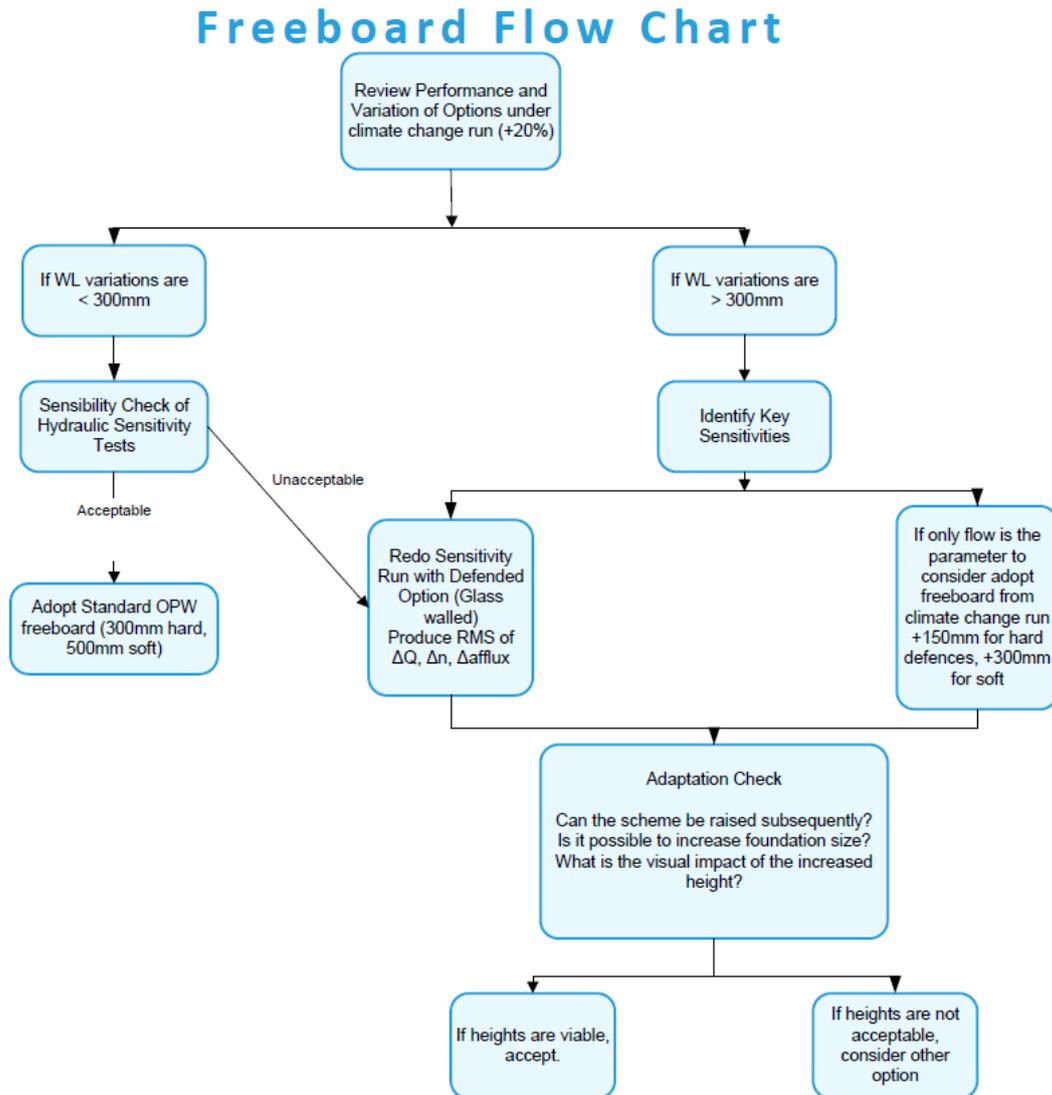


Figure D-2 outlines the approach taken to determine the required freeboard for proposed options. The sensitivity of an option to changes in water levels has been initially determined by comparing the model results from existing and MRFS design standard events within the option in place. If the water level change was less than 300mm in the case of hard defences and less than 500mm for soft (embankments) defences then the standard OPW freeboard defence of 300mm and 500mm was applied.

However, if the water level variations were found to be greater than 300mm for hard or 500mm for soft defences, the freeboard has been derived from a more detailed sensitivity analysis. The findings of the sensitivity analyses reported in the hydraulic modelling reports have been reviewed and the freeboard calculation developed from the key parameters identified. Finally, a review of the suitability of the scale of the constructed defence has been completed to confirm that it remains acceptable inclusive of freeboard.

D.7 Stakeholder input

The involvement of external parties is essential in the development of viable options. It is important to ensure that the knowledge, experience and views of the project steering group, stakeholders and the general public are taken into account throughout the development and selection of options for an area as well as meeting the statutory requirements for consultation with the relevant parties.

D.7.1 Project Steering Group

The project steering group, which included representation from the OPW, relevant local authorities and the Environmental Protection Agency, was responsible for the overseeing and directing the study, and reviewing the key outputs and deliverables.

D.7.2 Project Progress Group

The project progress group included representation from local authorities and the OPW. The progress group fed into the detail of the study providing guidance on the approach and feedback on deliverables. Through this forum meetings were arranged with local area engineers from the local authority and OPW for all AFAs to discuss the options.

D.7.3 Public consultation

Public consultation days (PCD)s have been held in all AFAs where screening of options was undertaken to raise awareness of the study and to provide an opportunity for the general public to express their views and comment on draft outputs. Feedback from the PCDs is presented within each of the specific AFA reports and has been incorporated into the assessment where necessary. Table D-2 shows the dates, times and venues for the PCDs within UoM 30.

Table D-2: POR PCDs dates

AFA	Date	Venue	Number of Attendees
Corrofin	30 June 2016	Dr. Duggan Hall	17
Galway City	22 Sept 2016	Harbour Hotel, New Dock Road	21
Oughterard	30 June 2016	The Courthouse, Oughterard	15

D.8 Evaluation of options

The appraisal of flood relief schemes in the past has been primarily based on economic costs and benefits, with an EIA undertaken to minimise negative impacts on the environment and public consultation undertaken to ensure social acceptability. The National Flood Policy Review (OPW, 2004) set a broader range of objectives for flood risk management in Ireland, which was subsequently reinforced by the EU ‘Floods’ Directive [2007/60/EC].

The MCA framework has been developed to broaden the range of potential impacts taken into account in the development and selection of FRM options and strategies, and their subsequent prioritisation. It is based on the numeric, but non-monetarised assessment of options against a range of objectives. The extent to which these objectives are met is scored on how an option compares against set targets that range between a Basic Requirement and Aspirational Target.

The score for each objective is weighted nationally. This weighting can then be adjusted at an AFA scale reflecting the importance of that objective in the context of the SSA.

The sums of the scores for each objective, set against the total costs of their achievement, represents the preference for a given option. These total scores can be used to inform the decision on the selection of (a) preferred option(s) for a given location and the prioritisation of potential schemes between locations.

Each component of the MCA Framework is explained in more detail below.

D.9 MCA methodology

D.9.4 Objectives

The FRM objectives reflect what the overall flood risk management programme is seeking to achieve, expanding on the requirements of the National Flood Policy Review and the EU ‘Floods’ Directive.

At a local level, and for the purposes of the MCA, the objectives sets out an aim that each flood risk management option should be seeking to achieve. The degree to which an option achieves the objective for the cost is an indication of the ‘success’ of the option, and equally, the more an

option achieves across all of the objectives, then the greater the preference that will be given to that option relative to others.

D.9.5 Global weightings

Global Weightings are assigned to each objective to give it more or less weight in the overall assessment of the suitability or value of the option. The Global Weightings are fixed nationally to ensure a consistent approach and basis for prioritisation, and are intended to represent the 'societal value' for the objective relative to the others, i.e., with those of most weight representing the most important objectives.

D.9.6 Local weightings

The Local Weightings are assigned to each objective for each location under consideration (i.e., each spatial scale of assessment (SSA)), and are intended to represent the local importance of that objective within the local context. They are very important within the framework as they provide scale to the process, allowing locally important objectives to have a greater weight in selection of the option. Similarly, the importance of an issue / objective in one location relative to another can also be provided for through the Local Weightings.

D.9.7 MCA scoring

Each sub objective has a basic requirement and an aspirational target associated with it. The Basic Requirement represents a neutral status or 'no change', whereby if an option has no impact on the matter the objective relates to, or meets what might be termed for some objectives as minimum requirements for acceptability, then that option will have met the Basic Requirement. If an option performs worse than the Basic Requirement, i.e., has a negative impact (a dis-benefit) or does not meet the minimum requirements for acceptability, it will score a negative-value score for that objective.

The aim is defined as an Aspirational Target, whereby an option would be deemed as perfect with respect to the given objective if it were to meet the Aspirational Target. Typically, this will represent complete removal of a risk, or the full achievement of another benefit. Once all the objectives have been analysed the MCA score for each criterion can be calculated by multiplying the score for each sub objective by the global and local weighting and then by summing the weighted scores for all the sub objectives under that criteria.

D.10 MCA outcomes

A suite of different scores present the findings of the MCA. These are compiled of different elements of the MCA to demonstrate how each option delivers against the objectives. The scores are as follows:

- Technical Criteria Score – this is produced for each of the technical, economic, social and environmental objectives and is the sum of their respective sub-objectives
- MCA Benefit Score – this score represents the net benefits of the scheme and is the sum of 'Technical Criteria Scores' from the economic, social and environmental objectives.
- Option Selection MCA Score - this is the sum of all the 'Technical Criteria Scores'
- MCA BCR - this score presents the benefits per euro invested and is the 'Options Selection Score' divided by the cost of the scheme.
- The Economic BCR - this is the traditional comparison of the reduction in damages expected against the cost of the scheme. This has been discussed in Appendix B.

The results of the MCA process were used to guide the decision making process, subject to application of professional judgement and consultation with the steering and progress groups. Greatest weight was given to the MCA Benefit score as this provides a method of the overall benefits per invested euro. Local consultation was also taken into account. The reasoning for the preferred option selection is recorded and reported in the relevant individual POR reports. It should be recognised that whilst a numeric scheme is used by the OPW in the MCA process, the selection of scores and overall recommendation of preferred option is still subjective and based on experience.

The identified preferred options will form actions and methods, and the basis of the flood risk management strategy for the Unit of Management, which will be developed and detailed within the Flood Risk Management Plan.

A summary table, detailing the outcome of the MCA process for this AFA, is provided in Appendix E.

D.11 Environmental appraisal report

An environmental assessment matrix has been carried out for each viable flood risk management option. It details the indicators, impacts during construction and operation on the sensitive receptors in the area. It is included as an appendix in the AFA standalone preliminary options report for any area where viable options have been carried forward. The options have been assessed under the social and environmental objectives in line with the multi-criteria assessment. The criteria detailed in Table D-4 were assessed, and the summary for the AFA is provided in Appendix E.

Table D-4: Environmental option report assessment criteria

Social	Minimise Risk to human health and life of residents
	Minimise risk to high vulnerability properties
	Minimise risk to social infrastructure
	Minimise risk to local employment
	Minimise risk to flood-sensitive social amenity sites
Environmental	Prevent deterioration in status, and if possible contribute to, the achievement of good ecological status / potential of water-bodies, including reduction of risk of pollution
	Avoid detrimental effects to, and where possible enhance, Natura 2000 sites
	Avoid damage to or loss of, and where possible enhance, nature conservation sites and protected species or other known species of conservation concern
	Maintain existing, and where possible create new, fisheries habitat including the maintenance or improvement of conditions that allow upstream migration for fish species
	Protect, and where possible enhance, visual amenity, landscape protection zones and views into / from designated scenic areas within the zone of influence
	Avoid damage and reduce risk of flooding to, or loss of, features of architectural value and their setting
	Avoid damage and reduce risk of flooding to, or loss of, features of archaeological value and their setting

E MCA Outcomes and Environmental Appraisal

E.1 MCA Outcomes

Table E-1: MCA Local weightings for Galway AFA

MCA Local Weightings Objective	Local Weighting	Comment
1.a	5	The Local Weighting to be applied for this objective is constant, and should always be set equal to 5, as it always a consideration in option design and selection.
1.b	5	The Local Weighting to be applied for this objective is constant, and should always be set equal to 5, as it always a consideration in option design and selection.
1.c	5	The Local Weighting to be applied for this objective is constant, and should always be set equal to 5, as it always a consideration in option design and selection. It is recognised that the impacts of, and vulnerability to, potential future changes will vary significantly from community to community. However, this objective is used only for option selection, and is not used for prioritisation, and so the relative significance of the impacts and vulnerability to potential future change between communities is not relevant. As promoting adaptability is always important, the local weighting is to be kept constant.
2.a	5	Local Weighting based on the formula below. $\text{Local Weighting} = \frac{\text{AAD for the SSA}}{\text{€75,000}}$ AAD for Galway AFA is €399,740. Local Weighting may not exceed 5.
2.b	5	Local Weighting score is calculated as the sum of the factored scores for each transport route at risk from flooding, subject to a maximum score of 5. A number of urban roads and R336 regional road within Galway AFA at risk of flooding.
2.c	0	No utility infrastructure at risk
2.d	1	Minimal agricultural land, generally low quality pasture at risk of flooding along the coastline.
3.a.i	1.292	312 residential properties at risk within the AFA.
3.a.ii	0	None at risk.
3.b.i	3.05	39 social infrastructure properties at risk in AFA. Includes the Galway City Museum. Adjustment of +1 for Galway Fire Station within 10% AEP extent.
3.b.ii	1.003	152 employers at risk of flooding
4.a	5	The Local Weighting to be applied for this objective is constant, and should always be set equal to 5 as WFD objectives must be achieved and are relevant to all waterbodies.
4.b	5	Local Weighting set at maximum value of 5 in response to, Lough Corrib SAC, Galway Bay Complex SAC and Inner Galway Bay SPA.
4.c	5	Set to 5 due to high sensitivity of watercourse and potential habitat and species. Otter known to be present throughout and Lough Corrib proposed Natural Heritage Area.
4.d	5	Waterbody supports substantial fisheries and is of regional value for fishing/angling. Designated as Salmonid River under the EU Freshwater Fish Directive.
4.e	4	No specific landscape sensitivity/value, but landscape features/views are important at a local level and a significant feature of Galway City Centre for residents and visitors.
4.f.i	4	Long Walk, Dominic Street and City Centre Architectural Heritage Areas. Many Recorded Protected Structures present along waterways.
4.f.ii	4	Zone of Archaeological Potential (ZAP). Industrial archaeology such as canal walls, piers and millraces show the evolution of industry in the city.

Table E-2: MCA Results

No.	Criteria	Sub- objective	MCA Score	Option Score	Comments
1a	Technical	Ensure flood risk management options are operationally robust	100	1	Simple flood forecasting and warning systems with medium-range advance warning periods available (appx. 6 hours), with several rapidly deployed in-situ flood defences (e.g., flood gates, tipping defences)
1b		Minimise health and safety risks associated with the construction and operation of flood risk management options	100	1	working near water during construction, and then working near water during operation / maintenance. Challenging urban environment for limited construction space. High flow rate in River Corrib.
1c		Ensure flood risk management options are adaptable to future flood risk	200	2	Option is adaptable at moderate to significant cost, difficulty and impact, and provides no impediment to future interventions to address new potential future risk areas
		TECHNICAL SCORE	400		
2a	Economic	Minimise economic risk	600	5	Full reduction in design event damages.
2b		Minimise risk to transport infrastructure	238.25	4.765	Urban roads and R336 regional road protected to 0.5% AEP standard.
2c		Minimise risk to utility infrastructure	0	0	None at risk as Dyke Road protects current water supply infrastructure from flooding.
2d		Minimise risk to agriculture	0	0	Negligible agricultural land within AFA boundary at risk of flooding.
		ECONOMIC SCORE	838.25		
3a (i)	Social	Minimise risk to human health and life of residents	148.1	4.2	see Environmental Appraisal
3a (ii)		Minimise risk to high vulnerability properties	0	0	see Environmental Appraisal

No.	Criteria	Sub- objective	MCA Score	Option Score	Comments
3b (i)		Minimise risk to social infrastructure and amenity	93.375	3.4	see Environmental Appraisal
3b (ii)		Minimise risk to local employment	29.783	4.24	see Environmental Appraisal
		SOCIAL SCORE	271.25		
4a	Environmental	Provide no impediment to the achievement of water body objectives and, if possible, contribute to the achievement of water body objectives.	-80	-1	see Environmental Appraisal
4b		Avoid detrimental effects to, and where possible enhance, Natura 2000 network, protected species and their key habitats, recognising relevant landscape features and stepping stones.	-50	-1	see Environmental Appraisal OR -999 on basis of harbour requirement for IROPI.
4c		Avoid damage to or loss of, and where possible enhance, nature conservation sites and protected species or other know species of conservation concern.	-25	-1	see Environmental Appraisal.
4d		Maintain existing, and where possible create new, fisheries habitat including the maintenance or improvement of conditions that allow	-65	-1	see Environmental Appraisal

No.	Criteria	Sub- objective	MCA Score	Option Score	Comments
		upstream migration for fish species.			
4e		Protect, and where possible enhance, visual amenity, landscape protection zones and views into / from designated scenic areas within the river corridor.	-128	-4	see Environmental Appraisal
4f (i)		Avoid damage to or loss of features of architectural value and their setting.	-48	-3	see Environmental Appraisal
4f (ii)		Avoid damage to or loss of features of archaeological value and their setting.	-48	-3	see Environmental Appraisal
		ENVIRONMENTAL SCORE	-444		
MCA OPTION SELECTION SCORE			1066		
MCA BENEFIT SCORE			666		
COST (€Million)			€ 9.54		
BENEFIT OF OPTION (€Million)			€ 9.54		
ECONOMIC BCR			1.00		
MCA BCR (Benefit per invested Euro)			0.698		

E.2 Environmental Appraisal Summary

Criteria	Objective	Sub-Objective	Indicators	Impacts during Construction	Impacts during Operation	Receptor		
Social	a	Minimise risk to human health and life	i	Minimise risk to human health and life of residents	Number of residential properties at risk from flooding.	<p>Construction of all methods will require a health & safety plan. All risks to property and the public will be addressed.</p> <p>Disruption to local residents will include access to properties and parking restrictions.</p>	<p>Reduction in risk to life of residents and visitors.</p> <p>Ongoing structure, embankment and channel maintenance will be required to sustain the proposed level of protection.</p>	198 residential properties within the 0.5% tidal or 1% fluvial AEP flood extent. Many ground floor and upper storey apartments. Upper flood apartments not included in the 198 residential properties, many of which are above car parks or other non-residential uses.
			ii	Minimise risk to high vulnerability properties	Number of high vulnerability properties at risk from flooding (e.g. hospitals, health centres, nursing and residential homes).	None.	None.	No utility infrastructure at risk.

