

Western CFRAM Unit of Management 31

**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
EPA	Environmental Protection Agency
FRA	Flood Risk Assessment
FRM	Flood Risk Mapping
FRMP	Flood Risk Management Plan
GSDSDS	Greater Dublin Strategic Drainage Strategy
HEFS	High End Future Scenario
ICPSS	Irish Coastal Protection Strategy Study
IED	ISIS Event Data file
LAP	Local Area Plan
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
SUDS	Sustainable Urban Drainage Systems
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 31, also referred to as Galway Bay North, which covers an area of 936 square kilometres of the Western RBD in County Galway. There is only one Area for Further Assessment within UoM 31, Roundstone.

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 30-31 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 (Volume 2f covers Roundstone) and the mapping outputs from the study (Volumes 3f covers Roundstone). The coastline in Roundstone was modelled. The hydraulics report summarises the main findings of the hydraulic modelling stage, sources of flood risk within Roundstone, including details of historical flooding and flood defences.

This report presents the findings of the preliminary options investigations for UoM 31. 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 measures 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 properties are shown to be at risk of flooding within the design standard flood extents for Roundstone.

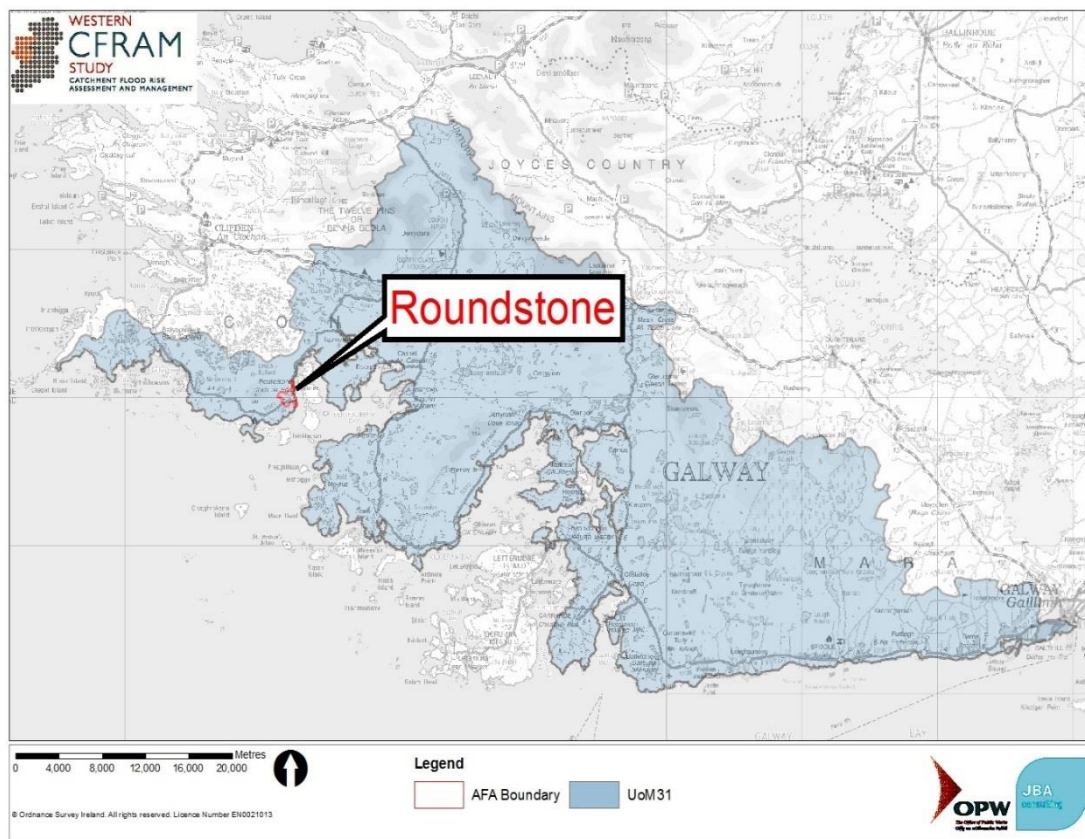
For Roundstone an assessment of viable structural flood risk management measures has been completed. This assessment is detailed in full in the adjoining AFA specific Preliminary Options Reports (Volume 2).

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

The AFAs within UoM 31, Galway Bay East, are shown in Figure 1-1. For UoM 31 the review of the flood extent maps confirmed there are properties at risk of flooding in the 0.5% AEP tidal

event in Roundstone. This AFA was assessed for viable structural flood risk management measures and so has a specific Preliminary Options Report in Volume 2

Figure 1-1: AFAs within UoM 31



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 measures, 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
- Western CFram UoM 30-31 Inception Report³
- Western CFram Flood Risk Review Report⁴
- Western CFram SEA Scoping Report⁵
- Western CFram SEA Constraints Report

¹ JBA Consulting (2014), Western CFram Unit of Management 30 and 31 – Corrib and Owengola Hydraulics Report, Final Report, Office of Public Works

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

³ JBA Consulting (2012), Western CFram Unit of Management 30-31 – Corrib and Owengola 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.

- Western CFRAM Defence Asset Database: Handover Report and accompanying database files⁶

The reports in the suite for the Preliminary Options are:

- Western CFRAM UoM 31 Preliminary Option Report: Volume 1 - Overarching(this report)
- Western CFRAM UoM 31 Preliminary Options Report Volume 2f Roundstone

The letter code associated with the deliverables in Volumes 2 will be consistent for a given AFA, so in the example above the letter 'f' applies to the Roundstone AFA in both Volume 2 of the Hydraulics Report and Volume 2 of the Preliminary Options Report in UoM 31.

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) measures 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 relevant individual POR AFA reports.
- 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 (measures)
- 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 measures 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 measures which are set out in full in the relevant AFA reports in Volume 2. Section 4 discusses non-structural flood risk management measures and the recommendations for this UoM.

Section 0, 6 and 7 provide the detailed analysis of non-structural measures applicable at the UoM level. Section 0 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.

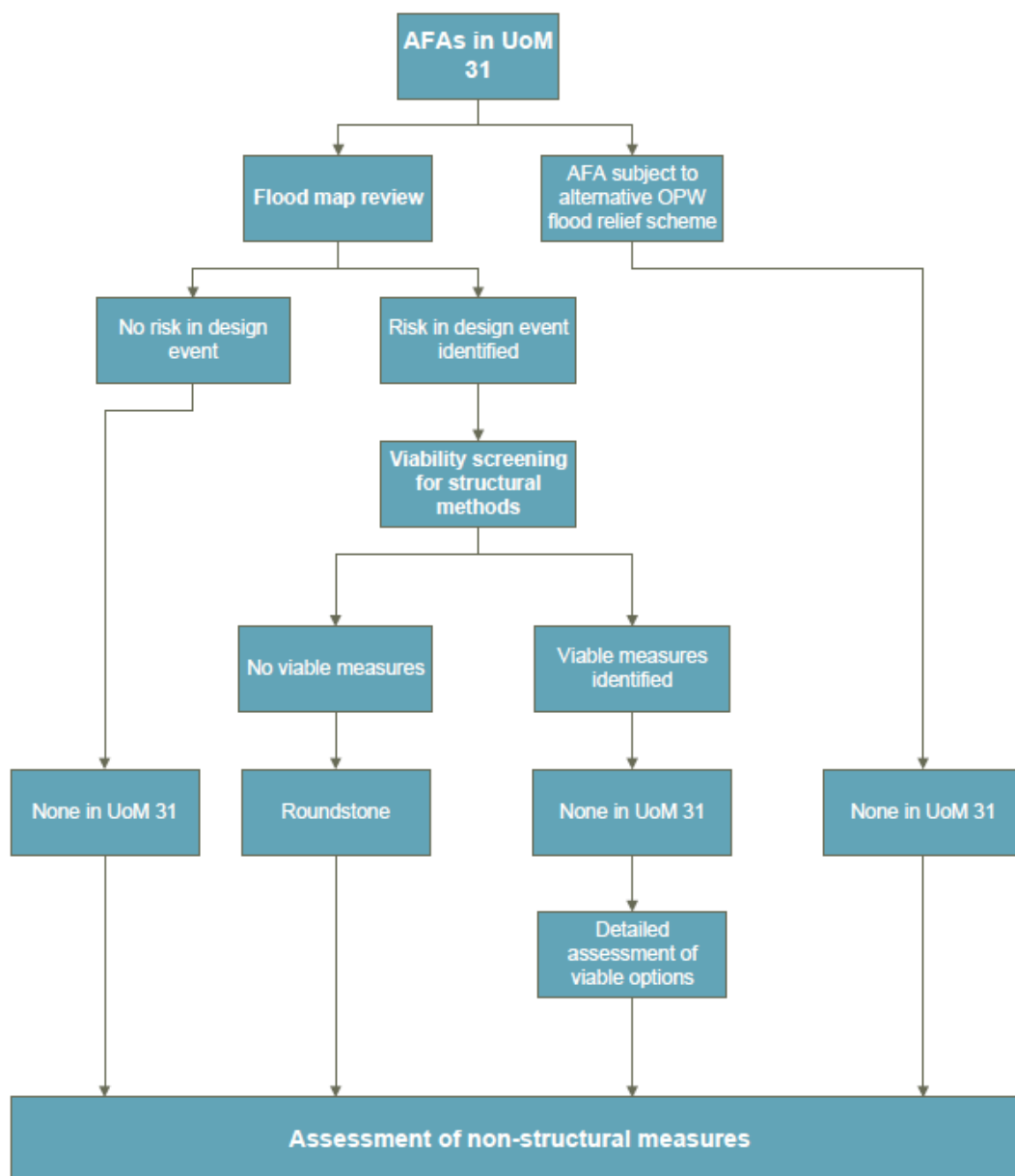
⁶ JBA Consulting (2013), Western CFRAM Defence Asset Database, Handover Report, Office of Public Works. WCFRAM UoM 31 Preliminary Options Report - Overarching Report v3.0.doc