Criteria	Objective	Sub-Objective	Indicators	Impacts during Construction	Impacts during Operation	Receptor		
	b	Minimise risk to community	i	Minimise risk to social infrastructure and amenity	<p>Number of social infrastructure assets at risk from flooding (e.g. educational institutions, fire and garda stations, bord gais facilities).</p> <p>Number/length of key strategic transport assets at risk of flooding.</p> <p>Number of amenity assets at flood risk.</p>	<p>Potential temporary disruption to local social infrastructure during construction.</p>	<p>Ongoing structure, embankment and channel maintenance will be required to sustain the proposed level of protection.</p> <p>Protection of fire station from flood risk is a major contribution to local resilience and recovery from flooding and other emergencies.</p>	<p>39 social infrastructure properties, including Galway City Fire Station.</p>

Criteria	Objective	Sub-Objective	Indicators	Impacts during Construction	Impacts during Operation	Receptor	
		ii	Minimise risk to local employment	Number of non-residential properties at risk from flooding.	Potential temporary disruption to some businesses during construction. Timing of construction works may need to avoid disruptive work (noise, dust, visual and access) during main tourist season for some seasonally dependent businesses.	<p>Long term benefits to sustainability of local businesses and employment in the city centre.</p> <p>Potential secondary negative impact on tourist industry from the potential damage to visual and cultural heritage attractions.</p>	<p>152 businesses within the 0.5% tidal or 1% fluvial AEP flood extent. A mix of businesses across a range of sectors.</p> <p>Objective does not cover potential impact on tourism economy and employment which could be impacted through the negative impacts of flood defence walls on visual appearance, public realm and cultural heritage.</p>

<p>Environmental</p>	<p>a</p>	<p>Support the objectives of the WFD</p>	<p>i</p>	<p>Prevent deterioration in status, and if possible contribute to, the achievement of good ecological status / potential of waterbodies, including reduction of risk of pollution</p>	<p>Assessment of flood risk management options and their impact (e.g. disconnection/re-connection with floodplain, in-channel works, barriers, reinstatement of more natural morphology). Number of potential contamination/ pollution sources (e.g. wastewater treatment plants, IPPC licensed sites, landfill sites) at flood risk (to assess impact on water quality).</p>	<p>Short term temporary localised impact from flood defence works. Due to lack of space, works are likely to be in and on the banks with some in-channel access required. This could lead to sediment release and water quality impacts. Mitigation of impacts would include de-watering, coffer dams, sediment management and other methods.</p> <p>Works to the foundations of flood defence walls may potentially disturb and release sediment.</p> <p>Risk to water quality during the construction of the scheme can be minimised through implementation of an effective Construction Environment Management Plan (CEMP) and following IFI's Guidelines on Protection of Fisheries</p>	<p>Proposed methods will have no impact upon hydromorphology. No impact upon the flow regime of the River Corrib from Lough Corrib to Galway Bay or on any of the waterways through Galway City.</p> <p>No impact of option on the brackish mix of fresh and saline water in Lough Atalia or tidal flows. The tidal barrage option has been screened out on this basis together with technical considerations.</p> <p>No change in water quality, or pressures and risks to achieving good water quality.</p> <p>Ongoing maintenance of the Dyke Road, which acts as a flood defence will continue to minimise pollution risk to water supply abstractions during flooding.</p> <p>Long term protection of contaminated land from</p>	<p>River Corrib river waterbody – currently good status at Salmon Weir monitoring point. At risk of not achieving good status.</p> <p>Terryland River – currently poor status river water quality at monitoring point.</p> <p>Corrib Estuary transitional waterbody – currently unpolluted status. At risk of not achieving good status.</p> <p>Lough Corrib lake waterbody – currently oligotrophic / mesotrophic water quality status. Possibly at risk of not achieving good status.</p> <p>Inner Galway Bay North coastal waterbody – currently unpolluted status. Strongly expected to achieve good status.</p> <p>Clare-Corrib, Ross Lake and Clarinbridge ground</p>
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					<p>during Construction Works in and Adjacent to Waters.</p> <p>Construction works unlikely to impact upon ground waterbodies, bathing waters, waste water treatment and water supply infrastructure or sources of pollution.</p> <p>Limited potential to expose contaminated land at Southpark during construction of the Nimmo's Pier embankment, which could result in leachate discharging to surface water bodies or groundwater.</p>	<p>flooding as a source of leachate which could discharge to surface water bodies or groundwater.</p> <p>Maintenance of flood defence structures will need to consider potential impacts of maintenance activity, including the timing of works.</p>	<p>waterbodies – currently good status. At risk of not achieving good status.</p> <p>Maam-Clonbur and Spiddal ground waterbodies – currently good status. Expected to achieve good status.</p> <p>Users of the river including the public and freshwater flora and fauna that is supported by the river.</p> <p>Designated bathing waters at Salthill, Silverstrand, Grattan and Ballyloughane designated under the Bathing Water Directive.</p> <p>Mutton Island Waste Water Treatment Plant is located outside of the AFA boundary but within Galway Bay.</p>
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Criteria	Objective		Sub-Objective		Indicators	Impacts during Construction	Impacts during Operation	Receptor
								<p>Water supply for Galway is abstracted from the Terryland River, which is fed from the River Corrib.</p> <p>There is one Seveso III site in the New Docks, which is outside of the present day flood extents and so not a potential source of pollution during flooding.</p>

	b	Support the objectives of the Habitats Directive and Birds Directive	i	Avoid detrimental effects to, and where possible enhance, Natura 2000 sites	<p>Area of internationally designated sites at risk from flooding and assessment of likely impact.</p> <p>Report conservation status of internationally designated sites relating to flood risk management.</p>	<p>Short term temporary localised impact from flood defence works. Due to lack of space, works are likely to be in and on the banks with some in-channel access required. This could lead to sediment release and water quality impacts. Mitigation of impacts would include de-watering, coffer dams, sediment management and other methods.</p> <p>Risk to Natura 2000 sites, habitats and species during the construction of the scheme can be mitigated by implementation of an effective Construction Environment Management Plan (CEMP) and following IFI's Guidelines on Protection of Fisheries during Construction Works in and Adjacent to Waters.</p>	<p>Proposed methods will have no impact upon hydromorphology or the connectivity of habitats, species and protected sites.</p> <p>No impact of option on the brackish mix of fresh and saline water in Lough Atalia or tidal flows.</p> <p>No encroachment into SAC boundaries.</p> <p>Maintenance of flood defence structures will need to consider potential impacts of maintenance activity, including the timing of works.</p> <p>Potential for spread of Invasive Species during maintenance work.</p>	<p>The River Corrib is potentially a key corridor between the Natura 2000 sites listed below and also for species movement to and from habitats (* denotes a priority habitat):</p> <p>Lough Corrib SAC (000297) designated features: Oligotrophic waters containing very few minerals of sandy plains (Littorelletalia uniflorae) [3110] Hard oligo-mesotrophic waters with benthic vegetation of Chara spp. [3140] Water courses of plain to montane levels with the Ranunculion fluitantis and Callitricho-Batrachion vegetation [3260] Semi-natural dry grasslands and scrubland facies on calcareous substrates (Festuco-Brometalia) (* important orchid sites) [6210]</p>
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					<p>Timing of works may be critical to avoiding impacts to some species such as Sea Lamprey, Salmon, overwintering and nesting birds. Timing of works also to avoid impacts on movement of species and connectivity between habitats during sensitive times of the year.</p>		<p>Molinia meadows on calcareous, peaty or clayey-silt-laden soils (Molinion caeruleae) [6410] Active raised bogs [7110] Degraded raised bogs still capable of natural regeneration [7120] Depressions on peat substrates of the Rhynchosporion [7150] Calcareous fens with Cladium mariscus and species of the Caricion davallianae [7210] Petrifying springs with tufa formation (Cratoneurion) [7220] Alkaline fens [7230] Limestone pavements [8240] Old sessile oak woods with Ilex and Blechnum in the British Isles [91A0] Bog woodland [91D0] Margaritifera margaritifera (Freshwater Pearl Mussel) [1029] Austropotamobius pallipes (White-clawed Crayfish) [1092] Petromyzon marinus (Sea Lamprey) [1095] Lampetra planeri</p>
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Criteria	Objective	Sub-Objective	Indicators	Impacts during Construction	Impacts during Operation	Receptor
						<p>(Brook Lamprey) [1096] Salmo salar (Salmon) [1106] Rhinolophus hipposideros (Lesser Horseshoe Bat) [1303] Lutra lutra (Otter) [1355] Drepanocladus vernicosus (Slender Green Feather-moss) [1393] Najas flexilis (Slender Naiad) [1833]</p> <p>Galway Bay Complex SAC (000268) designated features: Mudflats and sandflats not covered by seawater at low tide [1140] Coastal lagoons [1150] Large shallow inlets and bays [1160] Reefs [1170] Perennial vegetation of stony banks [1220] Salicornia and other annuals colonising mud and sand [1310] Atlantic salt meadows (Glauco-</p>

Criteria	Objective	Sub-Objective	Indicators	Impacts during Construction	Impacts during Operation	Receptor
						<p>Puccinellietalia maritimae) [1330] Mediterranean salt meadows (Juncetalia maritimi) [1410] Turloughs [3180] Juniperus communis formations on heaths or calcareous grasslands [5130] Semi-natural dry grasslands and scrubland facies on calcareous substrates (Festuco-Brometalia) (* important orchid sites) [6210] Calcareous fens with Cladium mariscus and species of the Caricion davallianae [7210] Alkaline fens [7230] Lutra lutra (Otter) [1355] Phoca vitulina (Common Seal) [1365]</p> <p>Inner Galway Bay SPA (004031) designated features: Great Northern Diver (Gavia immer) [A003] Cormorant (Phalacrocorax carbo) [A017]</p>

Criteria	Objective		Sub-Objective	Indicators	Impacts during Construction	Impacts during Operation	Receptor
							Grey Heron (<i>Ardea cinerea</i>) [A028] Light-bellied Brent Goose (<i>Branta bernicla hrota</i>) [A046] Wigeon (<i>Anas penelope</i>) [A050] Teal (<i>Anas crecca</i>) [A052] Shoveler (<i>Anas clypeata</i>) [A056] Red-breasted Merganser (<i>Mergus serrator</i>) [A069] Ringed Plover (<i>Charadrius hiaticula</i>) [A137] Golden Plover (<i>Pluvialis apricaria</i>) [A140] Lapwing (<i>Vanellus vanellus</i>) [A142] Dunlin (<i>Calidris alpina</i>) [A149] Bar-tailed Godwit (<i>Limosa lapponica</i>) [A157] Curlew (<i>Numenius arquata</i>) [A160] Redshank (<i>Tringa totanus</i>) [A162] Turnstone (<i>Arenaria interpres</i>) [A169] Black-headed Gull (<i>Chroicocephalus ridibundus</i>) [A179]

Criteria	Objective		Sub-Objective		Indicators	Impacts during Construction	Impacts during Operation	Receptor
								Common Gull (<i>Larus canus</i>) [A182] Sandwich Tern (<i>Sterna sandvicensis</i>) [A191] Common Tern (<i>Sterna hirundo</i>) [A193] Wetland and Waterbirds [A999]

Criteria	Objective	Sub-Objective	Indicators	Impacts during Construction	Impacts during Operation	Receptor	
	c	Avoid damage to, and where possible enhance, the flora and fauna of the catchment	i	<p>Avoid damage to or loss of, and where possible enhance, nature conservation sites and protected species or other known species of conservation concern</p> <p>Area of nationally designated sites at risk from flooding and assessment of likely impact, particularly where designated for Otter, White-clawed Crayfish or Freshwater Pearl Mussel</p> <p>Reported conservation status of nationally designated sites relating to flood risk management.</p> <p>Area/length of river within Freshwater Pearl Mussel sensitive areas where flood risk management actions are proposed, and assessment of likely impact.</p>	Same as objective b.	Same as objective b.	Likely protected species e.g. bat species and otter.

	d	Protect, and where possible enhance, fisheries resource within the catchment	i	Maintain existing, and where possible create new, fisheries habitat including the maintenance or improvement of conditions that allow upstream migration for fish species	Number of barriers to fish and Eel movements removed / modified / constructed as a result of flood risk management option.	<p>Short term temporary localised impact from flood defence works. Due to lack of space, works are likely to be in and on the banks with some in-channel access required. This could lead to sediment release and water quality impacts. Mitigation of impacts would include de-watering, coffer dams, sediment management and other methods.</p> <p>Works to the foundations of flood defence walls may potentially disturb and release sediment.</p> <p>Risk to water quality during the construction of the scheme can be minimised through implementation of an effective Construction Environment Management Plan (CEMP) and following IFI guidelines for works in river channels.</p>	<p>Maintenance of flood defence structures will need to consider potential impacts of maintenance activity, including the timing of works.</p> <p>Spread of Invasive Species during maintenance work.</p> <p>Proposed methods will have no impact upon hydromorphology.</p>	<p>EU designated freshwater fish watercourse for salmonid species. Also an important trout river.</p> <p>Invasive species could be introduced without sufficient mitigation.</p> <p>Inner Galway Bay South is a designated as economically significant shellfish growing waters. Unlikely to have any direct connectivity to the proposed activities during construction or operation.</p>
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Criteria	Objective		Sub-Objective		Indicators	Impacts during Construction	Impacts during Operation	Receptor
						<p>Timing of works will be critical to avoid salmon season or impact upon angling.</p> <p>Construction works unlikely to impact upon groundwater bodies, bathing waters, waste water treatment and water supply infrastructure or sources of pollution.</p> <p>Spread of Invasive Species during construction work.</p>		

	e	Protect, and where possible enhance, landscape character and visual amenity within the zone of influence	i	Protect, and where possible enhance, visual amenity, landscape protection zones and views into / from designated scenic areas within the zone of influence	Compliance with landscape character objectives relevant to flood risk management methods.	Potential for visual impacts during construction. Will need to consider timing in light of main tourist season and events. Visual impact may have secondary impact on tourist economy.	<p>Permanent impact on local/moderate value landscape character/feature in the zone of influence of the selected method.</p> <p>Individual property protection in Salthill will alter appearance of building fronts, but with potential to enhance visual appearance.</p>	<p>Public – both residents in Galway City and surrounding areas and tourists.</p> <p>View of the long walk from the Claddagh is a well-respected view and an Architectural Heritage.</p> <p>Inland waterways including the Terryland River, Eglinton Canal, River Corrib and lesser waterways of the Cathedral.</p> <p>Woodland at Terryland Forest Park.</p> <p>Landscape is a component of the open spaces and Green Network. Coastal areas and the rivers and waterways. View south from the Salthill Promenade and the Claddagh is a protected view.</p>
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Criteria	Objective	Sub-Objective	Indicators	Impacts during Construction	Impacts during Operation	Receptor
						The Salthill Promenade is a historical feature of heritage importance as a Victorian seaside resort.
	f Avoid damage and reduce risk of flooding to, or loss of, features of cultural heritage importance and their setting	i Avoid damage and reduce risk of flooding to, or loss of, features of architectural value and their setting	Number of architectural assets at flood risk and assessment of impact on their setting.	<p>Potential for visual impacts during construction and disturbance to architecture.</p> <p>CEMP will need to ensure control methods are in place.</p> <p>Will need to consider timing in light of main tourist season and events.</p>	<p>Changes to the setting of architectural features (Record of Protected Structures and NIAH) such that it is completely altered. Principally the Long Walk and numerous record of protected structures along waterways.</p> <p>Despite significant change in setting protection of architectural heritage area from flooding.</p>	<p>Many recorded protected structures. Architectural Conservation Areas: The City Core</p> <p>Lower Dominic Street</p> <p>The Long Walk</p> <p>Dock Road</p>