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 measures through the assessment. At each stage-end a decision is taken to confirm that proposed flood risk measures 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 Western CFRAM 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 measures 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 measures and maintenance, see Section 4.
2. Viability Screening - This stage includes the screening of structural flood risk management measures to identify where viable solutions or options exist. The key stages of work in this phase are the Screening of Measures, 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 Western CFRAM. This does not necessarily preclude options being taken forward outside of the CFRAM programme. Regardless of the viability of structural measures, for each AFA there has also been an assessment of non-structural measures, 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 Western CFRAM.

Figure 1-2: POR assessment process for UoM 31



For UoM 31 the Flood Map Review confirmed there are properties at risk of flooding in the 0.5% AEP tidal event in Roundstone.

2 Spatial scales of assessment

2.1 Overview

In order to identify coherent actions and methods, the applicability of each possible measure 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 6 respectively).

2.3 Sub catchment level

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, where the estuary area may be treated as a Sub-Catchment SSA. This is the case with Roundstone and in response the potential for a tidal flood forecasting system for Galway Bay was explored.

2.4 AFA level

At this scale, measures benefitting only the AFA in question were considered, even if the implementation of a given measure 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 measures and options, such as protection measures, conveyance improvement, etc. Measures proposed at an AFA scale are discussed in detail in the relevant AFA Preliminary Options Report.

In most cases a single measure to address all risk within an AFA will not be sufficient, and proposed options comprise a range of measures 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 Western CFRAM is the 1% AEP fluvial or the 0.5% AEP tidal event. Structural measures 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 measure and summarises the findings of the assessments.

Structural flood risk management measures have been considered for Roundstone. Full details of the screening assessments and development of preferred options for these AFAs is set out in the AFA specific report in Volume 2. Table 3-1 details the number of properties at risk and the present value damages in the 10%, 1% / 0.5% and 0.1% AEP Events.

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 (€)
Roundstone	10% AEP Event			
	0	0	0	0
	1/0.5 % AEP Event (Design Event)			
	2	2	0	20,769
	0.1% AEP Event			
	12	12	0	52,713

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 measure 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 measure results in an appropriate reduction in flood risk
- Economically viable - the measure is not cost prohibitive in comparison to the damages predicted to arise from flooding
- Environmentally sustainable - the impacts of the measure on the environment can be expected to be managed
- Socially acceptable - the measure does not have an overtly negative impact on the local community
- Safe - the measure 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 measure 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 measure 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 measure as a standalone option is screened out on technical viability.

Where the measure is considered technically unviable as a standalone, but viable in conjunction with other methods, the reduced scale and extent of the measure 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 measure 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 measure would require application of the IROPI⁷ process and at least one alternative measure is available then the measure 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 measure 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 measure'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 measure / option which has been shown to result in detrimental impacts to a Natura site.
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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 31

Structural methods have been investigated for Roundstone only. A summary of the findings of the screening assessment is presented in Table 3-3.

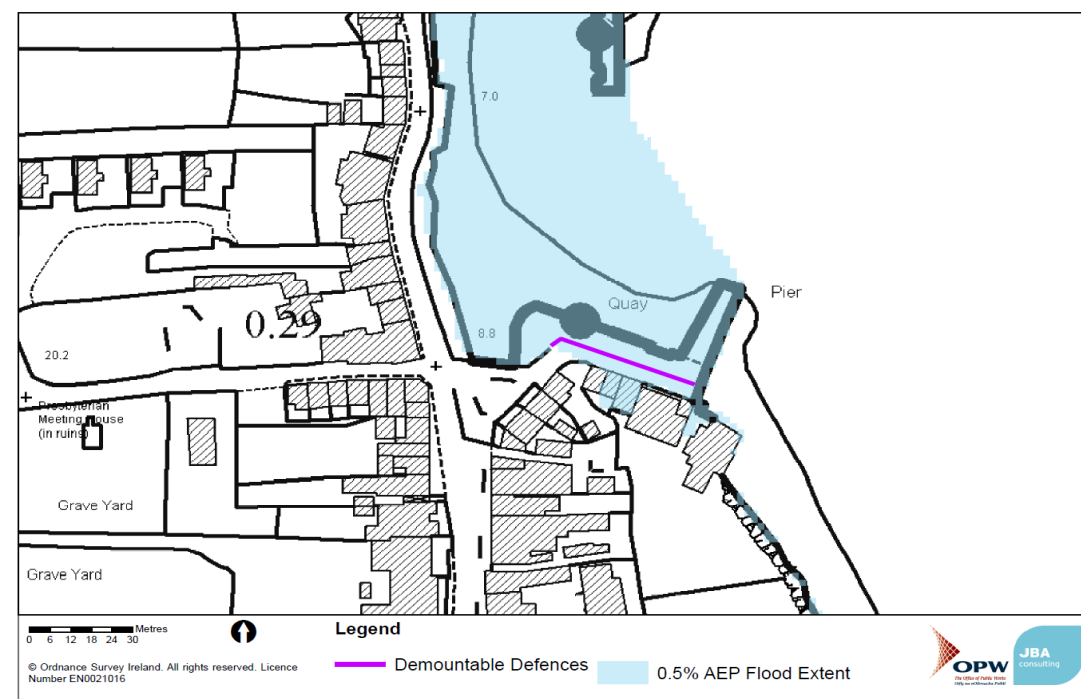
The aim of the screening assessment was to identify viable, structural methods from which flood risk management options for the AFA as a whole have been developed.

Figure 3-1 presents the technically viable structural flood risk management method identified for Roundstone. This method was not 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 31

AFA Name	Options for screening	Conclusion ⁸
Roundstone (Volume 2f)	Demountable Defences The provision of demountable defences (1.2m high) at times of flood risk.	Not economically viable - BCR 0.03

Figure 3-1: Technically viable methods identified for Roundstone



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.

⁸ BCR - Benefit Cost Ratio. A ratio greater than 1 was needed to allow an option to be developed further.
WCFRAM UoM 31 Preliminary Options Report - Overarching Report v3.0.doc

Climate change impacts in Roundstone are related to sea level rise and are projected to be significant. 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 Roundstone 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 measures 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 Roundstone 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
Roundstone	No zonal local area plan completed for Roundstone. Current zoning within the County Development Plan SFRA are based on PFRA flood maps and should be updated to consider CFRAM Flood Zones.	There is an increased future risk of flooding in the northern section of Roundstone during a 0.5% AEP flood event with areas within the town centre and southern section experiencing extension of Flood Zone 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 Roundstone which is summarised in Table 4-1.

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

AFA	Applicability of SUDS
Roundstone	Due to the even distribution of runoff routes from the hills there is little potential for regional attenuation of runoff to reduce surface water flood risk in Roundstone.

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

Coastal forecasting system	
Roundstone	By tying into the national storm surge model developed by the OPW warning can be provided

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 Western CFRAM, 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	
Roundstone	2	0	The costs of a community scale option are prohibitive for Roundstone given the current level of flood risk. Individual property methods should be considered here mindful of the long term effectiveness of such methods with respect to climate change.

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 there is no arterial drainage within UoM 31.