Criteria	Objective	Sub-Objective	Indicators	Impacts during Construction	Impacts during Operation	Receptor	
		ii	Avoid damage and reduce risk of flooding to, or loss of, features of archaeological value and their setting	Number of cultural heritage and archaeological assets at flood risk and assessment of impact on their setting.	<p>Potential to discover unknown archaeology during construction. Potential impact on archaeology in situ.</p> <p>CEMP will need to ensure control methods are in place.</p>	<p>Changes to the setting of archaeological features (Recorded Monuments) such that it is completely altered. Further potential for unknown archaeology in waterways.</p> <p>Despite significant change in setting protection of archaeological heritage area from flooding.</p>	<p>Zone of high archaeological potential throughout city centre.</p> <p>Industrial archaeology along the waterways.</p> <p>Medieval city walls, including the Spanish Arch.</p>

F Design Risk Health and Safety Assessment



Hazard Identification and Risk Assessment (including Particular risks & Other Significant Risks)

L = Likelihood 1 = Very Unlikely 2 = Unlikely 3 = Likely 4 = Almost Certain 5 = Certain	S = Severity 1 = Minor injury 2 = Lost time injury 3 = Long term absence 4 = Major permanent incapacity 5 = Fatality	
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Galway City Preliminary Options			Project nr:- 2015s2288	
Prepared by	Jo Cullinane	Prepared Date	17/06/2016	
Verified by	Declan White	Verified Date	20/06/2016	
Approved by	Sam Willis	Approved Date	20/06/2016	
			Discipline	Flood Relief Scheme
			Stage	Preliminary Design

Design Issue or Element:- Site Constraints / Public Safety Issues / Falls / Collisions

Ref	Hazard	Design Mitigation Measures	Other Possible Mitigation Measures including measures by Contractor on-site	Risk After Controls			
				Likelihood (L)	Severity (S)	Risk = L x S	
1	Risk associated with site constraints and public access	Impact / collision of site plant/pedestrians	<p>Given the nature of the project, it is not possible to completely eliminate these hazards by design.</p> <p>Site boundary to be set out to minimise interaction between plant and pedestrians.</p> <p>With the exception of possible re-pointing of quay walls, working at heights should be minimised in the design where possible.</p> <p>Constraints in relation to traffic flows to be included in the specification document, example diversions and one-way systems, timing of works etc.</p> <p>Requirements in relation to site security and fencing to be included in the specification for the works</p>	<p>Contractor to develop and enforce a traffic management plan, including site road layouts, speed control measures and proximity to excavations. Traffic management plan implemented during off-peak traffic levels.</p> <p>Compliance by contractor in relation to site security, house keeping, vehicle management etc.</p> <p>It is considered that these risks should be capable of safe management and control by a competent contractor using safe systems of work and the appropriate levels of resources and equipment</p>	1	4	4
		Falling objects			1	5	5
		Collapse of scaffolding			1	5	5
		Unauthorised access into site			2	3	6
		Slip, trip and fall injury along the site entrance			2	3	6
		Collision with workers, pedestrians and motorists while erecting Traffic Signal Equipment/Signs			1	5	5
		Workers or public hit by moving delivery truck. Blow from falling load			1	5	5
		Risks associated with falling off quay walls into excavations, into manholes, from machinery etc.			1	5	5

Design Issue or Element:- Piling and Excavations

2	Risk associated with Excavations	Collapse of excavation or burial due to instability	Given the nature of the project, it is not possible to completely eliminate these hazards by design.	Contractor to investigate and confirm route of services and then re-route or protect them.	1	5	5
		Exposure to contaminated materials	Site investigation in due course shall identify any dangerous contaminants in the soil.	Temporary support/battering back of excavations dependent on Contractors chosen construction method.	1	5	5
		Injury due to trapped gases in redundant culverts / basements / manholes	A GPR survey shall be carried out by the contractor to identify existing services in the area.	Vehicular traffic to be kept back sufficiently from open excavations using banksmen and/or bollard protections.	1	5	5
		Injury due to lifting pipe lengths and manhole components	Existing services identified in the excavation area shall be located and re-routed before any piling works shall commence.	It is considered that these risks should be capable of safe management and control by a competent contractor using safe systems of work and the appropriate levels of resources and equipment	1	5	5
		Contact with existing services, especially the gas pipelines	All existing services shall be brought to the contractors attentions as part of the tender package.		1	5	5

Design Issue or Element:- Works Close to Existing Quay Wall - risk of collapse

3	Risk associated with Excavations	Excavation adjacent to existing quay walls may cause instability in existing wall during construction works	Given the nature of the project, it is not possible to completely eliminate these hazards by design.	During the excavations, any existing walls and adjacent buildings on the landside will be monitored daily both visually and by surveying methods to identify any movement during the course of the works. If movement is detected, the works are to cease until such time as the working area and the structures are made safe and works can continue.	1	4	4
		Underpinning existing foundations	Design team to review condition of the walls in due course and advise of risk of collapse.	The contractor is to avoid storing heavy materials adjacent to the quay walls.	1	5	5
		Risk of collapse of existing quay walls caused by installation of the works, e.g.. Vibrations, contact between machinery and existing quay walls, heavy loading of the site etc.	It will be a requirement of the contract that the contractor will appoint a competent person to monitor the condition of the walls during the works, taking into account the specific methodology of the contractors work. This person will be responsible for considering the condition of the wall, the proposed methodology of the works, and deciding what special measures (if any) are required to allow the works to proceed safely, e.g. carrying out the works in very short lengths, temporary propping of existing walls etc.	The contractor will need to assess the weight of his equipment and where his plant and equipment is placed in order to prevent collapse as a result of the works. He will also need to ensure that the proposed works do not impose loads or vibrations on existing walls so that they would collapse.	1	5	5
		Existing quay walls to be repointed if necessary and pressure grouted before any excavations are carried out. This will reduce the risk of collapse. It will also reduce seepage through the walls and therefore reduce the risk of groundwater flooding due to high water levels in the quays					
		Any damage to the existing quay walls as part of any advanced contract may be addressed during the main scheme works but if so, the subject area is to be made safe in the interim.					
		Undertake seepage analysis and consider cut-off wall to mitigate risk of					

Design Issue or Element:- Damage to / clashes with existing services

	vices	Clashes with unmapped underground services	Given the nature of the project, it is not possible to completely eliminate these hazards by design.	Contractor to investigate and confirm route of all services and then re-route them or protect them as required.	2	3	6
--	-------	--	--	---	---	---	---

4	Risks of damages to existing services	Striking overhead or underground electricity and telecom cables	Electromagnetic utilities survey of the site (Ground Penetrating Radar) will be given to the contractor. It should be noted that the information provided will be indicative only and that it remains the contractor's responsibility to confirm the location on site of all services by careful site investigation methods, and to avoid interference with existing services. Presence of overhead lines will be highlighted to Contractor on utility drawings. Information to be attained from service providers in the form of drawings of existing services (indicative only) and this info to be taken into account in the design. This info should also form part of the tender packages	Contractor to liaise with public utility companies where appropriate. Presence of representative of utility company on site during excavation Hand digging. Erect goal posts with warning tape / bunting as appropriate. Contractor to investigate and establish route of services and then re-route them or protect them as required.	1	5	5
		Damaged or severed watermains resulting in water leak, gas leak or ground contamination			1	5	5
		Damaged or severed lighting and security systems underground services - cables, ducts			1	4	4
		Falls of persons into manholes			1	5	5

Design Issue or Element:- Noise and Vibration During Excavation and Construction

5	Risks of damages to existing services	Temporary or permanent hearing damage / loss for construction workers / local residents	Given the nature of this project, it is not possible to completely eliminate these hazards by design	Contractor to liaise with local residents. Appropriate PPE to be worn at all times. Noise reduction barriers to be used. Working hours restricted to 08:00 - 18:00, Monday to Friday (inclusive) Noise and vibration generating activities, e.g. breaking out surface obstructions, to be restricted to limited hours per day, to reduce exposure. Noise monitoring in sensitive locations to be carried out for the duration of the works	1	5	5
		Noise and vibration disturbances for local residents			1	5	5

Design Issue or Element:- Restricted Works Area

6	Risks associated with Restricted Working Areas	Operation of suitable plant	The site boundary within the available area to be maximised as far as possible. The work area available to be considered in the design of all flood defence works. Given the nature of the project, it is not possible to completely eliminate these hazards by design	The Contractor to compile a detailed operation and traffic management plan for the construction works. It is the responsibility of the Contractor to put in place the required mitigation measures to ensure the safe construction of the works. The Contractor is to be aware of the restricted site conditions and plan works accordingly. Areas taken over for the works shall be made good after construction and returned to the original condition	1	5	5
		Site control and logistics			1	5	5
		Safety of construction workers			1	4	4
		Taking control of lands to increase work space			1	5	5

Design Issue or Element:- Working near a Watercourse

7	Risks associated with Restricted Working Areas	Drowning	Given the nature of this project, it is not possible to completely eliminate these hazards by design.	Barrier to be erected between existing quay wall and site. Life jackets to be freely available Contractor to provide a suitable stable pontoon in the river, certified to support the equipment required.	1	5	5
		Falling over quay wall			1	5	5
		Working on pontoon or parapet in the river, risk of capsizing, operatives drowning			1	4	4

	Risks Res	Flooding due to groundwater, especially as this is a tidal area		Contractor to monitor levels of ground water and have prepared contingency plan to prevent flooding in case high tides or heavy rain	1	5	5
--	-----------	---	--	--	---	---	---

Design Issue or Element:- Work on live Roads - Traffic Management

8	Risks associated with working on live roads	Risk of collision between construction traffic and public traffic, i.e. cars, buses, HGV's, emergency vehicles	Constraints in relation to traffic flows to be included in the specification (e.g. diversions and one-way systems, timing of some of the works).	The Contractor shall put in place Temporary Traffic Management measures in accordance with the specification which has detailed requirements to ensure that members of the public i.e. public vehicles, pedestrians and cyclists do not come into contact with the works	1	5	5
		Risk of collision between construction traffic and pedestrians and cyclists using the road or footpaths	Given the nature of this project, it is not possible to completely eliminate these hazards by design.		1	5	5
		Risk of disruption to emergency vehicles during the works	It is considered that these risks should be capable of safe management and control by a competent contractor using safe systems of work and the appropriate levels of resources and equipment		1	4	4
		Risks associated with construction traffic entering and leaving the site i.e. collision with public traffic, pedestrians & cyclists			1	5	5
		Risk of contractor personnel coming into contact with plant and equipment resulting in injury			1	5	5
		Risks associated with lack of co-ordination on the project			1	4	4
		Risk of slips, trips and falls by Contractors personnel & members of the public due to inadequate housekeeping and site management			1	5	5

Design Issue or Element:- Work with Chemical or Biological Substances

9	Risks associated with chemical or biological substances	Risk of exposure to chemicals, solvents or biological substances while carrying out the works	Given the nature of this project, it is not possible to completely eliminate these hazards by design.	The Contractors welfares facilities should have a hot water supply for washing purposes. Detailed control measures are to be developed by the Contractor to mitigate all risks to health and safety; including a planned sequence of work, suitable emergency plans, and issue suitable PPE as per requirements of: - Safety Health and Welfare at Work (Construction) Regulations 2006 - Safety Health and Welfare at Work (General Application) Regulations 2007 - Safety Health and Welfare at Work (Chemical Agents) Regulations 2001 - Chemicals Act 2008 and Chemicals Amendments 2010	1	4	4
		Risks associated with working with bitumen, bituminous liquids, i.e. thick coat, sealing joints with molten bitumen, Cementous products, thermoplastics and road marking materials on the project	It is considered that these risks should be capable of safe management and control by a competent contractor using safe systems of work and the appropriate levels of resources and equipment		1	5	5
		Risks associated with removal of road markings i.e. inhalation of dust and fumes by Contractor personnel and by members of the public			1	5	5
		Risk of exposure to Weil's disease			1	4	4
		Risk of encountering unexpected contaminated soils (note: there is no known evidence at this stage to suggest contaminated soils may be encountered)			1	5	5

Design Issue or Element:- Assembly or dismantling heavy prefabricated components

10	Heavy Components	Risks associated with handling and installing prefabricated components, i.e. concrete road kerbs, drainage pipework and road gullies, sheet piles etc.	Given the nature of this project, it is not possible to completely eliminate these hazards by design. Any prefabricated units specified are considered to be suitable for their purpose and capable of safe installation by a competent Contractor using adequate safety systems and resources	Detailed control measures are to be developed by the Contractor to mitigate all risks to health and safety, including a planned sequence of work, and issue a suitable PPE	1	5	5
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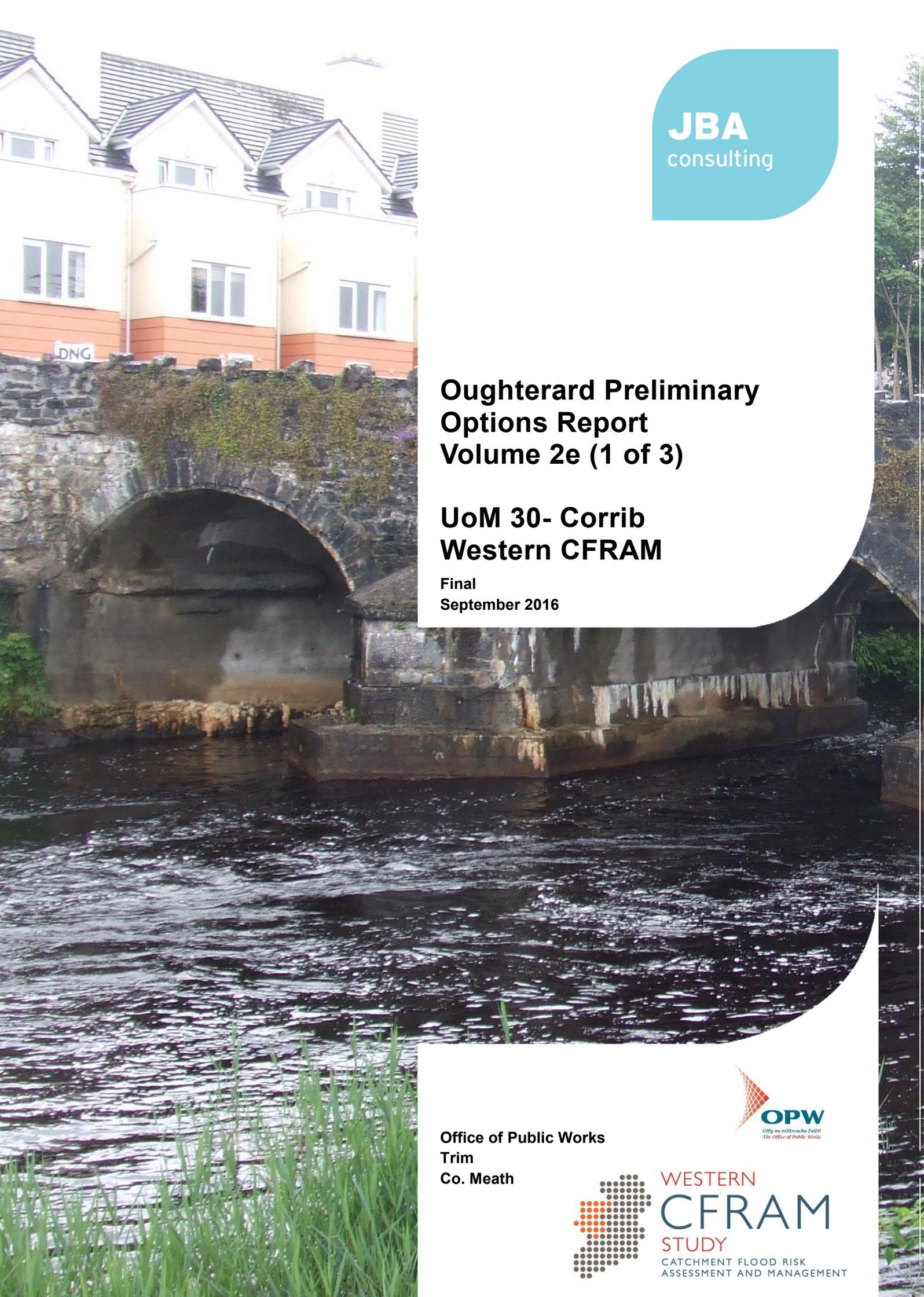
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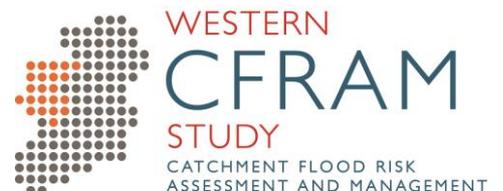
**Oughterard Preliminary
Options Report
Volume 2e (1 of 3)**

**UoM 30- Corrib
Western CFRAM**

Final
September 2016



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Contract

This report describes work commissioned by The Office of Public Works, by a letter dated (28/07/11). The Office of Public Works' representative for the contract was Clare Butler. David Moran of JBA Consulting carried out this work.