- **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 there no drainage districts within UoM 31.
- **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

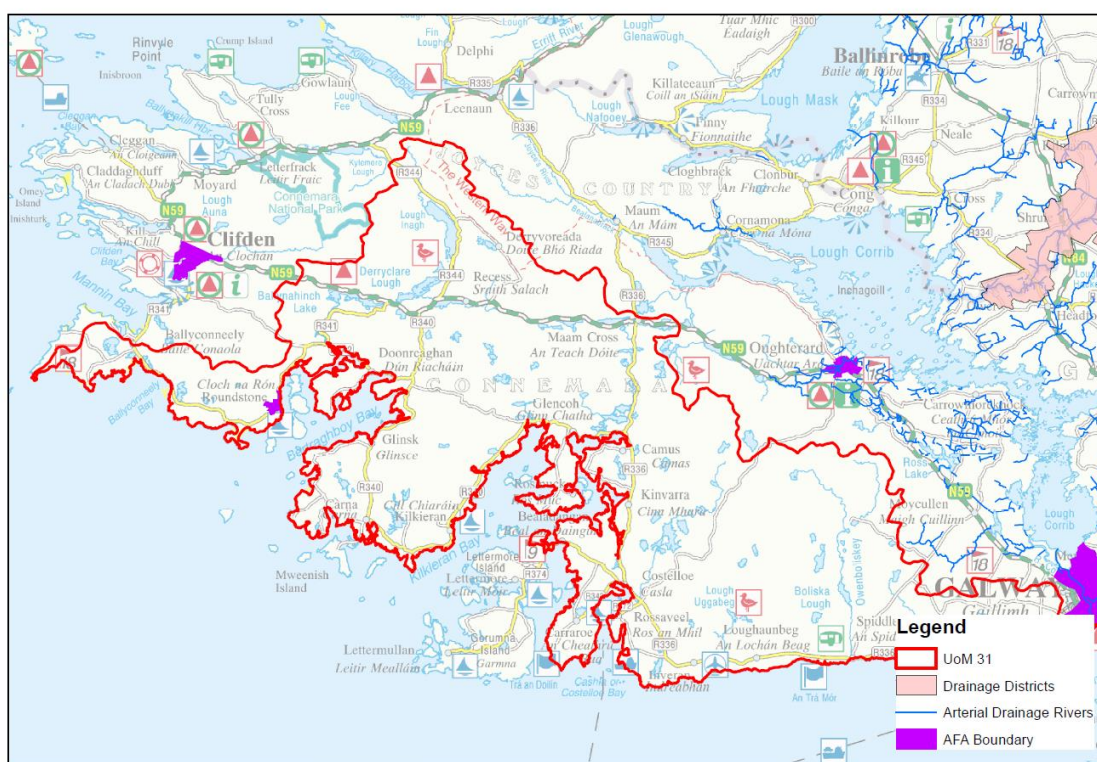


Table 4-5 summarises the maintenance considerations for Roundstone.

Table 4-5: Maintenance considerations for each AFA

AFA Name	Site overview	Recommendations
Roundstone	<p>The walls around the quay provide a level of protection to the properties in the area. The new wall constructed in the village is considered a structural defence. The upkeep and maintenance of all existing walls is essential in providing some protection to the properties in the short term.</p> <p>Ongoing maintenance of the sea walls, coastal structures and surface water drainage network and outfalls is critical to maintaining the level of flood risk management provided to Roundstone.</p>	<p>Maintenance may include infilling small gaps and removing vegetation to prevent further degradation of the structures.</p>

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 measures 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 SEPA⁹ 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).

Sediment management	boulders)
	Reach restoration (e.g. remeandering)
	Offline storage areas and washlands
	Reach restoration (e.g. remeandering)
	Sediment traps
Estuarine surge attenuation	Bank restoration (e.g. riparian planting, green bank restoration)
	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 Western CFRAM, 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 a high level assessment applicable for the Western CFRAM area as a whole. 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.

4.5.4 Sediment management

The sediment management maps are sourced from the hydromorphology assessment completed as part of the Western CFRAM 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 measures.

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 4-2.

Figure 4-2: Catchment scale classification of natural flood management methods

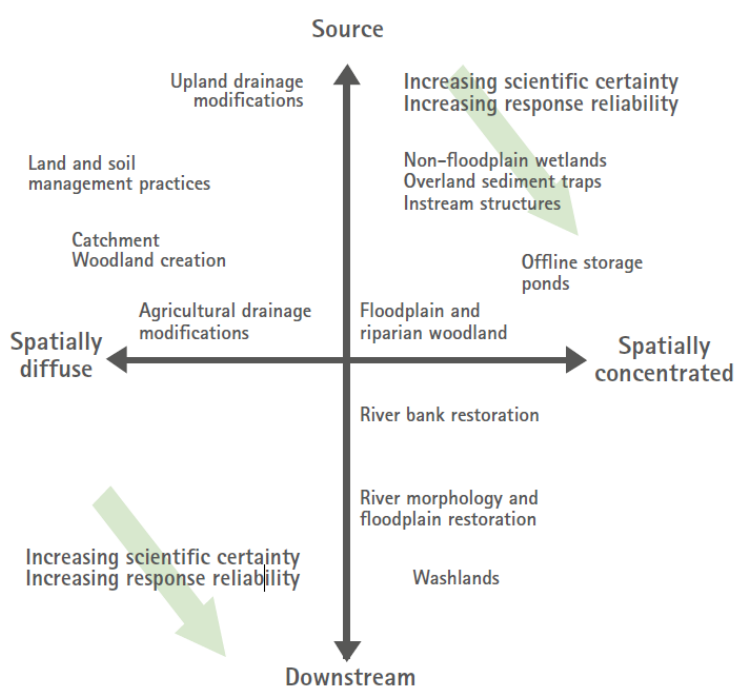


Figure extracted from SEPA Natural flood management hand book¹⁰ and adapted from Thorne et al¹¹.

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.

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 4-3 to Figure 4-5 show the results of the screening assessment for UoM 31 and a short comment on suitability is provided below each map.

Figure 4-3: Runoff reduction NFM screening map for UoM 31

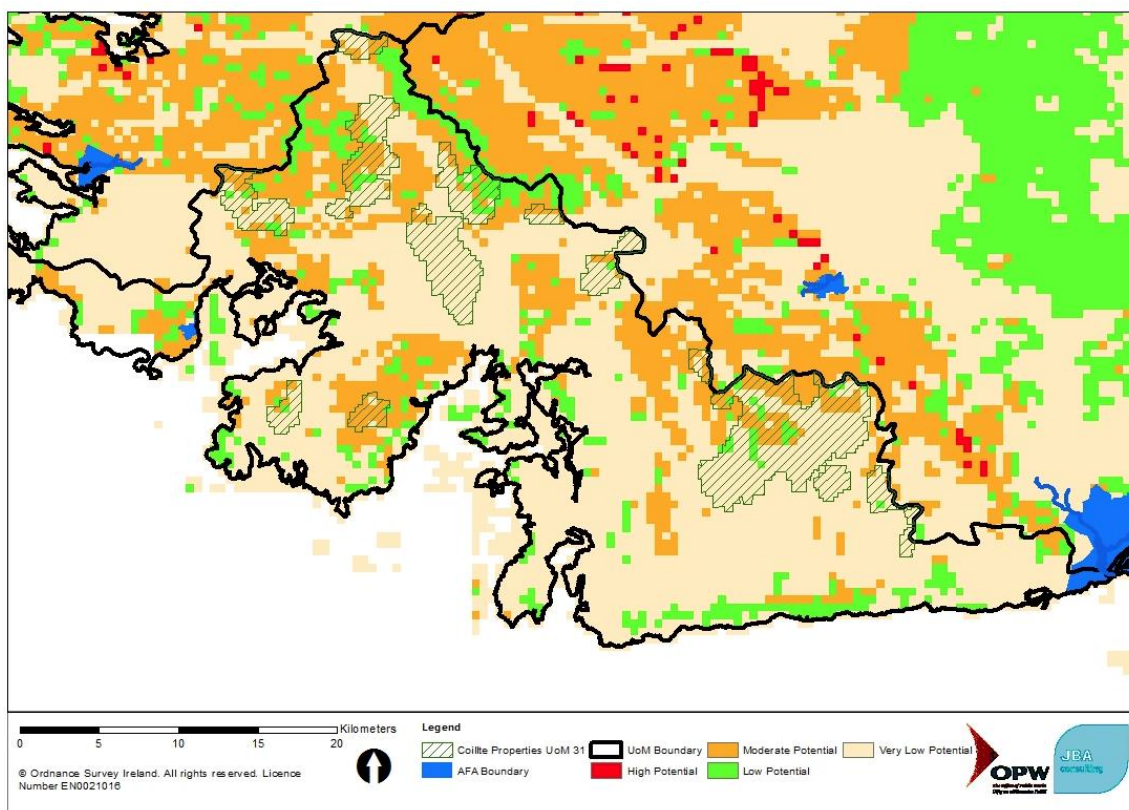


Figure 4-4: Re-naturalisation NFM screening map for UoM 31

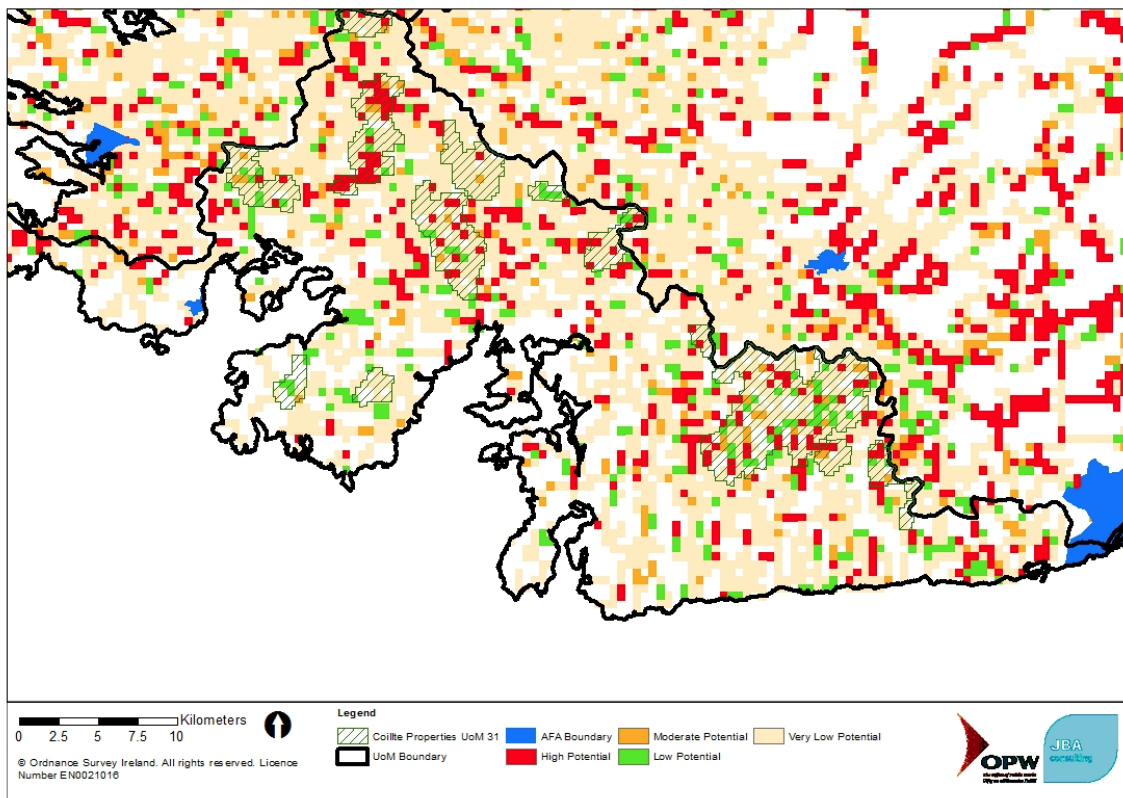
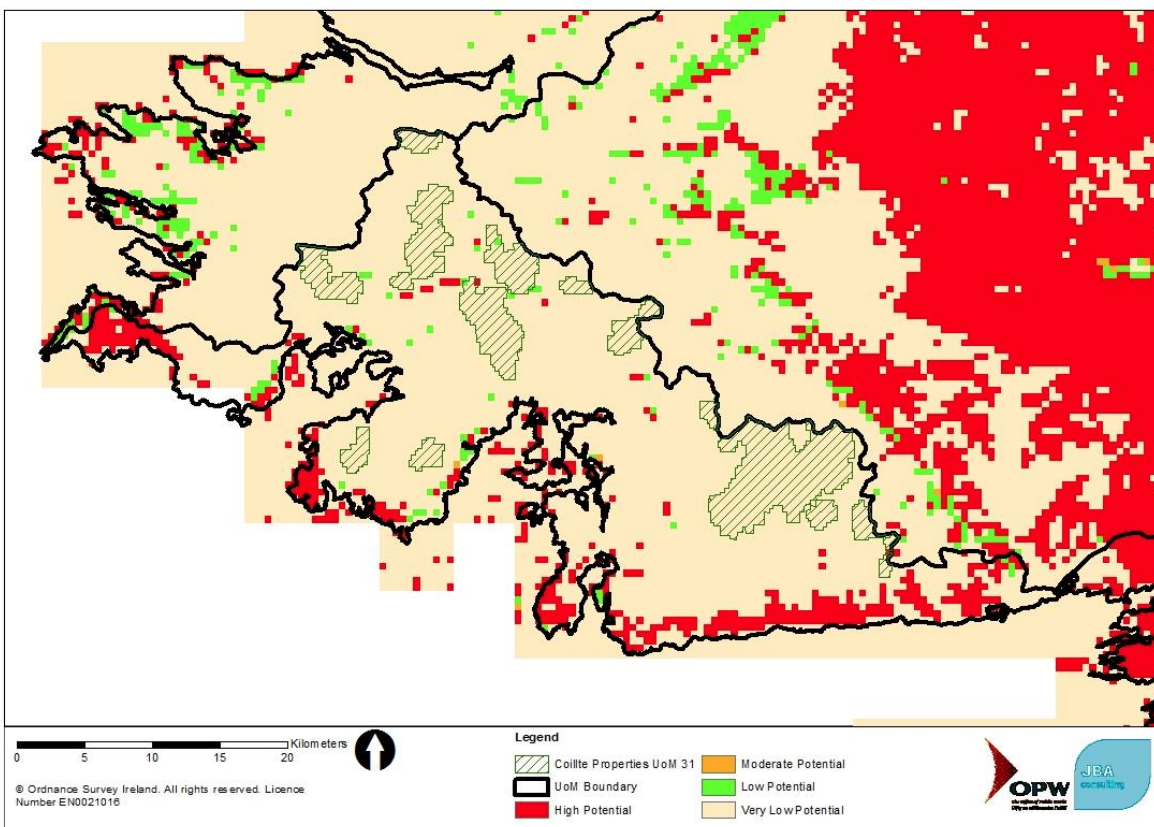


Figure 4-5: Floodplain storage NFM screening map using slope for UoM 31



4.5.6 Appropriate natural flood management objectives

Runoff reduction

Figure 4-3 shows there is little potential for runoff reduction natural flood management methods. The greatest potential is to the west of the catchment, in the Twelve Bens area of Connemara. The blanket bog that covers much of the catchment may limit the potential benefit, however some of the catchment is pasture or tillage and so there is the potential for significant benefits from only two methods (mowing and grazing practices). 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. There are no rivers or watercourses in Roundstone but there is moderate potential to reduce runoff to manage pluvial flood risk. NFM for runoff management could also manage pluvial flood risk outside of AFAs.

The main constraint to Roundstone 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. For the 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.

Currently, there is significant forestry in UoM 31. Forest can play an important role in flood risk management as a measure to reduce runoff and methods include woodland planting (including upland floodplain, riparian, gully or cross slope tree shelters).

Floodplain storage

The only AFA in UoM 31 is Roundstone, which is impacted by coastal flooding, so there is little scope for floodplain storage and renaturalisation of channels to reduce flooding. It may have limited potential outside of AFAs to reduce localised flooding.

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 31.

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 a considerable amount of forestry. Forestry and trees is 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.

Wave dissipation

Flood risk from wave overtopping has been considered in Roundstone, within UoM 31. The shoreline within Roundstone is vertical coastal walls/ quay walls which the toe of which is submerged at high tide. There is therefore no opportunity to improve or increase natural wave dissipation structures as none exist outside of Roundstone itself. Natural flood management measures for wave dissipation are not viable within Roundstone and therefore not been considered further for UoM 31.

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 31.