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Glossary

AAD.....	Average annual damages
AEP.....	Annual exceedence probability
AFA.....	Area for further assessment
BCR.....	Benefit cost ratio
CC.....	Climate change
CFRAM.....	Catchment-based flood risk assessment and management study
CPI.....	Consumer price index
DEM.....	Digital elevation model (Includes surfaces of structures, vegetation, etc)
DTM.....	Digital terrain model ('bare earth' model; does not include surfaces of structures, vegetation, etc
FHRC.....	Flood Hazard Research Centre
FRISM.....	Flood risk metric tool
FRM.....	Flood risk management
FRMP.....	Flood risk management plan
FRR.....	Flood risk review
GIS.....	Geographical information system
HEFS.....	High-end future scenario
HPW.....	High priority watercourse
IROPI.....	Imperative Reasons of Overriding Public Interest
LA.....	Local authority
LAP.....	Local area plan
LIDAR.....	Light detection and ranging
MCA.....	Multi-criteria analysis
MCM.....	Multi-coloured manual
MPW.....	Medium priority watercourse
MRFS.....	Mid-range future scenario
NDHM.....	National digital height model
OPW.....	Office of Public Works
OSi.....	Ordnance Survey Ireland
PCD.....	Public consultation day
POR.....	Preliminary options report

PPP	Purchase price parity
PVd	Present value damages
SAC	Special area of conservation
SEA	Strategic environmental assessment
SPA	Special protection area
SSA	Spatial scale of assessment
STP	Social time preference
STPDR	Social time preference discount rate
SUDS	Sustainable Urban Drainage Systems
UK	United Kingdom
UoM	Unit of management
WCFRAM	Western catchment-based flood risk assessment and management study
WTP	Water treatment plant
WWTW	Wastewater treatment works

1 Introduction

1.1 Scope of report

This report details the preliminary options investigation for addressing flood risk in Oughterard. The report should be read in conjunction with the Preliminary Options Overarching Report for UoM 30, a full understanding of flood risk management recommendations for Oughterard.

The Preliminary Options Investigations represent the next phase of the Western CFRAM study. The work already completed has identified the scale and extent of flood risk within Oughterard. Reports which are relevant to this AFA are:

- Western CFRAM Flood Risk Review Report
- Western CFRAM UoM 30 Inception Report
- Western CFRAM UoM 30 Hydrology Report
- Western CFRAM UoM 30 Hydraulic Modelling Report
- Western CFRAM UoM 30 - Corrib East Hydraulic Modelling Report: Volume 2e - Oughterard
- Western CFRAM UoM 30 Hydraulic Modelling Report: Volume 3 - Flood Risk maps

Using the work already completed the OPW have identified a requirement to develop methods to manage flood risk, both now and into the future, within Oughterard. The scope of this study is to identify a preferred flood risk management option for Oughterard.

The work completed includes the screening of possible methods to identify technically feasible and economically viable structural and non-structural methods to manage flood risk sustainably. From these preferred options have been identified, consulted on, and appraised against societal, environmental and cost criteria to identify a single recommended option. The final recommendations from this study will feed into the overarching Flood Risk Management Plan for Oughterard.

1.2 Flood Risk Overview

The Owenriff River is the main watercourse passing through Oughterard with a smaller tributary, the Tonweeroe stream, flowing into the Owenriff at the town. The source of flood risk in Oughterard is from the Tonweeroe where a series of culverts at the downstream end of the stream generate out of bank flow during extreme events. The head wall on the left bank is diverting flows away from the properties to flow overland in a south westerly direction towards the Owenriff River and impacting a number of properties.

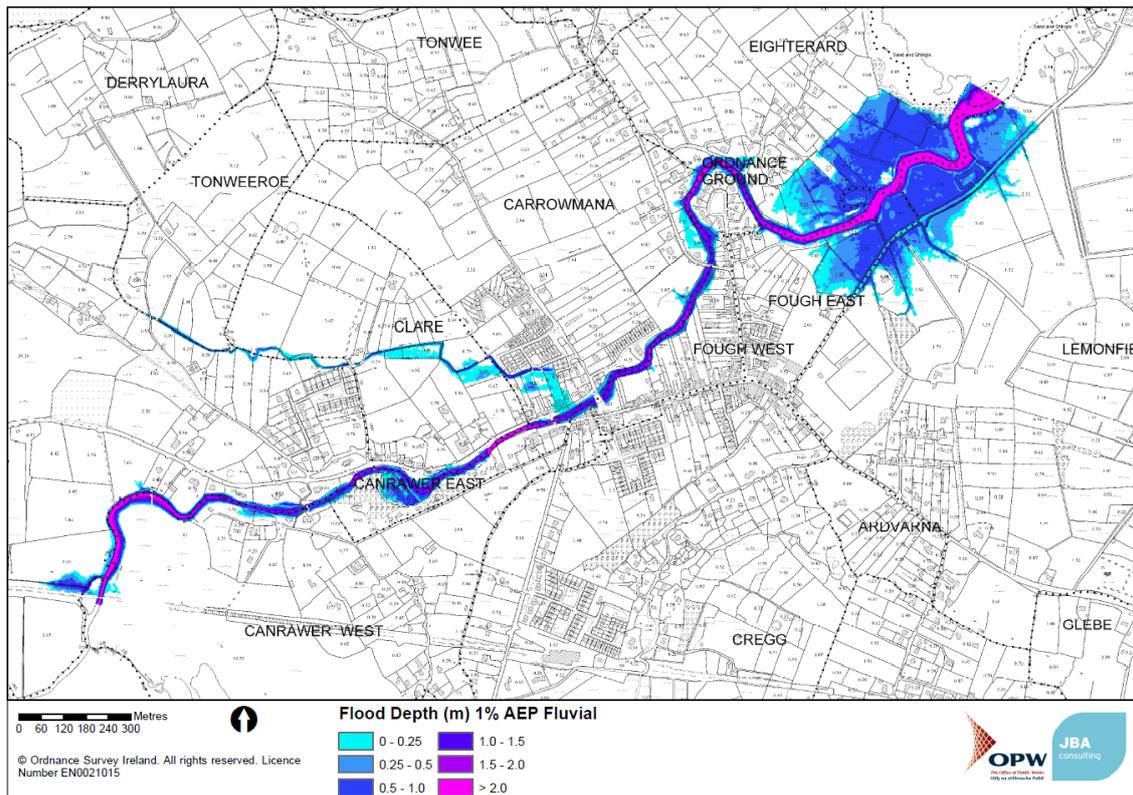
Figure 1-1: Tonweeroe culvert entrance



1.2.1 Current flood risk

Flood risk in Oughterard is associated with the Tonweeroe watercourse. The flooding is primarily related to a series of small culverts along the lower reach of the watercourse, and particularly the final 130m culvert connecting to the Owenriff River that is undersized and cannot convey the design flows. Flood water that flows out of the lower Tonweeroe channel towards property are initiated between the 10% and the 2% AEP event and 4 properties are affected in the 1% AEP. This flooding has the potential to increase significantly in the event of culvert blockage which is fairly likely given the flat screen on the final (downstream) culvert.

Figure 1-2: Overview of Flood Risk



1.2.2 December 2015 Flooding

On the weekend of the 4th/5th of December 2015 flooding was reported on the N59 road upstream of Oughterard Bridge on the left bank. Flood waters came out of bank upstream at near Sweeny's Hotel, flowed down the road and ponded in the area just upstream of the bridge. Flood depths were approximately 100mm on the road. During the event emergency works involved breaking a hole in the wall upstream of the bridge to allow waters to return to the main Owenriff channel (Figure 1-3). The N59, though close to being closed, remained open during the event. There was no reported internal property flooding during the event,

The flood mapping and hydraulic model was examined following this event. In events greater than the 1% AEP water exits the channel upstream near Sweeny's hotel as happened in this event, flows down the road and ponds behind this wall. Gauge records of the downstream bridge were sought but unfortunately the gauge was down during the event. This prevented the study determining the return period of the event.

A model run was completed removing this wall from the model, however it did not totally alleviate flooding in this area, a number of properties were still flooding. The council could consider replacing the wall with a crash barrier, for health and safety reasons, with gap between road surface and the barrier to prevent waters from ponding in this area. This may provide some alleviation but not total protection in larger events. Only a short reach of wall removal is required to help alleviate the risks, though it does not entirely remove the risk. In large events, greater than the 1% AEP, water spills out of bank upstream and significant walls would be required to contain and given the frequency of flooding in the area this would not cost beneficial currently.

Figure 1-3: N59 Flooding December 2015

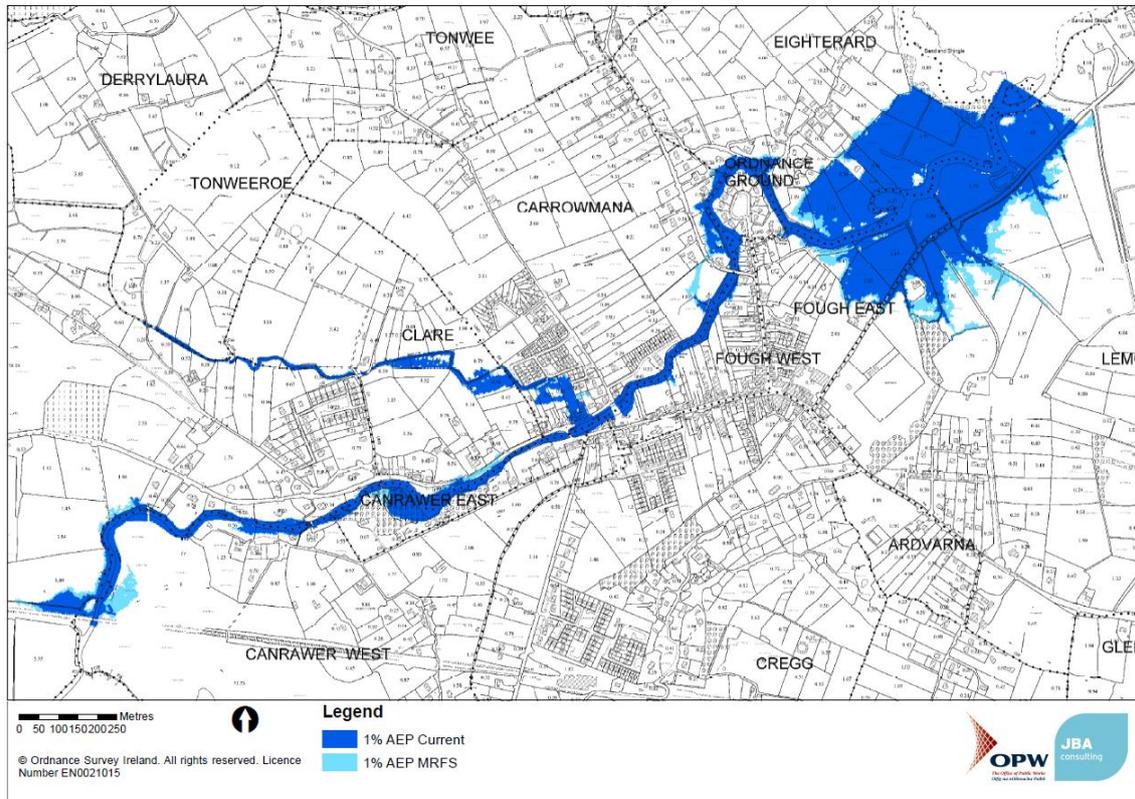


1.2.3 Future Flood Risk

The future scenarios, based upon the CFRAM specification climate change projections alter the profile of flood risk in Oughterard. Figure 1-4 below shows the current and medium range future extents for the 1% AEP fluvial design events. The increase in fluvial flow by 20% and the increase in lake level of 0.50m over the course of the next 100 years under the medium range forecast are the driver of change in fluvial flood risk.

The MRFS extent indicates limited increase in flood extent and properties are flooded from the same flood source described in the current scenario.

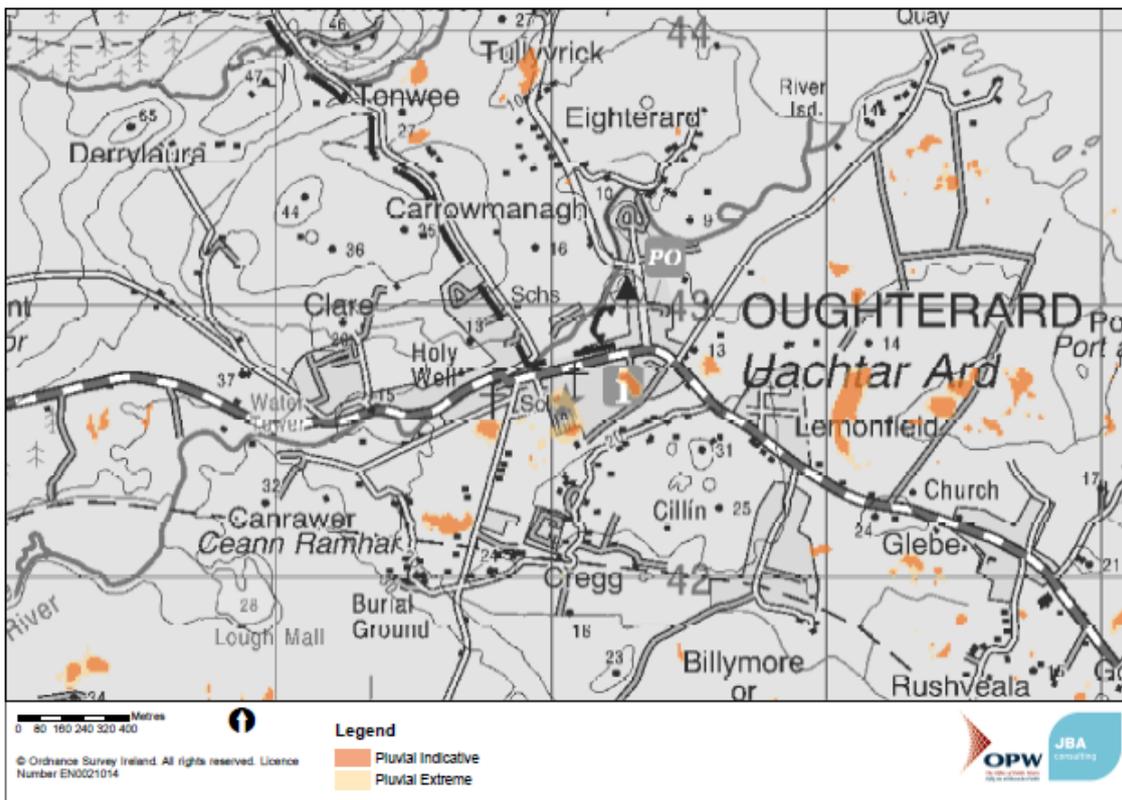
Figure 1-4: Current and future (MRFS) 1% AEP fluvial flood extent



1.2.4 Pluvial, groundwater and sewer flood risk

Oughterard is located on karstified bedrock which has the potential to cause groundwater flooding, and pluvial and groundwater flooding have been experienced in the south of the town. The pluvial risk from the Preliminary Flood Risk Assessment (PFRA) is indicated in Figure 1-5. Both the historical flood risk and the information presented in Figure 1-5 are outside of the fluvial flood risk areas which are the focus of this study and so will not impact on any flood management methods considered.

Figure 1-5: Pluvial flood risk maps



1.3 Economic Benefit

To provide an understanding of the likely scale of a cost beneficial scheme within Oughterard a preliminary assessment of the benefits associated with the protection of properties to the 1% AEP event has been completed. This assumes any scheme will remove all properties from the 1% AEP extents. Full details of the methodology used to determine these benefits is set out in Appendix A.

Damages are based on a short duration flood event and properties are assumed to have a threshold of mean LIDAR based on local observations. Benefits are €12,263 and €34,404 in the 1% AEP event for the current and MRFS respectively. Capping does not affect these benefits in either scenario.

Figure 1-6 and Table 1-1 show the number of properties flooding during the different design events for the current and MRFS. It also shows the cumulative damages for each of the return periods which can be presumed to give a rough indication of likely scheme benefits associated with a given standard of protection. Figure 1-7 details the distribution of the damages across the AFA.