Table 4-9: Summary of natural flood management methods in UoM 31

NFM flood reduction objective	Scope	Methods
Runoff reduction	The screening maps highlights area close to the 12 bens where runoff reduction NFM methods are likely to be beneficial.	Woodland planting Land management including soil and bare earth improvements, changing agricultural field drainage
Floodplain storage	There is limited potential for floodplain storage and renaturalisation in UoM 31 as the only AFA is affected by coastal flooding.	Deciduous tree strips and hedgerows Removal of arterial drainage maintenance spoil heaps to improve floodplain connectivity River and floodplain restoration
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 31.	Deciduous tree strips and hedgerows Reduced grazing or stock levels Reduced and managed use of heavy farm machinery Reach restoration
Estuarine surge attenuation	Not applicable in UoM 31	-
Wave energy dissipation	There is no potential for wave dissipation in Roundstone	-

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 31. 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 31 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.
- 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 31 a new tidal gauge in the vicinity of Roundstone bay could be used to provide warning to the residents and tie in with the national tide and storm surge model.

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 measures 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 measures 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 measures 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 SFRAs 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, none are within UoM 31. 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

UoM 31 is covered by Galway County Council. 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 Roundstone 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 UoM31

County	Plan	Date	UoM 31 AFAs covered
Galway County	Galway County Development Plan	2015-2021	Roundstone

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 UoM31, and LAPs outside UoM31 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 Roundstone

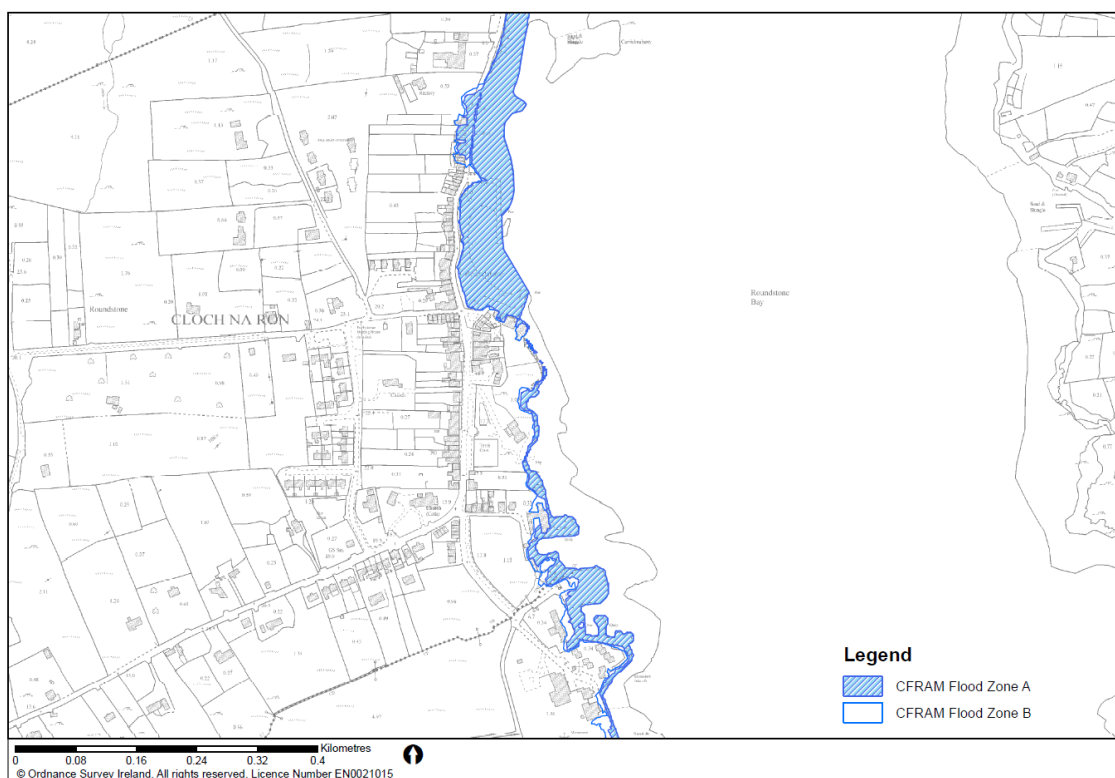
Local Area Plan

Roundstone is classified as "other settlements and the countryside" in the Galway County Development Plan 2015-2021. Roundstone does not have a local area plan and the An Gaeltacht Local Area Plan 2008-2014 is extended to 2018. 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 as shown in Figure 5-2 and consider the impacts of climate change.

Current risk

Flood Zones A and B cover lands along the coastline as expected. There are existing residential properties within Flood Zone A & B in the centre of Roundstone and southern section. Limited flooding of agricultural lands to the north is also identified.

Figure 5-2: CFRAM Flood Zones in Roundstone



Future risk

There is an increased future risk of flooding in the northern section of Roundstone during a 0.5% AEP flood event with areas within the town centre also experiencing extension of Flood Zone B and slight increase in Flood Zone A. A significant increase in the extent of Flood Zone A & B is

identified along the southern section of Roundstone which results in inundation of residential properties.

6 Surface water drainage strategy

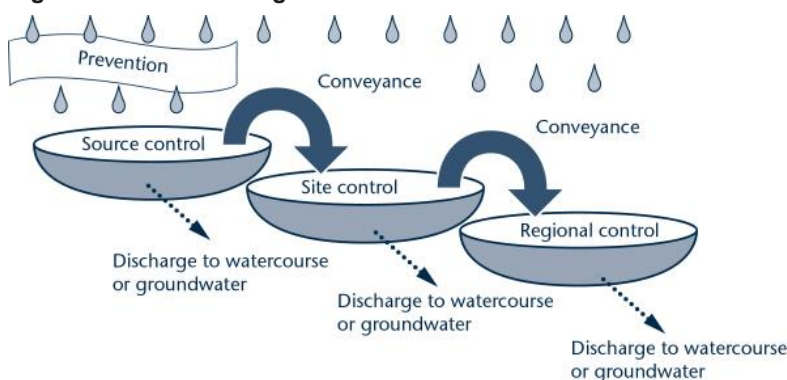
6.1 Overview

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 GDSDS, 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 GDSDS 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 measure, 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.

6.5 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.

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.

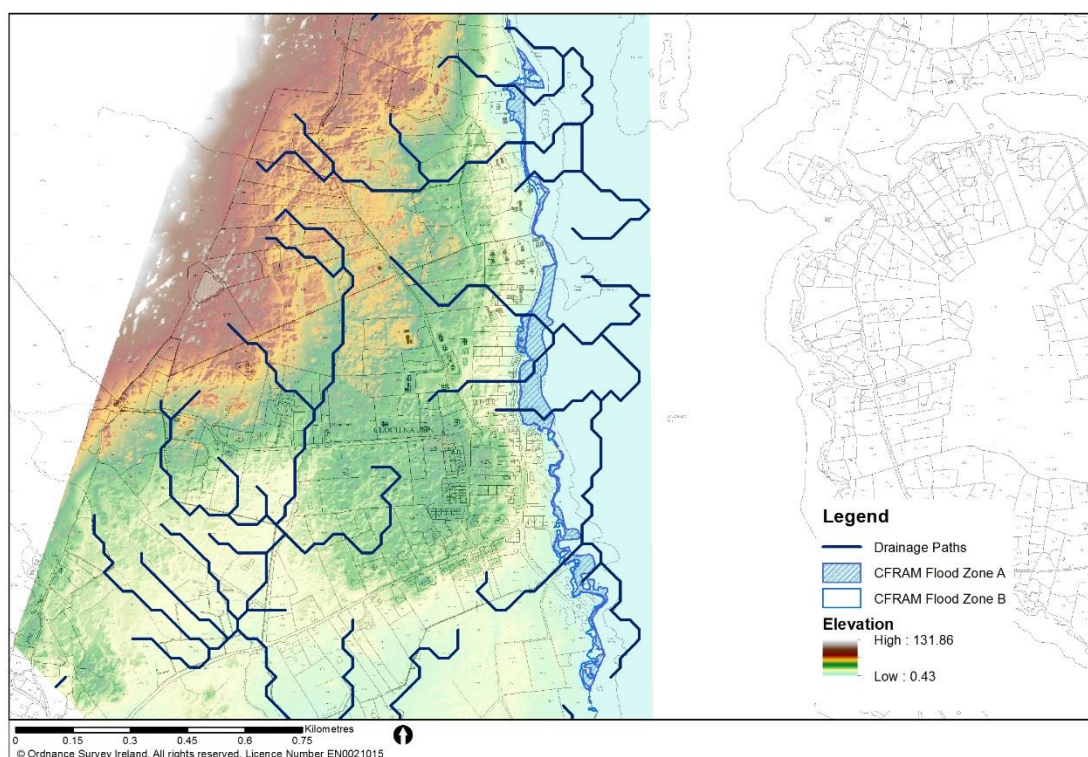
Ponds and wetlands generally require little or no drainage to ground and are therefore better suited to low permeability ground conditions. However, an engineering solution can also be used in high permeability areas by lining the pond with low permeability fill or an artificial liner.