Figure 1-6: Property Damages (Current and MRFS, Uncapped and Capped)

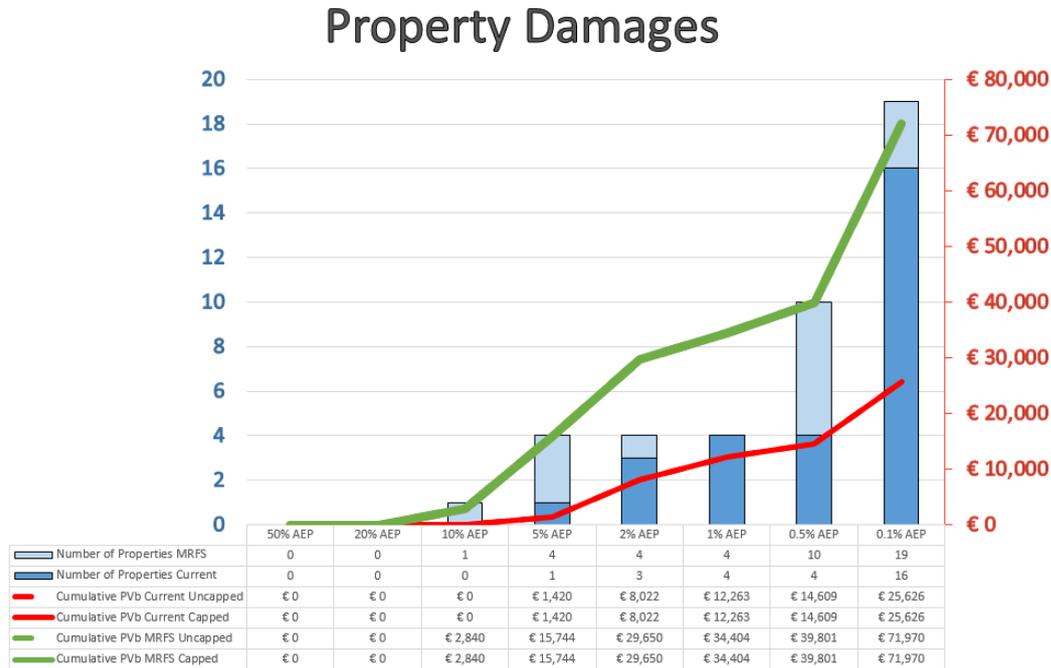
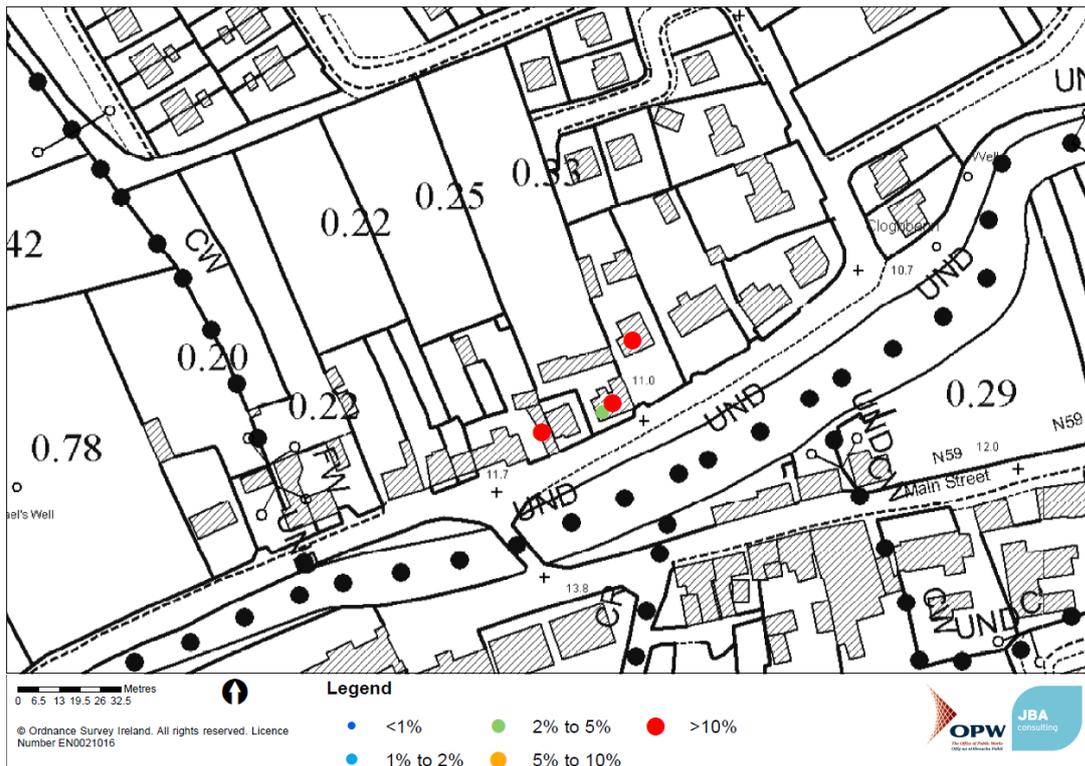


Table 1-1: Flood cell property damages (current and MRFS)

	Return Period (% AEP)							
	50%	20%	10%	5%	2%	1%	0.5%	0.1%
Current								
No. of properties	0	0	0	1	3	4	4	16
PV Damages (€)	0	0	0	1,420	8,022	12,263	14,609	25,626
MRFS								
No. of properties	0	0	1	4	4	4	10	19
PV Damages (€)	0	0	2,840	15,744	29,650	34,404	39,801	71,970

Figure 1-7: Distribution of property damages

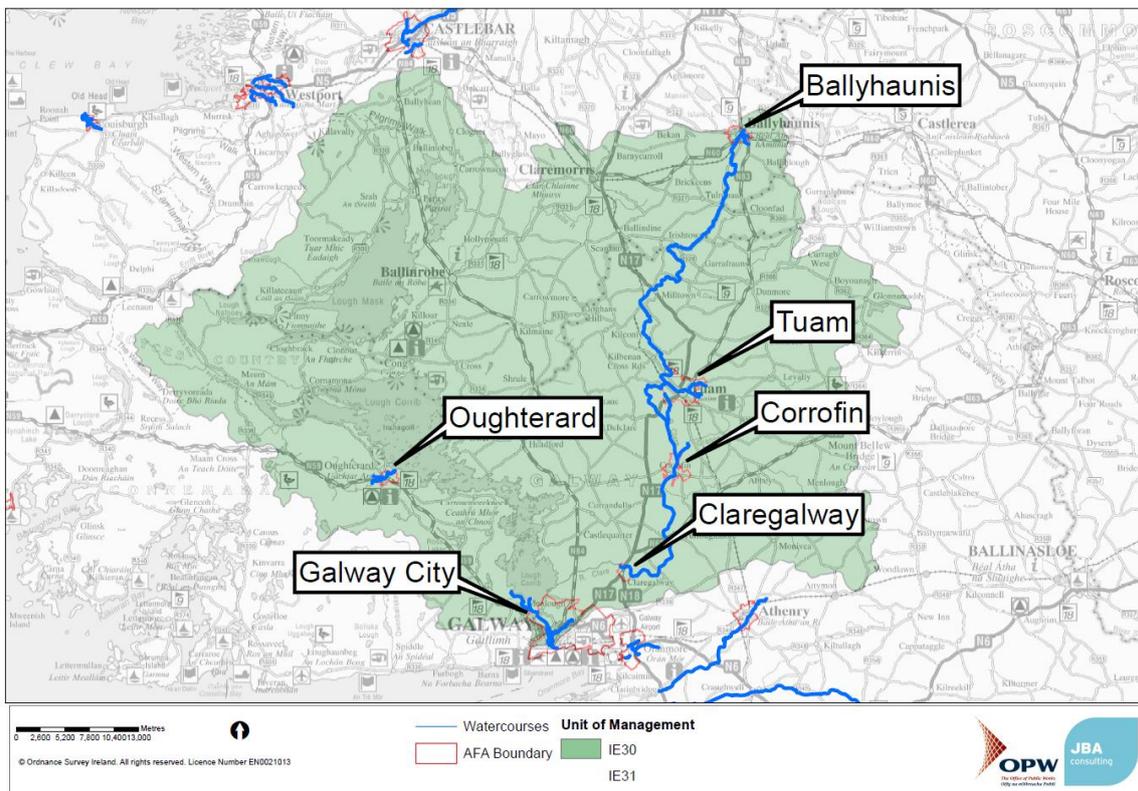


2 Scheme Spatial Scales of Assessment

2.1 Overview

This section documents the analysis of spatial scales of assessment and the identification of flood cells for the Oughterard options appraisal. The interactions between flood risk, hydrology, hydraulic, economic, social, cultural and environmental aspects of Oughterard have been considered. Figure 2-1 shows the location of Oughterard in relation to other AFAs within the Corrib UoM. This section will discuss the hydraulic connectivity of the site with other AFAs and in particular justify where there is no such interconnectivity.

Figure 2-1: Corrib UoM Overview



2.2 Key environmental, social and cultural constraints

This section summarises the social, cultural and environmental issues relating to flood risk in Oughterard and the spatial scales they relate to.

2.2.1 West of Ireland (Mayo, Galway, Sligo)

Oughterard is called "The Gateway to Connemara". The N59 which links Galway City to tourist destinations in the Gaeltacht region of Galway passing through the village is currently inundated during flood events. This is a major transport link for the area and the future vulnerability of network link that services the wider area needs to be considered as part of the county development plan, flood management plan and other service plans and strategies.

Flooding in Oughterard is unlikely to have a notable economic or social impact on the rest of Ireland. Lough Corrib is a designated SAC and the Natura 2000 designated sites are important internationally and so any detriment to the habitats or species could potentially have an impact on a European scale.

2.2.2 Galway County

Oughterard is identified as an 'Other Village' in the Galway County Development Plan. Other Villages are defined as settlements that have a population less than 1500 people and provided a more limited range of services to smaller hinterlands than the key towns. Service provision often include a range of retail and educational services but limited financial, health and community services.

The future vision and zoning for the riverside in Oughterard as set out in development plan and policy documents needs to be reflected in, or revised in response to, the flood management plan. The uncertainty in future flood risk needs to be considered in these plans.

As discussed above, flooding of roads in the climate change scenarios could cause disruption to national roads.

2.2.3 Oughterard

Oughterard is part of the Corrib SAC. The features of interest and conservation objectives of these European designations are likely to require a full Natura Impact Statement as part of the Appropriate Assessment for projects or plans. All structural and some non-structural flood management methods are likely to have impacts through surface water, land & air and groundwater pathways.

On a local scale Oughterard has a number of properties effected during flood events.

Access to Scoil Naomh Pól, a key location facility for the town is affected by flooding. Whilst, the School itself is not subject to any inundation the surrounding area is flooded during events preventing access.

2.3 Spatial Scales of Assessment

2.3.1 Unit of Management Spatial Scale

There are multiple AFAs within the Corrib Unit of Management. Non-structural methods such as planning and development control, SuDs, targeted public awareness campaigns and development of emergency plans will be assessed at the UoM scale in cooperation with the relevant authorities.

2.3.2 Sub-Catchment Spatial Scale – Corrib

Oughterard is located on the Owenriff which discharges into Lough Corrib. Galway City AFA is situated at the mouth of the Corrib and subject to fluvial flooding. However, the 1% AEP discharge from the Owenriff is a tenth of the flow reaching Galway, which is heavily regulated by sluices at the bottom of Lough Corrib.

Any methods in Oughterard are unlikely to have any significant effect on method in the Galway City AFA.

2.3.3 AFA Spatial Scale - Oughterard

Localised structural methods will be assessed on an AFA scale. This will include analysing the suitability of flood containment methods. Any containment methods in Oughterard will not have an effect on water levels in other AFAs due to its secluded location within the Corrib catchment. Any flood method within the town is likely to impact on the SAC.

3 Screening of Possible Methods and Options

3.1 Introduction

A flood risk management option consists of one or more combinations of flood risk management methods; a method being one distinct approach to flood risk management in a specific location such as a flood wall or flood warning system. Flood risk management options consist of all methods required to deliver mitigation at the relevant spatial scale.

This section provides an overview of the screening of all possible flood methods to arrive at a suite of viable methods. The purpose of the screening process is to filter out methods that are not acceptable or viable either alone or in combination with other methods, for the SSA under consideration.

3.2 Existing Scenario

To analyse the impact of flood management methods it is first necessary to assess the existing scenario. Currently there is no flood forecasting or warning system in Oughterard.

Flood hazard maps have been produced that show the 'Risk to Life'. These indicate the level of risk to human life based on depth and velocity. Figure 3-1 and Figure 3-2 indicates the risk levels in Oughterard in the current and the future scenario. Where the Owenriff flood from extreme lake levels the risk levels are classified as significant danger to most. Where property is flooded the risk level is relatively low with areas of moderately dangerous for some.

Figure 3-1: Risk to Life (Current)

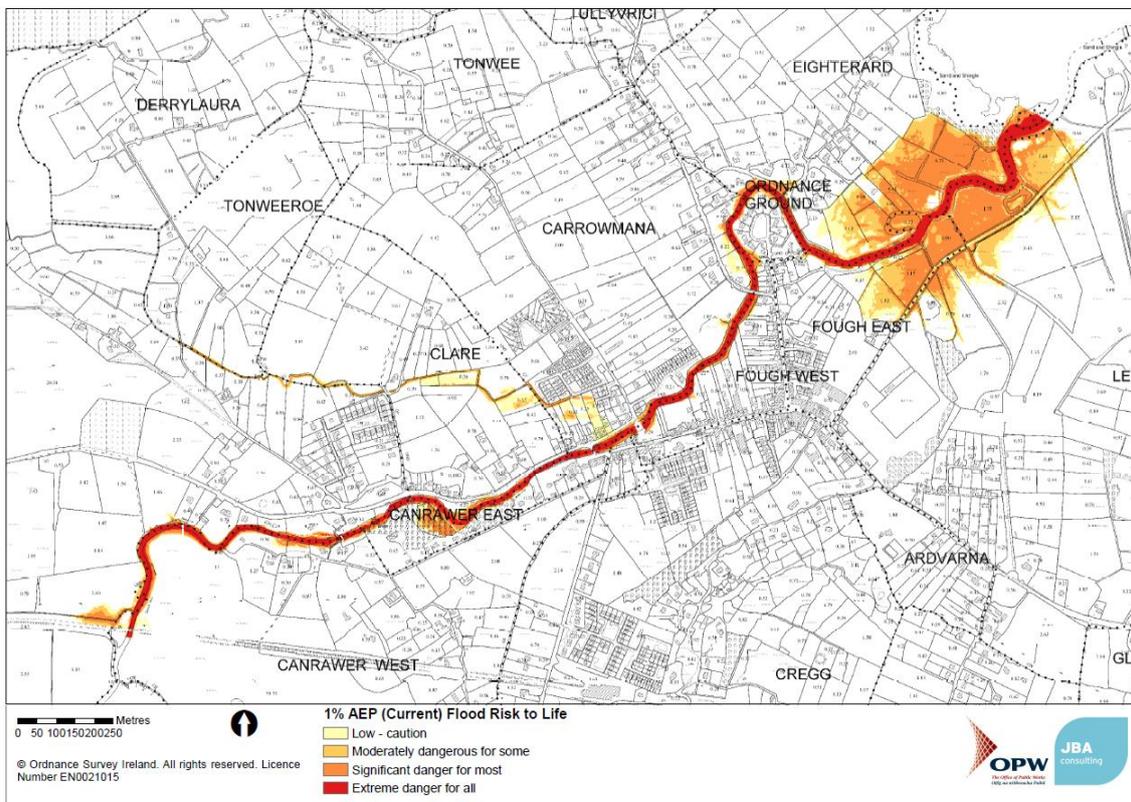
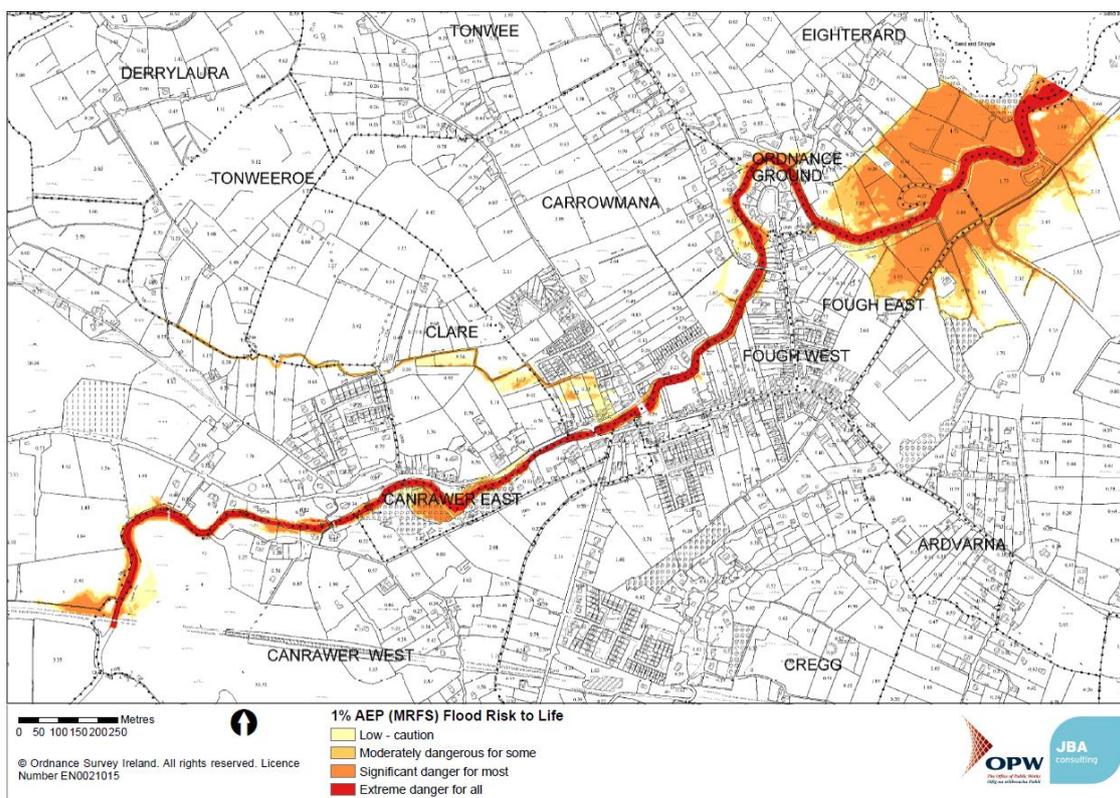


Figure 3-2: Risk to Life (MRFS)



3.3 Screening of Possible Flood Risk Management Methods

The objective of the screening process is to develop a long list of technically feasible and economically viable methods to feed into the option identification stage. Options have only been discounted at this stage on technical or economic grounds, however, the process has also required social and environmental constraints identified as part of the work to be recorded to support the further development of options and the SEA process.

Details of the cost estimates are provided in Appendix B and an overview of the screening considerations for environmental and social constraints is provided in Appendix C.