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

6.5.1 Roundstone

The coastal nature of Roundstone which is developed in a ribbon along the coast limits the necessity for SuDS as flood risk management measures, however they provide important water quality functions for the receiving coastal and groundwater bodies. There is however, a high level of pluvial risk behind the wall and SuDS measures can help alleviate this. Most of the natural drainage paths from the blanket bog and hills to the west of Roundstone flow away from the centre of the village (Figure 6-2), however should development proceed immediately to the west of current development then SuDS features will be necessary to ensure runoff does not flow rapidly down the steep slopes into the existing village.

Figure 6-2: Natural drainage paths in Roundstone



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 Roundstone. These figures

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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)
Roundstone	596<970

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 measures 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 31 mindful of the proposals in adjacent UoMs 32 and 30.

At present in UoM 31 flood forecasting and flood warning services are provided by Met Éireann, who issue general nationwide and regional flood alerts. The OPW storm surge model will also provide warnings to Galway County Council and other relevant bodies.

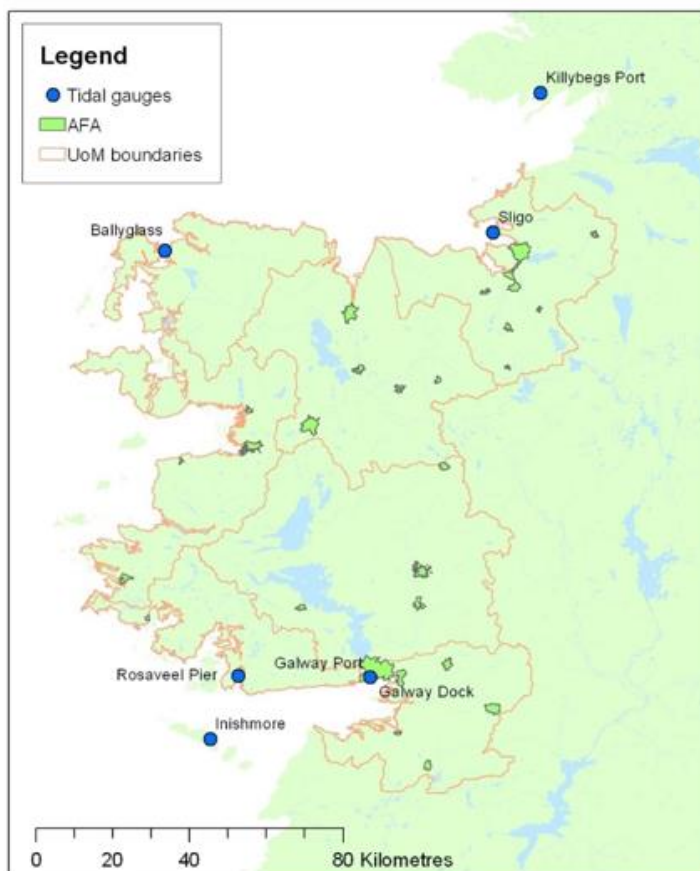
The assessment of the viability of a flood forecasting system within UoM 31 have examined the current infrastructure and, focussing on the AFAs, determined the requirements to operate a real-time localised flood forecasting or warning service. Roundstone is impacted by coastal flooding.

7.2 Coastal flood forecasting

7.2.1 Tidal data

Figure 7-1 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. 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 7-1: Tidal gauge network



7.2.2 Roundstone

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 7-2: Components of sea level variation that lead to typical coastal flooding

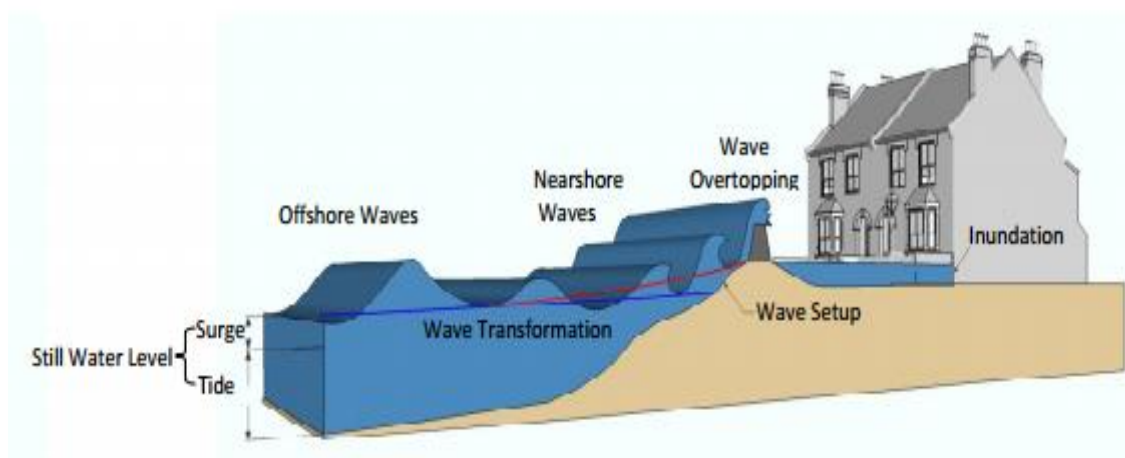


Figure 7-2 illustrates the main components of sea-level variation that contribute to coastal flooding during a storm event. The still water sea-level is comprised of the underlying astronomical tide and any storm surge affects. These two components determine the average sea-level for a particular location 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 Roundstone.

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 provide probabilistic early flood forecasting information. Currently the OPW issues a high tide advisory notice to Local Authorities.

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 extended to provide warning to the residents in Roundstone. 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.

7.2.3 Roundstone

As per Section 7-2 above 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.

The current system of tidal flood warning utilised for Galway City such as the OPW's national tidal and storm surge forecasting system along with a European Flood Awareness System (EFAS) can be expanded to include Roundstone if cost effective to do so. Additional tidal gauges may be required in the vicinity of Roundstone to enable calibration of any proposed warning system.

7.3 Conclusion

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

Table 7-1: Summary of Results for UoM 31

Coastal forecasting systems		
	Proposed system	Limitations - Benefit to cost ratio
Roundstone	Tie into the national storm surge model developed by the OPW	May required additional tidal gauge in the vicinity of Roundstone to improve accuracy and enable calibration if required.

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 Roundstone 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

AFA	Current flood risk	Future flood risk
Roundstone	No zonal local area plan completed for Roundstone. Current zoning within the County Development Plan SFRA are based on PFRA flood maps and should be updated to consider CFRAM Flood Zones.	There is an increased future risk of flooding in the northern section of Roundstone during a 0.5% AEP flood event with areas within the town centre and southern section experiencing extension of Flood Zone A & B.

Table 8-2: Applicability of SUDS with the AFA

AFA	Applicability of SUDS
Roundstone	Due to the even distribution of runoff routes from the hills there is little potential for regional attenuation of runoff to reduce surface water flood risk in Roundstone.

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 31 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

Coastal forecasting system	
Roundstone	By tying into the national storm surge model developed by the OPW warning can be provided

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; i.e. Roundstone. 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 Roundstone are summarised in Table 8-4.

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

AFA Name	Options for screening	Conclusion ¹²
Roundstone (Volume 2f)	Demountable Defences The provision of demountable defences (1.2m high) at times of flood risk.	Not economically viable - BCR 0.04

¹² BCR - Benefit Cost Ratio. A ratio greater than 1 was needed to allow an option to be developed further.
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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 Roundstone.

Table 8-5: Recommendations for individual property protection

AFA Name	No. of properties with depths:		Recommendations
	< 600mm	> 600mm	
Roundstone	2	0	The costs of a community scale option are prohibitive for Roundstone given the current level of flood risk. Individual property methods should be considered here mindful of the long term effectiveness of such methods with respect to climate change.

Table 8-6: Maintenance Considerations within each AFA

AFA Name	Recommendations
Roundstone	Maintenance may include infilling small gaps and removing vegetation to prevent further degradation of the structures.

A Breakdown of risk receptors

Table A-1: Flood risk to receptors in Roundstone

Risk Type	Receptor	Roundstone				
		10% AEP	1% / 0.5% AEP	0.1% AEP	1% AEP MRFS	1% AEP HEFS
Social	Residential property	0	2	9	24	31
	School	0	0	0	1	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	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	2	5	5



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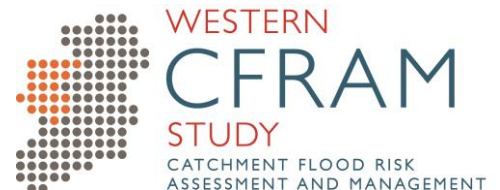
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**Roundstone Preliminary
Options Report
Volume 2f (1 of 1)**

**UoM 31 - Corrib-Galway Bay
North- Western CFRAM**

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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 Roundstone. The report should be read in conjunction with the Preliminary Options Overarching Report for UoM 30/31 for a full understanding of flood risk management recommendations for Roundstone.

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 Roundstone. Reports which are relevant to this AFA are:

- Western CFRAM Flood Risk Review Report
- Western CFRAM UoM 31 Inception Report
- Western CFRAM UoM 31 Hydrology Report
- Western CFRAM UoM 31 Hydraulic Modelling Report
- Western CFRAM UoM 31 - Galway Bay North Hydraulic Modelling Report: Volume 2a - Roundstone
- Western CFRAM UoM 31 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 Roundstone. The scope of this study is to identify a preferred flood risk management option for Roundstone.

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 UoM 31.

1.2 Flood Risk Overview

Roundstone has a coastline of approximately 1.8km within the boundaries of the AFA. The key areas of flood risk within the AFA are properties in the centre of the village, particularly adjacent to the pier. Houses to the north of the main village pier, shown in Figure 1-1, including the local library have historically been affected during extreme events. Recent works, since the Winter 2014 flooding to improve the wall here have protected these properties from flooding. The primary risk receptors in Roundstone are shown in Figure 1-2.

Figure 1-1 Properties previously flooded



Figure 1-2 Location of various risk receptors in Roundstone

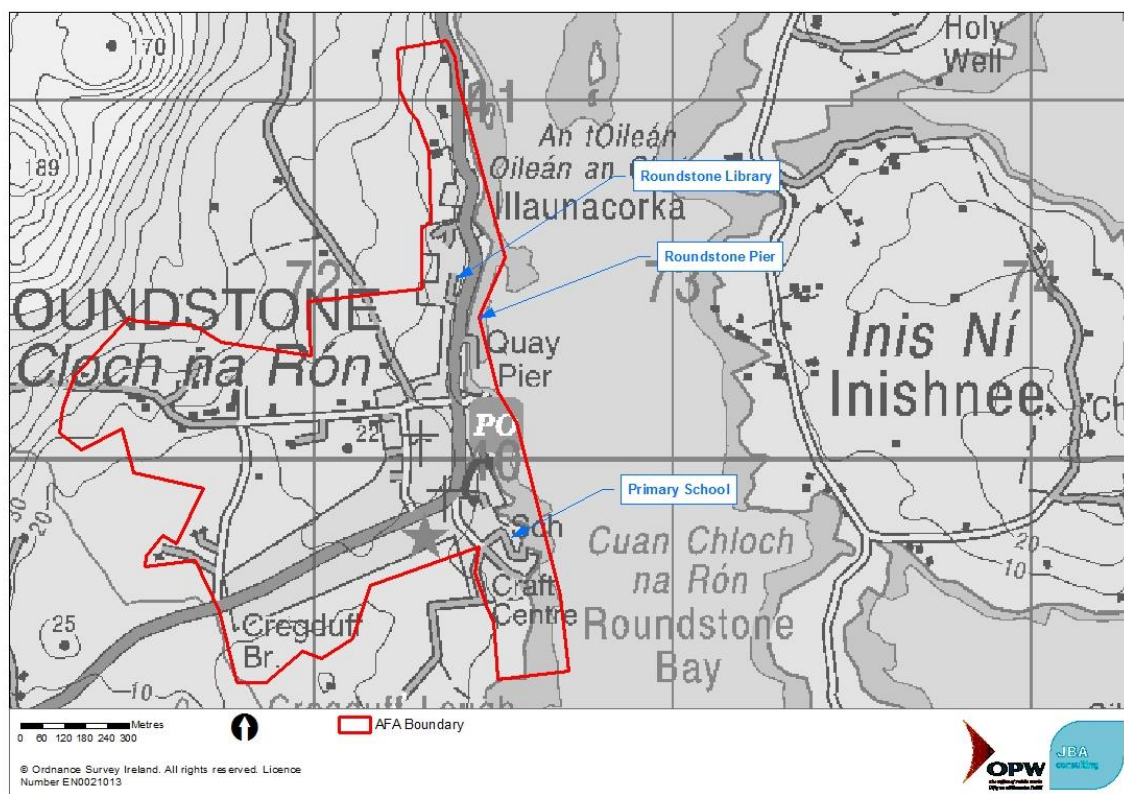


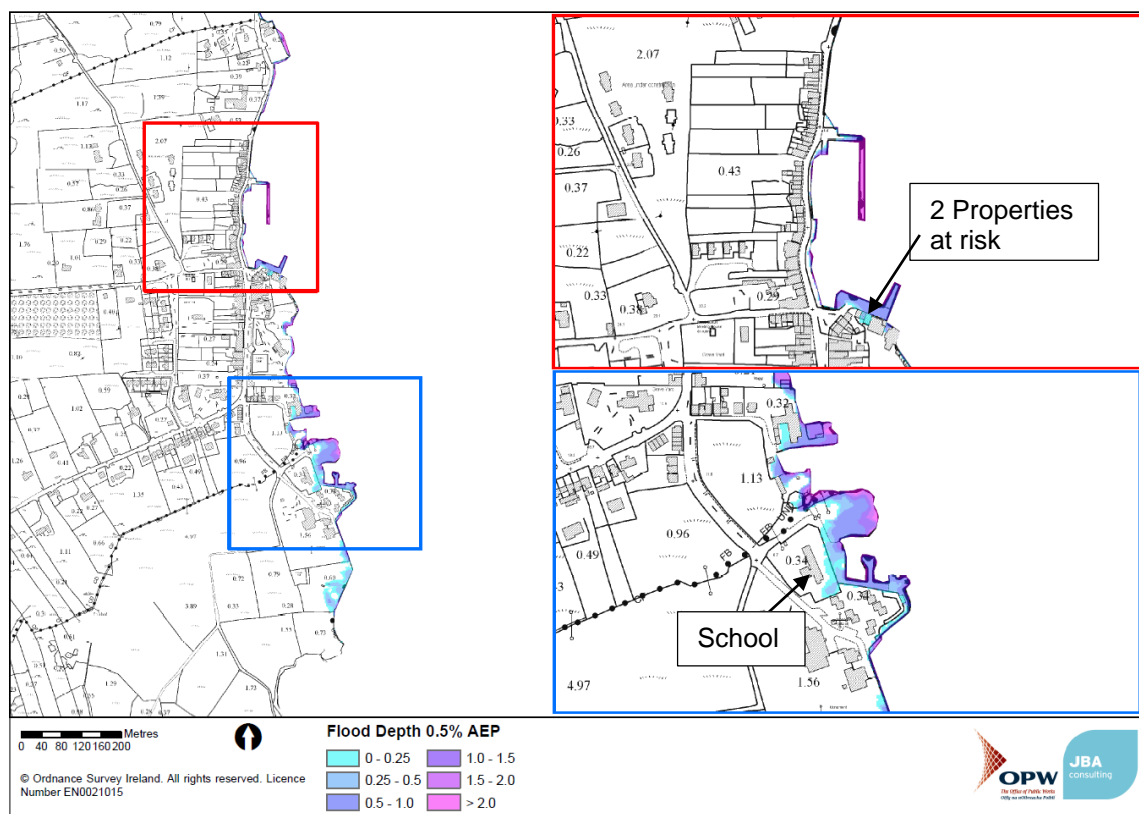
Figure 1-3 New wall with gap filled in it at northern extent of Roundstone



1.2.1 Current flood risk

Flood risk in Roundstone is a result of high sea levels exceeding the quay walls (and infiltrating gaps which have now been filled in and walls improved, following the January and February 2014 events Figure 1-3) to the north of Roundstone and in the centre where open quay exists, the quay level. The current flood risk extent in the 0.5% AEP event is presented in Figure 1-4 and a brief description of the key flood risk sites and flooding mechanisms is provided below.

Figure 1-4: Overview of Flood Risk



Prior to improvements to the sea wall the frequency of flooding was relatively high within Roundstone, as frequent as once or twice a year for the R341 road. Flooding within the village is due to a combination of high tides and storm surge, exacerbated by wave action. Floor levels have been raised in properties adjacent to the southern jetty in the centre of the village. Roundstone primary school is also vulnerable to extreme tides, as shown in Figure 1-5.