Information was recorded under the following criteria as follows:

- **Technical** - Methods were screened on feasibility only, requiring a high level description of what the likely method would entail. Where methods were not considered to be technically feasible or not relevant to the site no further consideration has been given.
- **Economic** - Technically feasible methods have been reviewed for economic viability. As noted previously, approximate benefits associated with the 1% AEP event are €12,263 so any standalone methods or combination of methods will be required to cost less than this, assuming a benefit cost ratio of 1:1.
- **Health and Safety** - The degree of health and safety risk during construction and operation was assessed at a level appropriate to the screening stage. Risks have been recorded for future reference, however if the risk could not be managed or mitigated then the method was screened out.
- **Environmental** - The environmental screening has made use of the SEA scoping report and has taken into account the key environmental constraints noted in Section 2.2. Methods may be rejected on the basis that a measure may have a detrimental impact on an environmentally or culturally valuable or protected site, and may need to complete the costly IROPI process to proceed.

Table 3-1 shows the results of the screening process for each method considered. A method can Pass (P) or Fail (F) the above criteria. A method must pass all four criteria to be considered viable. The below criteria were also considered at the screening stage however methods were not rejected based on these criteria but the key constraints were noted.

- **Social and Cultural** - Again methods were not rejected based on social and cultural constraints at the screening stage however the constraints were noted.
- **Adaptability to Climate Change** - The likely impacts of climate change have been assessed at an early stage to determine the suitability of identifying methods based on current flood risk. Where there is a significant increase in flood risk in the future, methods will need to be reviewed in light of this risk.

Oughterard is not significantly affected by the effects of climate change. The estimated benefits increase from €12,263 in the current scenario to €34,404 in MRFS Scenario.

Only structural methods have been screened. Non-structural methods such as planning and development control, SuDs, targeted public awareness campaigns and development of emergency plans will be assessed at the UoM scale and are detailed in the overarching UoM Report with issues relevant to this AFA discussed in Section 4.

Table 3-1: FRM Method Screening

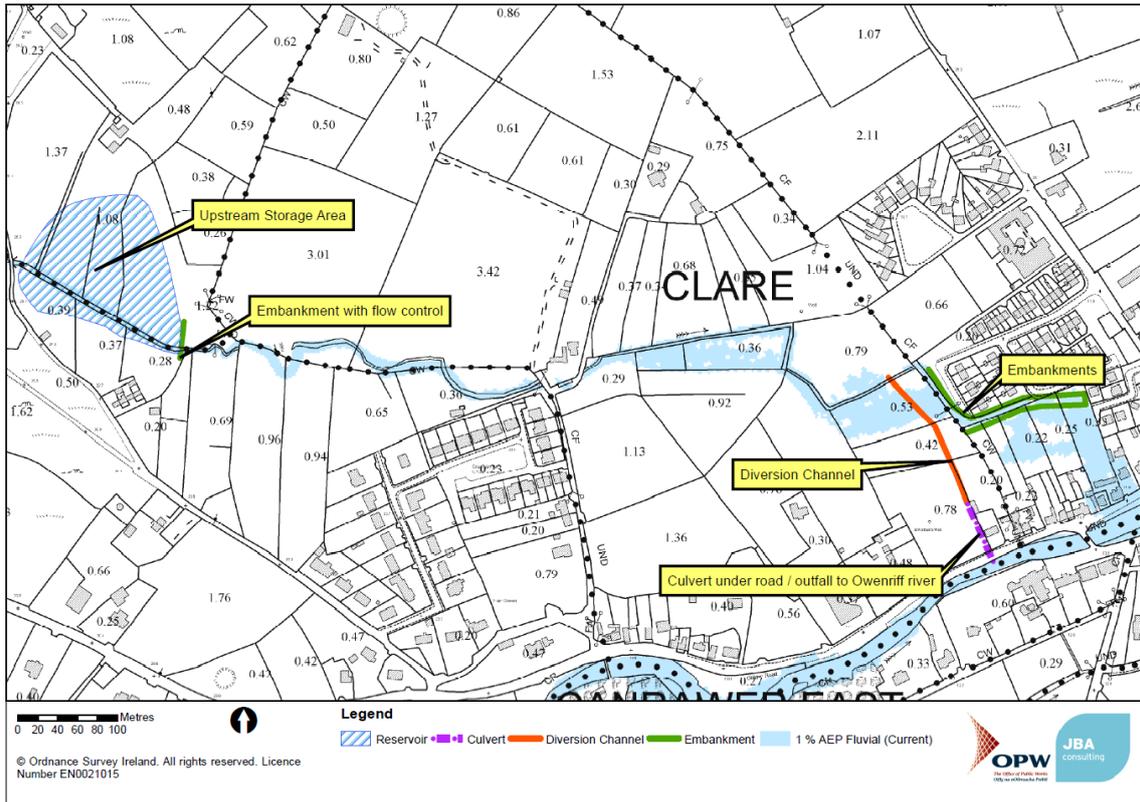
Possible Flood Risk Management Method	Technical	Economic	Health and Safety	Initial Screening Result	Comment
Do Existing	Pass	Pass	Pass	Viable	The risk maps show a low risk to life within the flood cell of interest. This in conjunction with the relatively low frequency of flooding of properties suggests there is no an immediate risk to life in this area. This may change if blockage of the culvert structure is considered in detail.
Fluvial Methods					
Storage Options	Pass	Fail	-	Not Viable	There is a possible upstream storage location on the Tonweeroe to mitigate flooding. The storage area can contain a flood volume to reduce flow sufficiently that the downstream culvert is able to convey the method would require a 70m long 3m high embankment to act as a dam and a Hydro-Brake to control outflow. A storage volume of 12,000m ³ is required for this method. The estimated total cost of €156,727 (Appendix B.1)
Flow Diversion	Pass	Fail	-	Viable	A flow diversion channel can be formed linking the Tonweeroe to the Owenriff. This would run for 130m adjacent to the rugby pitch requiring approximately 520m ³ of excavation and a 85m length of culvert at the downstream end. The Owenriff is a designated SAC and a known fresh water pearl mussel habitat. Any potential impact from this option will need to be mitigated. The estimated cost for this scheme is €476,631 (Appendix B.2)
Increased Conveyance - Dredging/Widening and Straightening	Fail	-	-	Not Viable	This is not a technically viable options due the number of culverts which would still control the conveyance. Increasing conveyance by increasing culvert capacity is discussed below.
Increased Conveyance - Removal of Local Obstructions	-	-	-	Not Applicable	There are no local obstructions with the exception of the long culvert, which is discussed below.
Upgrade Culvert Capacity	Pass	Fail	-	Not Viable	The existing culvert runs under or adjacent to properties and it would be unfeasible to upgrade without large cost implications.
Flood Containment Methods					
Rehabilitation of Existing Walls	-	-	-	Not Applicable	Not applicable there is currently no walls in the areas to be rehabilitated.
Walls	Pass	Fail	-	Not Viable	Generally, there is the space for embankments, however, the pinch point at the inlet of the culvert would require a wall rather than embankments. Due to cost implications it has been costed as an embankment for all but this short 30m reach as discussed below.
Embankments	Pass	Fail	-	Not Viable	This method would require a 320m long embankment to contain the flow. A stretch of 30m at a

					pinch point would require a wall as there is not enough room for an embankment. The estimated cost of this would be €224,372 (Appendix B.3) and as such this is not economically viable. The alignment of the embankment serves two functions, firstly to contain flow and second increases the head on the culvert thus increasing its conveying capacity.
Demountable Walls	Fail	-	-	Not Viable	Demountable walls can only be provided in conjunction with a flood forecasting systems which is not viable.
Road Raising	-	-	-	Not Viable	Not applicable there is currently no roads in the areas to be raised.
Individual Property Protection Methods					
Relocation of Properties	-	-	-	Not Applicable	The relocation of properties is highly stressful for property owners and should be considered where there are no clear viable alternatives. This is not the case in Oughterard and as such this method has not been considered.

3.4 Findings of the screening assessment

The screening assessment has found no economically viable structural methods for Oughterard. The options assessed are presented in Figure 3-3.

Figure 3-3: Locations of flood mitigation methods



	Option 1	Option 2	Option 3	Option 4
Present day	<p>Do Existing - Targeted Public Awareness</p> <p>This option would raise awareness of flood risk to affected properties only with no further methods implemented.</p>	<p>Upstream Storage</p> <p>This option would involve creating an upstream storage area by the construction of a storage embankment and hydrobrake.</p>	<p>Flow Diversion Channel</p> <p>This option will create a 200m bypass channel from the Tonweeroe to the Owenriff.</p>	<p>Embankment / Walls</p> <p>A 320m embankment and 30m (1.2high) wall to cut off the flow routes to the properties</p>
In the future	<p>This option would not negatively impact on potential future methods and monitoring flood risk in the future will allow alternative management methods to be developed if required.</p>	<p>This option will provide partial benefit in the future even if designed to current design standard. However, such a scheme should be designed with climate change in mind as the additional costs would be significantly less than adapting an adaptable approach. The current embankment is considerably high at 3m and may not be adaptable.</p>	<p>This option will provide partial benefit in the future even if designed to current design standard. However, such a scheme should be designed with climate change in mind as the additional costs would be significantly less than adapting an adaptable approach.</p>	<p>Currently, the defence height is only 1-1.2m and could be extended to accommodate climate change flows.</p>
Conclusions	<p>This option does not provide a standard of protection but will encourage residents to live with the flood risk. Because of the short response times in the catchment permanent resilience methods will need to be adopted by the owners. Low flooding depths mean there could be a range of options available.</p>	<p>This option will provide the 1% AEP design standard of protection but future increases in design standard may not be justifiable.</p>	<p>The Owenriff is a designated SAC and a fresh water pearl mussel habit an AA screening will be required to mitigate any environmental impact</p>	<p>This option will provide the 1% AEP design standard of protection and is easily adaptable to climate change.</p>
Cost	Not applicable	€156,727	€476,631	€224,370
BCR	Not applicable	0.08	0.03	0.05

A breakdown of the estimated costs for the options for Oughterard is presented in Table 3-2. It is noted that for the screening stage, the additional cost allowances only included optimism bias, maintenance and preliminaries to reduce the risk of omitting potentially cost beneficial options at this stage. Full details of the assumptions made in the cost estimates are provided in Appendix A. Individual method costs are detailed in Appendix B.

Table 3-2: Indicative screening costs

Option 1- Do Existing		€
Do Existing - No Costs Involved		
Option 2- Upstream Storage		€
Construction costs		
Rural clay embankment		45,251
Hydrobrake		30,820
Construction costs - Subtotal		76,071
Preliminaries	32%	24,343
Capital costs - Subtotal		100,414
Optimism Bias	50%	50,207
Capital costs - Total		150,621
Operation and maintenance net present value		
Embankment O&M Cost; average estimates		4,071
Operation and maintenance - Subtotal		4,071
Optimism Bias	50%	2,036
Operation and maintenance costs - Total		6,107
Option cost for cost benefit analysis		156,727
Option 3 - Flow Diversion		€
Construction costs		
Culvert Under Road (85m)		193,800
Headwall		16,579
Excavation of New Channel		10,577
Construction costs - Subtotal		220,956
Preliminaries	20%	44,191
Capital costs - Subtotal		265,147
Optimism Bias	50%	132,574
Capital costs - Total		397,721
Operation and maintenance net present value		
Culvert maintenance; average estimates		41,509
Channel Maintenance;		11,098
Operation and maintenance - Subtotal		52,607
Optimism Bias	50%	26,304
Operation and maintenance costs - Total		78,911
Option cost for cost benefit analysis		476,631
Option 4 - Walls and Embankments		€
Construction costs		
Wall (30m - 1.0m high)		49,093
Embankment 320m - 1m high		49,970
Construction costs - Subtotal		99,063
Preliminaries	32%	31,700
Capital costs - Subtotal		130,763
Optimism Bias	50%	65,382
Capital costs - Total		196,145
Operation and maintenance net present value		
Wall (30m - 1.0m high)		208
Embankment 320m - 1m high		18,610
Operation and maintenance - Subtotal		18,818
Optimism Bias	50%	9,409
Operation and maintenance costs - Total		28,227
Option cost for cost benefit analysis		224,372

None of the identified methods qualify for funding as part of the national CFRAM programme as they have a benefit cost ratio of less than 1.

In the interim non-structural methods can provide a reduction to risk and damages for the area. These are discussed in detail in Section 4.

3.5 Stakeholder engagement

Throughout this process, the OPW regional engineers and local authority engineers have been consulted in the form of steering group, progress group and engineer meetings and their input has feed into the preliminary option stage.

Public Consultation Day (PCD)

On 30th of June 2015, a public consultation was held at The Couthouse, Oughterard, to outline possible methods for the town.

This PCD was attended by 15 people. At the PCD, attendees were invited to provide feedback, in the form of a questionnaire. The questionnaire sought opinion on the public's attitude to some of the types of methods being explored for the town. A detailed report on the PCD has been prepared. This report details all responses received on the day. Table 3-3 outlines the main concerns and how they have been incorporated into the POR stage by the study team. Positive feedback in general, a number of residents concerned about insurance, in general there was good agreement with flood maps and extent of flood risk shown.

The diversion channel appeared to be the preferred method.

Table 3-3: PCD feedback

Comments received	Study response
<p>There are a number of underground rivers in the area. In particular, in the vicinity of the downstream section of the Tonweeroe Stream. It is reported that not all of the water in the Tonweeroe Stream enters the culvert at the downstream end but some of this stream disappears underground upstream of the council estate and it is thought to re-emerge further downstream in un-developed land to the east before re-entering the Owenriff River. Anecdotal evidence states that flooding occurs from this underground stream at the council estate on a regular basis; flooding occurred during construction and one local saw photos showing floodwater flowing out the window of a house.</p>	<p>This is a ground water issue and beyond the scope of this Study. The issue has been raised with the OPW.</p>
<p>Locals regularly remove rubbish and debris from the Tonweeroe upstream of the culvert to help reduce the risk of flooding to their properties. Previous plans were proposed to alleviate flooding in this area by the provision of a piped diversion through land to the west adjacent to the old shop, however ultimately the works did not go ahead as the shopkeeper was opposed to the proposal to lay a smaller capacity (12 inch) pipe to take water under the N59 and discharge into the Owenriff</p>	<p>The blockage of the downstream culverts has been highlighted in this study and a rigorous maintenance regime for same has been proposed.</p>
<p>Significant previous flooding was reported in the Carnrower area to the south of the river (9 inches of internal flooding).</p>	<p>This is a ground water issue and beyond the scope of this Study. The issue has been raised with the OPW.</p>

4 Non-structural methods

Non-structural flood risk management methods are proven methods and techniques for reducing flood risk and flood damages incurred within towns. Besides being very effective for both short and long term flood risk and flood damage reduction, non-structural methods can be very cost effective when compared to structural methods. A particular advantage of non-structural method when compared to structural methods is the ability of non-structural methods to be sustainable over the long term with minimal costs for operation, maintenance, repair, rehabilitation, and replacement.

Full discussions on non-structural methods has been discussed in overarching UoM preliminary options report. The section provides a bit more detail on these methods and how they could be implemented, either as standalone or in conjunction with a structural flood relief scheme in Oughterard.

<p>Non-structural methods</p> <p>Planning development and control</p> <p>Spatial planning and impacts on development</p> <p>Oughterard falls within the Galway County Development Plan. Oughterard is classified as "other villages" in the Galway County Development Plan 2015-2021. The status of the Oughterard Local Area Plan 2006-2012 is "to be commenced". The LAP for Oughterard pre-dates the publication of the Planning Guidelines on Flood Risk Management, so makes no reference to flooding and does not include an SFRA.</p> <p>Flood Zones A and B cover land zoned for development to the north of Oughterard. An SFRA should assess the level of risk to these sites and recommend changes to land zoning objectives.</p> <p>Further detail on flood risk and land zoning objectives under both current and future scenarios is provided in Section 5 of the UoM30 Overarching Report.</p> <p>Sustainable Drainage Systems</p> <p>Having reviewed the potential for various types of SuDS in Oughterard and it indicates there is a high potential for infiltration within the town.</p> <p>Development within Oughterard is likely to be of low density and so attenuation of surface water runoff is likely to be able to be achieved within each individual development site boundary. Should large scale development proposals be expected then regional SuDs infiltration and attenuation features should be considered.</p> <p>More detail on the applicability of SuDS in Oughterard, and indicative storage volumes, are provided in Section 6 of the UoM30 Overarching Report</p> <p>Flood preparedness methods</p> <p>Flood forecasting and warning systems</p> <p>Flood forecasting potential has been assessed for Oughterard. Given the current risk is on the Tonweeroe stream, which has a catchment of less the 5km² it is not possible to attain the advance warning period and accuracy level required and is therefore un viable.</p> <p>More detail on the applicability of flood forecasting in Oughterard is provided in Section 7 of the UoM30 Overarching Report</p> <p>Emergency response planning</p> <p>Until such time as a scheme is built in Oughterard, the existing risk to life will remain unless a flood response plan can ensure necessary actions are taken and all vulnerable residents can be safely evacuated and accommodated, if necessary. Well prepared and executed emergency plans can significantly reduce the impact of flood events. Galway County Council has produced a Major Emergency Plan, which incorporates a "Flooding Sub Plan and should be implemented by Galway County Council in times of flood emergency.</p> <p>Targeted public awareness</p> <p>Individuals and communities that are aware of any prevalent flood risk are able to prepare for flood events such that is and when such events occur, people are able to take appropriate actions in advance of, during and after a flood to reduce the harm and damages a flood can cause. There has been limited attendance to both the flood mapping and POR Public Consultation Days (PCD) in the town, with 18 and 15 people in attendance respectively; Public awareness through education schemes or increased awareness by the relevant authorities is needed to ensure that the residents of the area are aware of the risk.</p>

Individual property resilience

Resilience method may be suitable for properties vulnerable to repeated flooding where the depth of flooding exceeds 600 mm (CIRIA 2007). When floodwater exceeds this level it may be more appropriate to allow water into a property, preventing possible structural damage to walls in a way that limits the potential damage, cost, disruption and ultimately the time that a property is uninhabitable. In Oughterard current flood depths in the 1%AEP are less than 300mm so individual property protection would be more applicable than resilience methods.

Individual property protection

Flood resistance, or dry proofing, techniques prevent floodwater from entering a building. This approach includes, for example, using flood barriers across doorways, airbricks and raised floor levels. Household flood resistance methods aim to prevent floodwaters from entering a building structure. Individual Property Protection methods may be appropriate in areas that frequently flood to shallow depths, and where community-scale defences are unlikely to be a viable option. In Oughterard, individual property protection to the 4 residential within the 1% AEP extent have estimated depths of less than 600mm. Individual property protection to this site should be considered. Properties along the N59 upstream of Oughterard bridge flood in events larger than the 1% AEP and would also benefit from individual property protection and resilience methods.

Maintenance

Both the Owenriff and Tonweeroe watercourse are part of the Corrib-Headford arterial drainage scheme. Under the 1945 the OPW has responsibility to maintain the scheme.

The likelihood of blockage to the culvert passing beneath the housing estate on the Tonweeroe river has been highlighted. Existing low capacity of the structure and a poorly designed trash screen on the upstream face likely results in blockage if not maintained. Feedback received at the PCD indicated that the residents regularly remove debris from the channel. A rigorous maintenance regime is required along with upgrading of the trash screen to one which is adequately designed and allows access for maintenance.

5 Conclusion

The hydraulic modelling demonstrated that there is flood risk to properties in Oughterard due to the lack of culvert capacity at the downstream extent of Towenree watercourse. All identified methods have a benefit cost ratio of less than 1 meaning they will not qualify for funding as part of the national CFRAM programme. For this reason, no further work has been undertaken investigating a preferred option. In the case of Oughterard, the proposed methods are technically viable and if funding is identified from alternative sources then it is recommended further consideration be given to the methods discussed to mitigate flood risk.

Possible non-structural methods have been discussed which are proven methods and techniques for reducing flood risk and flood damages incurred and should be utilised as viable methods to reduce risk and should be used in conjunction with any scheme that is built in the future.

A Economic appraisal of methods and options

A.1 Overview

The economic appraisal of a method or option is based on the assumption that the cost of implementing a method should not exceed the benefit associated with the reduction in flood risk following the implementation of that method. The cost of implementing a method reflects the costs of construction and whole life costs arising from maintenance. The benefits associated with the reduction in flood risk as a result of a method are discussed in detail in this Section.

For each AFA with a technically viable method or set of methods, the following economic appraisal has been carried out. Where there are no technically viable methods, economic appraisal has not been undertaken.

The starting point for determining the benefits of a flood relief scheme is to identify the tangible costs associated with a flood event, or those costs which would be removed if a flood relief scheme were put in place. The tangible costs are those factors for which there is a clear monetary cost resulting from a flood. These costs can be split in to direct and indirect costs. Direct costs are the damages incurred to property as a result of a flood. Indirect costs are costs incurred as a result of a flood other than direct damages, for example the rental costs of temporary accommodation or the costs associated with a flood event response by the emergency services.

There are also intangible costs associated with a flood event. These represent the human impacts on an event such as anxiety, stress and ill health.

The total economic costs associated with a flood event are assumed to equal the total of the tangible and intangible costs. The methodology for calculating these costs is set out in the following sections.

Having established the potential benefits of a method or option, the viability of selected methods is dependent on the likely costs of construction and long term maintenance compared to the benefits.

Indicative costs have been calculated as part of the screening assessment where the screening assessment confirmed an economically viable option was available, the costs have been refined as part of the full scheme development costings. In both cases, costs have been determined using the unit cost database.

The unit cost database has been used to maintain consistency in estimated costs of construction and maintenance of methods nationwide under the CFRAM project.

The screening cost estimate consists of construction costs, associated preliminaries, operation and maintenance costs and an allowance for optimism bias. The final option costs also include additional allowances detailed design, archaeology, land compensation and art.

The following section step through the process of calculating benefits (Sections A.2 to A.5) and costs (Section A.6). The costing summary sheet for all technically viable options is provided in Appendix B.

A.2 Direct flood damages

A.2.1 Source data

Economic flood damages have been estimated using the data and general methodologies outlined in 'The Benefits of Flood and Coastal Risk Management: A Handbook of Assessment Techniques 2010), which is often referred to as the 'Multi-Coloured Manual' (MCM). This manual provides depth damage curves for different types of residential and commercial properties compiled from historical data of damages incurred in past flood events. By extracting the flood depths for affected properties from WCFRAM hydraulic modelling outputs the total damages in a given flood event can be determined.

Property types have been derived from the An Post geodirectory. The An Post directory assigns one of four codes to each of the property points to indicate the property type. These are R – residential, C – commercial, B – both and U – Unknown. A review of property points assigned a

B code confirms it is generally the commercial property on the ground floor and so, subject to flood risk, residential costs in these instances have been removed.

Residential properties are further categorised in the geodirectory into detached, semi-detached, terraced, duplex and bungalow. Unknown (U code) properties were found to include a description of the property type (detached, semi-detached etc.) and so were assumed to be residential.

Commercial properties in the geodirectory have a NACE code assigned; this is a European equivalent to the MCM codes but not directly comparable. To facilitate the analysis, each NACE code has been attributed an equivalent MCM code and so each commercial property attributed an appropriate MCM code. Where a NACE code was not available an appropriate MCM code has been determined based on knowledge of the town.

Property floor areas were extracted from OSi data and geographically linked to the An Post data. Where multiple An Post points existed within the same building polygon it was assumed the building footprint was divided equally between points. Where An Post data did not coincide with a building polygon a footprint area of zero was applied and hence no damages will be calculated for these points.

Property threshold levels are assumed to be equivalent to the mean LiDAR level over the buildings' footprint polygon plus a typical observed threshold level for the area.

A.2.2 Methodology

The depth damage curves used in the analysis for residential properties are based on the type of property described above only, i.e. detached, semi-detached etc. Where this data was not available a residential average was applied. Damage curves have been further selected based on local conditions such as whether the event had a short or long duration, defined as less than or greater than 12 hours, or whether salt water damage should be considered, as would be the case for tidal flooding. For residential properties damages begin at -0.3m to allow for damage to foundations.

In some AFAs, properties are affected by both fluvial and coastal flooding. However, hydraulic modelling has demonstrated that there is no joint probability risk from the two sources, so damages from each source can be treated independently. Once calculated for each individual source the total direct damage to an individual property is the sum of the damages from the two sources.

Prices (damage costs) in the data provided by FHRC 2010 have been converted to euro rates applicable to Ireland in 2013 (the reference date set by the OPW to allow a consistent comparison of findings across all CFRAMs) by:

- Applying a 'PPP' multiplication factor of 1.279. This is derived from the relative OECD Purchasing Price Parity values for the UK and for Ireland for 2010. The 'PPP' factor is net of currency conversion (i.e., already includes for exchange rates as well as price differences, and so no currency conversion rate should be applied in addition to this factor)
- Applying an inflation multiplication factor of 1.051. This is derived from inflation rates based on the CPI in Ireland for the period 2010 - 2013

Economic damages to infrastructural utility assets (e.g. electrical sub-stations, gas installations and pipe-work, telecommunications assets, etc.) are assumed to be 20% of total direct damages to properties for the AFA.

A.3 Intangible and indirect damages

Flood events can cause significant stress, anxiety and ill health to potentially affected people, during and then after a flood. Individuals generally also incur some costs due to their properties flooding that are not directly related to damage, such as evacuation, temporary accommodation, loss of earnings, increased travel and shopping costs, etc.

For residential properties the intangible and indirect flood damages shall together be set equal to the total direct property damages as calculated above.

Costs attributable to emergency services (which includes evacuation costs) are assumed to be equivalent to 8.1% of the total direct property damages. This value was derived as an average of the measured emergency services costs for the 2000 and 2007 floods in the UK.

Traffic disruption has not been included in the assessment of damages. Traffic disruption historically makes up a small percentage of damages and was not included at this strategic level.

A.4 Calculation of Annual Average Damage (AAD) and Present Value of damages (PVd)

A.4.3 Discount rate and project horizon

Given a choice between receiving a specific sum now and the same amount sometime later, most people will express a preference for the present sum. The tangible benefits accruing from a flood alleviation scheme will not provide cash sums to the beneficiaries; however, they will prevent a negative cash flow (avoidance of associated flooding costs) from the individuals.

The avoidance of fixed negative cash flow now is also preferable to avoidance sometime in the future. The “social time preference” (STP) can be measured by an appropriate Discount Rate (STPDR) and is taken as the compound rate of interest ‘r’ (% per annum) by which ‘y’ Euros in ‘x’ years’ time is equal to one euro now.

The benefits arising from a flood relief scheme commence on the completion of the scheme and exist for the life of the works. To obtain a method of the overall benefit in present day monetary values, it is necessary to:

- (a) Estimate the benefit arising each year of the project life, termed the Average Annual Damages (AAD)
- (b) Discount the AAD to present values using the appropriate discount rate.
- (c) Total the present values to obtain the overall benefit.

The Department of Finance's discount rate for public investment is 4%. The lifetime over which the benefits are discounted is taken as 50 years. For computation purposes, it is assumed that the residual value of the scheme at the end of the period is nil. This may be regarded as somewhat conservative, since works typically have a design life of 100 years.

A.4.4 Property capping assumptions

The present value damages for any given property should not exceed its current valuation. This is to prevent justification for a flood mitigation scheme being based on the repeated flooding of a property over the project life when it would be more cost beneficial to simply buy out the property. Estimated property values have been determined for both residential and commercial properties.

Residential Properties

Average prices for apartments, bungalows, detached, semi-detached and terrace properties were derived for each AFA as there was considerable difference in property values across all AFAs. The data was extracted from www.lpt.revenue.ie. The final capping value was set at twice the market value to allow for intangible damages.

Figure A-1: Residential capping assumptions

Area of further assessment (AFA)	Property type					Electoral district
	Apartment/Flat	Bungalow	Detached	Semi-Detached	Terraced	
Corrofin	150,000.00	150,000.00	150,000.00	150,000.00	100,000.00	Corrofin
Galway City (1)	150,000.00	200,000.00	250,000.00	200,000.00	150,000.00	Menlough
Galway City (2)	200,000.00	200,000.00	250,000.00	200,000.00	200,000.00	Dangan
Galway City (3)	150,000.00	150,000.00	150,000.00	150,000.00	150,000.00	St. Nicholas
Galway City (4)	150,000.00	200,000.00	200,000.00	200,000.00	200,000.00	Nun's Island
Galway City (5)	200,000.00	250,000.00	300,000.00	250,000.00	200,000.00	Claddagh
Galway City (6)	150,000.00	150,000.00	250,000.00	250,000.00	200,000.00	Eyre Square
Galway City (7)	150,000.00	150,000.00	200,000.00	150,000.00	150,000.00	Castlegar
Galway City (8)	150,000.00	200,000.00	250,000.00	200,000.00	200,000.00	Lough Atalia
Galway City (9)	200,000.00	200,000.00	250,000.00	250,000.00	200,000.00	Salthill
Oughterard	150,000.00	150,000.00	200,000.00	150,000.00	150,000.00	Oughterard
Ballyhaunis	100,000.00	150,000.00	150,000.00	150,000.00	100,000.00	Ballyhaunis
Tuam	150,000.00	150,000.00	150,000.00	150,000.00	100,000.00	Tuam Urban

Non Residential Properties

Average commercial property values have proved to be difficult to pinpoint. The high level approach outlined within the MCM is to estimate values as a factor of 10 greater than the rateable value, broadly defined as the annual rental value of the property. However, average commercial rental values are not widely available. Commercial rateable values were provided by the relevant county councils but these values are not equivalent to the rental value of the property and are not suitable for determining capping values. The Ireland Valuation Office is currently going through a revaluation process owing to the poor correlation between the rental value of properties and the rateable value but this information is not available for the west of Ireland.

Rateable values for all properties have been obtained from the April 2008 values for South West England from 'Commercial and Industrial Floor space and Rateable Value Statistics' (<https://www.gov.uk/government/statistical-data-sets/live-tables-on-commercial-and-industrial-floorspace-and-rateable-value-statistics>) as instructed by the OPW. These UK rateable values have been multiplied by the "PPP" multiplication factor of 1.279 and uplifted by the inflation multiplication factor of 1.051 resulting in the following euro rates. Non-residential properties were capped at 10 times the below rateable income.

Table A-4: Rateable incomes for non-residential properties

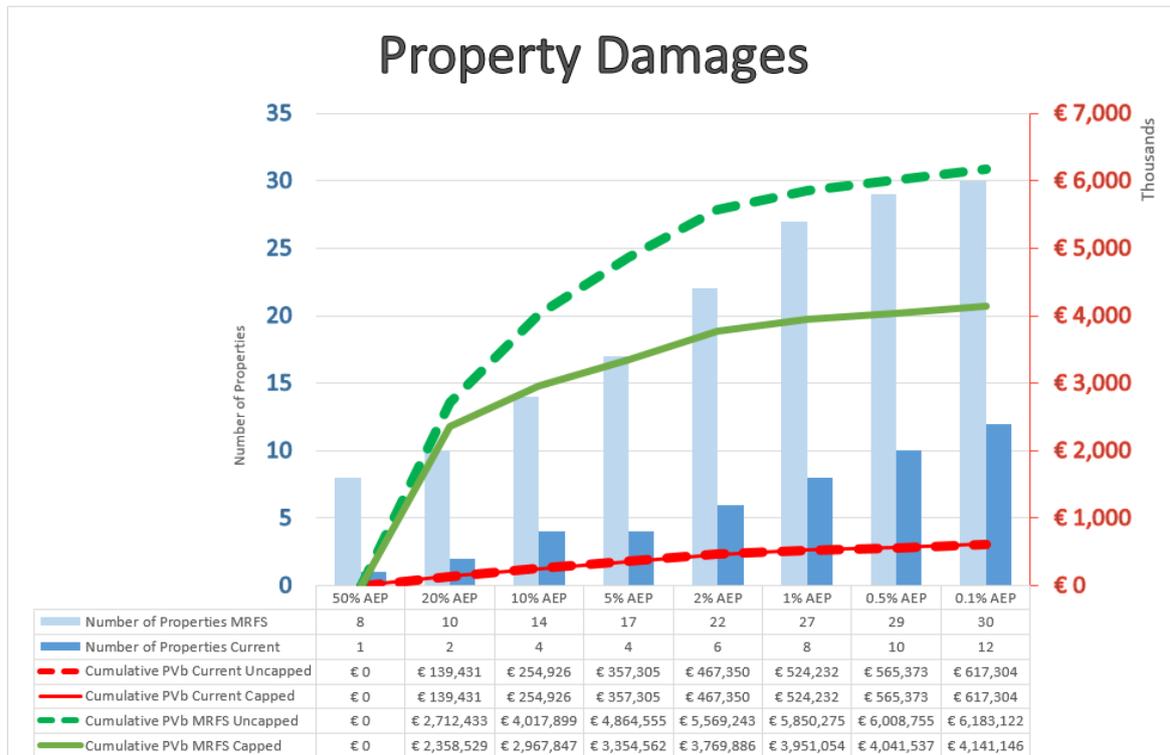
Property type	Rateable value per m ² (€)
Retail	161
Office	115
Warehouse	51
Leisure & Public	37
Industry	41

A.5 Benefit analysis

Using JBA's custom software package, FRISM, flood depths have been extracted and damages determined for each property for each of the eight defined design event probabilities. The Annual Average Damage (AAD) has then been calculated as the probability weighted sum of the damage values of each event up to and including the 0.1% AEP event. The Average Annual Damage, discounted at a rate of 4% per annum over a time-horizon of 50 years, produces the Net Present Value of the potential flood damage. An example of calculated damages is shown in Figure A-2.

It should be noted that, in the example shown in Figure A-2, the current and MRFS damages are both less than the equivalent capped damages, indicating that the value of residential and commercial properties has not impacted on the damages attributable to flood events.

Figure A-2: Damage calculation result (Sample)



The damages calculated using this method have been applied for both the verification screening and detailed options development stages of assessment.

A.6 Screening cost estimates

For each technically viable method identified as part of the screening assessment a cost estimate is provided in the relevant AFA report. An example breakdown of estimated costs for the screening assessment is shown in Table A-5 and details of the constituent parts provided in the following sections.

Table A-5: Screening costs (Sample)

Option 1- Do Existing		€	€
Do Existing - No Cost Involved			
Option 2		€	€
Construction of retaining wall at Town Property and embankments to protect main street and isolated property			
Retaining wall at Town Property			78,175
Embankment to the rear of properties on main street			7,626
Embankment at isolated property			15,253
Preliminaries	32%		32,337
Sub - Total			133,391
Optimism Bias	50%		66,696
Construction costs (Excl VAT)			200,087
Est. NPV Operation and Maintenance (Walls)		214	
Est. NPV Operation and Maintenance (Embankment Main Street)		5,864	
Est. NPV Operation and Maintenance (Embankment - isolated property)		5,864	
Optimism Bias	32%	3,821	15,763
Indicative Screening Cost			215,850

A.6.5 Construction costs

Construction costs were estimated based on typical unit and item costs (e.g. cost per metre length of reinforced concrete wall of given height, or cost of a pump of certain capacity) as set out by the unit cost database. Details of which unit and option cost have been applied are provided within the relevant AFAs reports. Summing the construction unit cost of the methods gives the Gross Capital Construction Cost.

A.6.6 Preliminaries

Preliminaries and other construction costs include the following items:

- Compound
- Site cabins and services
- Temporary power and generators
- Protection to overhead services
- Protection to underground services
- Road sweeping of public roads
- Preparation of as constructed drawings
- Health and safety
- Security
- Wheel wash provision at exits to public roads
- Manual washing prior to vehicles existing to public roads
- Supervision
- Setting out
- Mobilisation and demobilise
- Insurance

A relationship between the cost of preliminaries and the construction costs of a given scheme has been determined and is shown in Table A-6.

Table A-6: Preliminaries cost curve

Construction cost:	€100k	€250k	€500k	€1m	€2m	€5m	€10m	€15m
Total Preliminaries	€32k	€51k	€89k	€199k	€330k	€512k	€743k	€932k
Preliminaries as a % of total	32%	20%	18%	20%	16%	10%	7%	6%

In addition to the above, each of the separate unit costs includes an estimate of some of the additional preliminaries, such as temporary works, environmental mitigation and temporary flow controls. The temporary works costs are based on what would be required on all sites but are not intended to be definitive for all possible eventualities. Where non-standard, difficult or additional temporary works are deemed likely to apply the allowance for preliminaries in the individual method cost may be increased.

A.6.7 Operation and maintenance

Whole life cost estimation needs to identify all activities that constitute flood defence management practice e.g. inspection, vegetation management, repair, operations, incident management, general administration and regulatory activities. Operational costs may include annual maintenance as well as intermittent costs if relevant and proportional and data is available.

Operational costs are assumed to continue for the design life of the scheme. Present value costs for operation and maintenance have been determined using the same methodology set out in Section A.4.3, that is assuming a design life of the scheme of 50 years and a discount rate of 4%.

A.6.8 Optimism bias tool

There is a demonstrated, systematic, tendency for project appraisers to be overly optimistic when developing costs estimates for capital works. The aim of adding an optimism bias is to allow a contingency on these estimates to cater for unknowns and help ensure project promoters retain adequate project budget.

Different magnitudes of uplift or optimism bias are applied at different stages of the appraisal process. For example, a higher optimism bias is expected at the start of a project where there are a lot of unknowns, this optimism bias would expect to be reduced once detailed design has been completed and site conditions are better understood and approaches to manage risks have been identified or the additional costs associated the construction have been priced explicitly.

The proposed optimism bias has been determined from a Review of Large Public Procurement in the UK¹. This study reviewed cost estimates and resulting capital expenditure from public procurement projects over a period of 20 years. The findings of this review highlighted that an appropriate optimism bias for standard civil engineering projects at the outline business case stage, which broadly reflects the level of assessment in the CFRAM, is 44%. On this basis an optimism bias of 50% has been applied for all cost estimates in the WCFRAM.

¹ Review of Large Public Procurement in the UK, Mott MacDonald (2002).

B Screening cost summary tables

B.1 Option 1 - Upstream Storage

Embankment

Single Method Capital Cost Tool	
Embankment type	Rural clay embankment
Material	Imported
Embankment height (m) equivalent for unit cost rate	3
Embankment length (m)	70
Embankment unit rate (€/m)	€ 539
Over-ride unit rate (€/m)	
Total costs (€)	€ 37,709
Apply update to unit rate (CPI) if appropriate (€) (1.0)	€ 37,709
Enter other applicable costs (€)	-
Total capital cost (€)	€ 37,709
Consider amendments based on site issues/constraints (€) (Method factor 20%)	€ 45,251
Preliminaries (32%)	€ 59,731
Total capital cost (€)	€ 59,731

Operation and Maintenance Cost Tool	
Embankment length total (m)	70
Embankment O&M costs (€/m/yr)	Average estimates €2.73
Over-ride unit rate (€/m/year)	-
Total annual O&M costs (€)	€190
Present value O&M costs (€)	€4,071

Hydrobrake - A quote has been obtained for a hydrobrake for a maximum design head of 3m with a maximum design flow of 0.5m³/s. Budgeted cost excluding VAT is €30,820 unit cost (€40,682 total capital cost).

Summary

Total PV Cost	
Total capital costs (€)	€ 100,413
Total PVc costs (€)	€ 104,484
Optimism bias rate (%)	50%
Total Cost including Optimism Bias (€)	€ 156,727

B.2 Option 2 - Flow diversion - Open channel and culvert upgrade

Culvert

Single Method Capital Cost Tool	
Culvert ref	Culvert
Type of culvert	Rural
New culvert/replacement	New
Depth to invert (m)	2.5
Culvert size (m dia)	3.0 x 2.1 m
Culvert length (m)	85
Culvert unit rate (€/m)	€ 1,757
Over-ride unit rate (€/m)	1,900
Total costs (€)	€ 161,500
Apply update to unit rate (CPI) if appropriate (€) (1.0)	€ 161,500
Enter other applicable costs (€)	-
Total capital cost (€)	€ 161,500
Consider amendments based on site issues/constraints (€) (Method factor 20%)	€ 193,800
Preliminaries (20%)	€ 38,760
Total capital cost (€)	€ 232,560

Single Method Capital Cost Tool	
Culvert ref	Headwall
Type of culvert	Headwall
Culvert size (m dia)	2.4 x 2.1m headwall
Culvert length (m)	1
Culvert unit rate (€/m)	€ 13,816
Over-ride unit rate (€/m)	-
Total costs (€)	€ 13,816
Apply update to unit rate (CPI) if appropriate (€) (1.0)	€ 13,816
Enter other applicable costs (€)	-
Total capital cost (€)	€ 13,816
Consider amendments based on site issues/constraints (€) (Method factor 20%)	€ 16,579
Preliminaries (20%)	€ 3,316
Total capital cost (€)	€ 19,895

Operation and Maintenance Cost Tool	
Culvert length (m)	Long culvert
Depth to invert (m)	1.2-4.0m
Culvert O&M costs (€/yr)	Lower estimates €1,945
Over-ride unit rate (€/m/year)	-
Total annual O&M costs (€)	€1,945
Present value O&M costs (€)	€41,509

Excavate channel

Single Method Capital Cost Tool	
Volume of excavation (m3) to give an estimation	1000
Type of excavation	Soft soil and material taken away to waste facility

Unit cost (€/m3)	520
Volume of excavation (m3)	5000
Over-ride unit rate (€/m3)	-
Cost (€)	€ 8,814
Apply update to unit rate (CPI) if appropriate (€) (1.0)	€ 8,814
Enter other applicable costs (€)	-
Total capital cost (€)	€ 8,814
Consider amendments based on site issues/constraints (€) (Method factor 20%)	€ 10,577
Preliminaries (20%)	€ 2,115
Total capital cost (€)	€ 12,692

Operation and Maintenance Cost Tool

Volume of excavation (m3)	520
Annual unit cost rate (€/m3) (Assumed no maintenance required)	€ 0
Over-ride unit rate (€/m/year)	€ 0.5
User input to allow for channel maintenance	
Total annual O&M costs (€)	€ 260
Present value O&M costs (€)	€ 11,098

Summary

Total PV Cost

Total capital costs (€)	€ 265,147
Total PVc costs (€)	€ 317,754
Optimism bias rate (%)	50%
Total Cost including Optimism Bias (€)	€ 476,631

B.3 Option 3 - Wall and Embankments

Embankment

Single Method Capital Cost Tool	
Embankment type	Rural clay embankment
Material	Imported
Embankment height (m) equivalent for unit cost rate	1
Embankment length (m)	320
Embankment unit rate (€/m)	€ 128
Over-ride unit rate (€/m)	
Total costs (€)	€ 40,911
Apply update to unit rate (CPI) if appropriate (€) (1.0)	€ 40,911
Enter other applicable costs (€)	-
Total capital cost (€)	€ 40,911
Consider amendments based on site issues/constraints (€) (Method factor 20%)	€ 49,093
Preliminaries (32%)	€ 15,709
Total capital cost (€)	€ 64,802

Operation and Maintenance Cost Tool		
Embankment length total (m)		320
Embankment O&M costs (€/m/yr)	Average estimates	€2.73
Over-ride unit rate (€/m/year)		-
Total annual O&M costs (€)		€872
Present value O&M costs (€)		€18,610

Wall

Single Method Capital Cost Tool	
Wall Type	Retaining Wall, Urban (with stone cladding), <100m in length
Height (m)	1.2
Wall Length (m)	30
Wall unit rate (€/m)	€ 1,388
Over-ride unit rate (€/m)	
Total costs (€)	€ 41,642
Apply update to unit rate (CPI) if appropriate (€) (1.0)	€ 41,642
Enter other applicable costs (€)	-
Total capital cost (€)	€ 41,642
Consider amendments based on site issues/constraints (€) (Method factor 20%)	€ 49,970
Preliminaries (32%)	€ 15,990
Total capital cost (€)	€ 65,960

Operation and Maintenance Cost Tool		
Wall length total (m)		30
Wall O&M costs (€/m/yr)	Average estimates	€0.325
Over-ride unit rate (€/m/year)		-
Total annual O&M costs (€)		€10
Present value O&M costs (€)		€208

Summary

Total PV Cost	
Total capital costs (€)	€ 130,762
Total PVc costs (€)	€ 149,580
Optimism bias rate (%)	50%
Total Cost including Optimism Bias (€)	€ 224,372

C Environmental and social assessment of methods and options

C.1 Introduction

The environmental constraints and the scope of the Strategic Environmental Assessment (SEA) have been identified in the SEA scoping report. In the screening of methods and development of flood risk management solutions the possible constraints, environmental benefits and impacts associated with each method have been identified. The benefits and impacts have been considered in terms of quality, significance, duration and type.

C.2 Screening of methods

Alongside the technical and economical assessment of potential methods, an assessment into the key social, cultural and environmental issues relating to flood risk in the area were considered. This work built on the key constraints listed in the SEA scoping Report. This is included in Section 2.2 of each individual AFA POR report.

At this preliminary screening stage, methods were assessed in relation to:

- Location - would the placement of the method be located near or within a Natura 2000 site.
- Impact during construction or any operational requirements
- Presence of protected species within the area.

By outlining the key constraints, potential methods that would need to follow the full IROPI (Imperative Reasons of Overriding Public Interest) process can be discounted at the viability screening stage.

C.3 Environmental appraisal of options

C.3.1 Assessment criteria

The screening stage determined potentially viable methods and these were carried forward to full option development. In the full development of options an environmental appraisal of each viable option has been carried out and has been included in each individual POR report. The following has been considered.

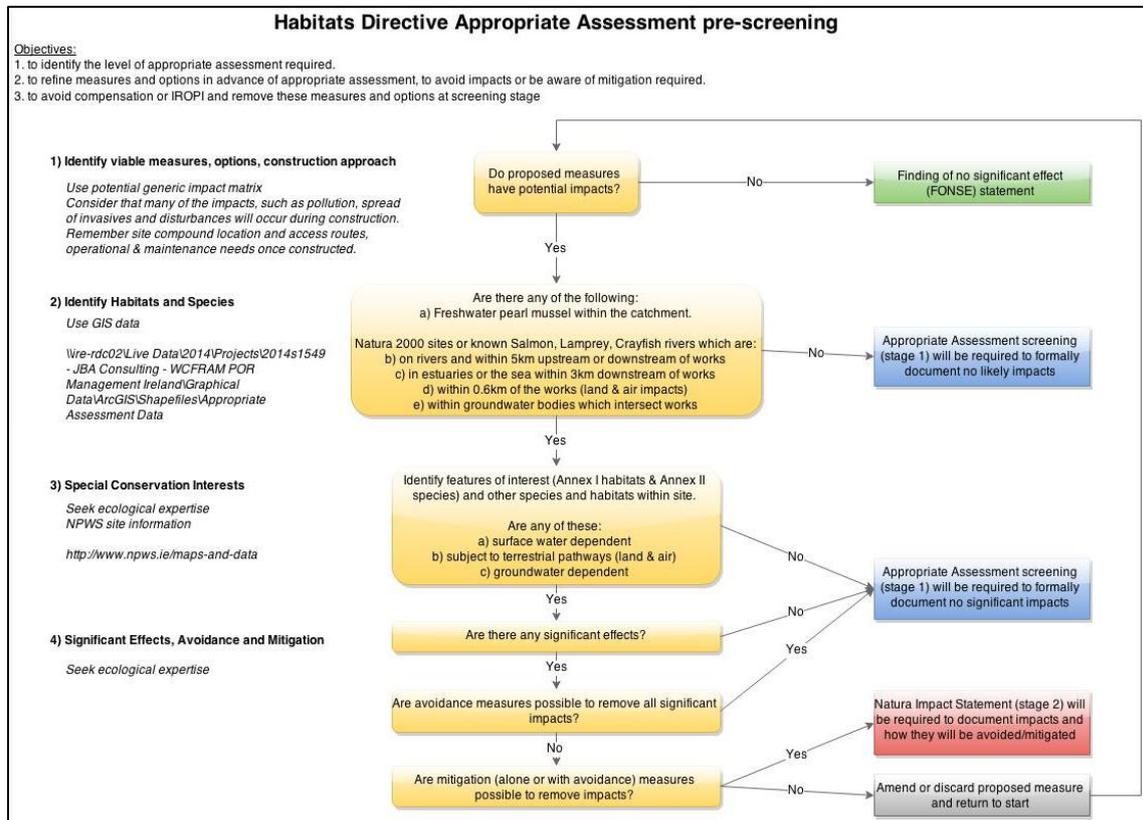
Table C-7: Environmental considerations

Habitat Loss	This is a permanent loss of habitat within the designated boundaries of a Natura 2000 site. For flood relief schemes this could arise from the construction of new structures within the site boundary, including provision for future maintenance. Dredging, bank alterations etc., and other activities can cause habitat loss.
Physical Damage	This includes degradation to, and modification of, habitats within the designated boundaries of a Natura 2000 site. This could arise in working areas and along access routes where construction works are undertaken within the site boundary.
Habitat Fragmentation	More indirect physical damage to habitats could occur, for example, through increased recreational pressure associated with certain methods, which could result in trampling, erosion or rubbish tipping.
Species Loss	Damage may be temporary or permanent.
Change in physical Regime	This is where activities result in the separation of available habitats or split extensive areas of suitable habitat. It is most likely to affect species, but can impact upon the functionality of habitats.
Changes in hydrological regime	This is a permanent loss of species such as Atlantic Salmon within the designated boundaries of a Natura 2000 site as a result of schemes e.g. removal of spawning grounds due to channel deepening and widening, loss of Otter due to damage to holts on river banks or loss of pearl mussel due to instream works. For flood relief schemes this could arise from the construction of new structures within the site boundary, dredging, channel widening, bank alterations or including provision for future maintenance. At coastal locations this may arise mainly for birds e.g. nesting terns on shingle or some rare plants. Dredging, bank alterations etc., and other activities can cause habitat loss
Disturbance (noise, visual, vibration)	These are changes to physical process that can alter the present characteristics of the Natura 2000 site (e.g. estuarine, fluvial and geomorphological processes, salinity levels, tidal regimes, erosion, deposition, sediment transport and accumulation). This could then result in degradation or loss of habitats.
Competition from non-native species	Certain activities may result in changes to the current hydrological regime. For example, a reduction or increase in the frequency, extent, duration and/or depth of flooding may affect estuarine, riverine and floodplain habitats.
Changes in water quality	Activities which may affect surface and groundwater levels, such as impoundments or defence construction, may also have adverse impacts on surface water or groundwater dependant habitats (rivers, fens, bogs, etc.) and species.
Pollution	A number of activities can result in disturbance, including visual and from noise. This is more frequently associated with construction activities, but could also be associated with the operational phases of some flood relief methods, in particular where recreational opportunities may be exploited. Disturbance can cause sensitive species, such as birds or mammals, to deviate from their normal, preferred behaviour, resulting in stress, increased energy expenditure and, in some cases, species mortality.
Landscape and Visuals	The visual impacts of the proposed options were assessed using the existing landscape ratings and status for the areas as outlined in the County Development and Local Area Plans.
Archaeology & Cultural Heritage	The potential impacts of the proposed flood management options were assessed against the archaeological and architectural features in the areas of the proposed works. Architectural Conservation Areas in town were taken into consideration during the assessments.

C.3.2 Habitats Directive Appropriate Assessment pre-screening

Pre-screening in relation to the Habitats Directive was carried out to examine the potential impacts on Natura 2000 sites early in the design process. Where an option could potentially involve Stage 3 & 4 of the AA process, this option was re-examined and in most cases options that would require an IROPI approval process were rejected and alternative options sought. This is illustrated below in Figure C-3.

Figure C-3: Habitats Directive Appropriate Assessment pre-screening





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