Figure 1-5: Roundstone primary school



The only forms of defence in the village are the new quay wall and resilience methods such as sandbags and localised raised threshold levels. This quay wall extends north from the pier along the R341 to the outskirts of the village. The wall maximum crest level varies from 4.5 mOD Malin, at the corner of the pier, before falling to a minimum of 3.5 mOD Malin approximately 100m to the north.

Flooding at Roundstone Village

Flooding within the village begins with water level raising above the pier levels. Inundation of the pier area occurs in the 20% AEP event and approximately 2 separate properties are shown to be within the 0.5% AEP event outline.

Wave overtopping

Wave overtopping has not been modelled at Roundstone as it was not found to be particularly vulnerable to it, as a result of a screening assessment undertaken as part of the ICWWS¹ study. Therefore, the flood risk in the AFA can be attributed to the still water level inundating the low-lying topography.

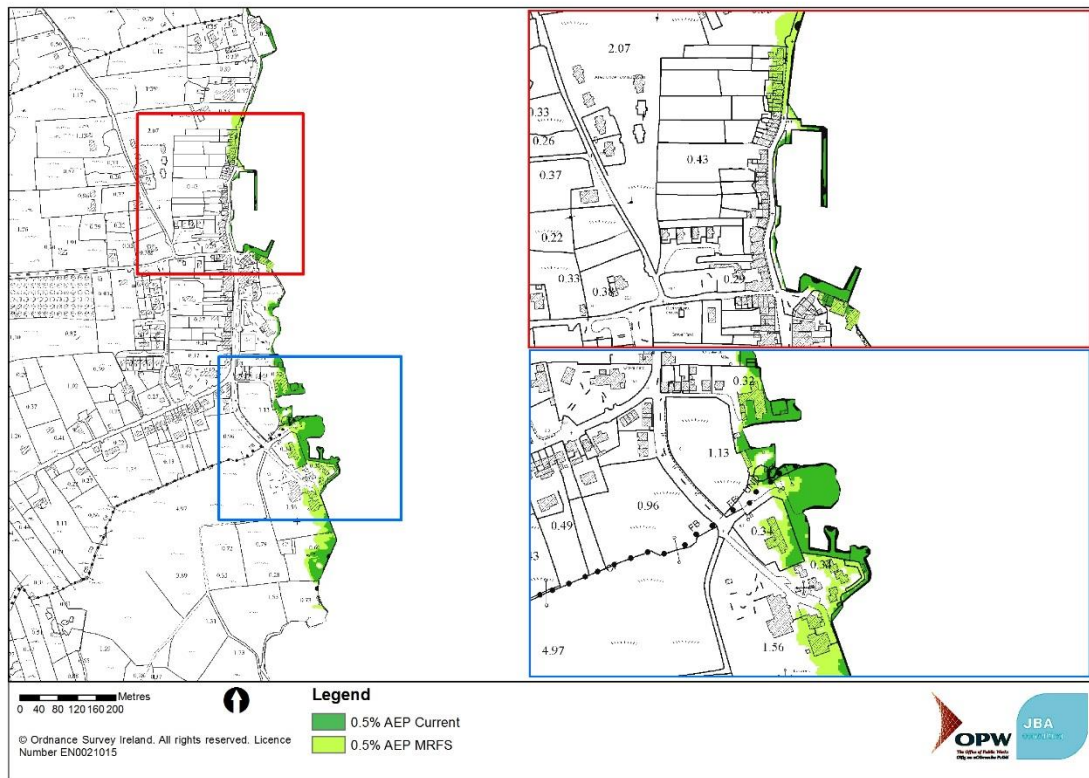
1.2.2 Future Flood Risk

The future scenarios, based upon the CFRAM specification climate change projections alter the profile of flood risk in Roundstone. Figure 1-6 below shows the current and medium range future extents for the 0.5% AEP tidal design events. The increase in sea level of 0.50m over the course of the next 100 years under the medium range forecast is the only driver of change in tidal flood risk.

¹ RPS Consulting Engineers. (2012) Irish Coastal Wave and Water Level Modelling Study (ICWWS)

Of particular importance is the introduction of new flood risk areas, particularly in the south of the AFA. Flood mapping indicates that an additional 20 properties are flooded under the medium range future scenario. This demonstrates the need to consider future changes in flood risk as part of the development of any management methods.

Figure 1-6: Current and future (MRFS) 0.5% AEP tidal flood extent



1.2.3 Pluvial, groundwater and sewer flood risk

There is a risk of pluvial flooding in Roundstone, as indicated in the PFRA in Figure 1-7. The topography of the town means that pluvial flooding will pond behind the quay walls in an area that is already at risk. This risk will need to be considered as part of any flood management methods.

Figure 1-7: Pluvial flood risk maps



Groundwater flooding has not been flagged as a local flooding issue at previous stakeholder consultations or desktop studies.

1.3 Economic Benefit

To provide an understanding of the likely scale of a cost beneficial scheme within Roundstone 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 €20,769 and €1.3 million in the 1% AEP event for the current and MRFS respectively. Capping reduces damages to €1.2 million in the MRFS.

Figure 1-9 shows the number of properties flooding during the different design events for the current and MRFS. 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 1-10 details the distribution of the damages across the AFA

Figure 1-8: Property Damages (Current, Uncapped and Capped)

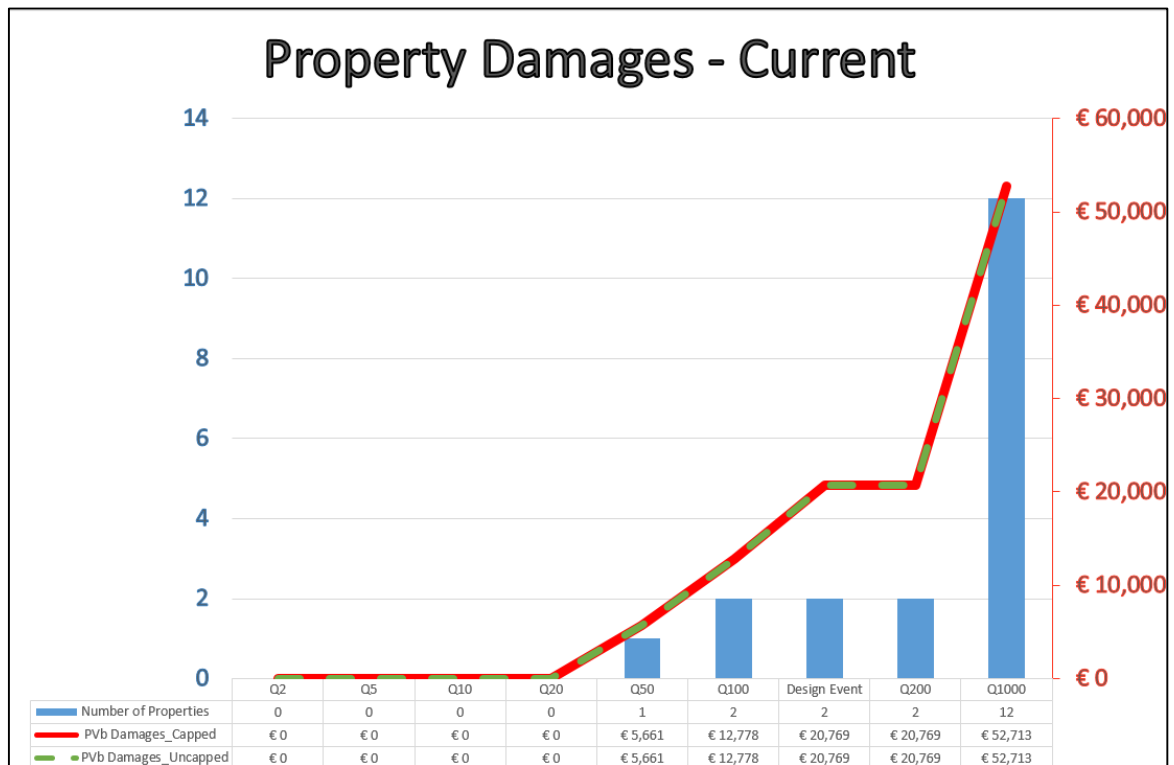


Figure 1-9 shows the damages that can be expected when climate change is taken into consideration. There is a significant increase in the number of properties affected and the resulting damages. The increase in damages is related to an increase in the frequency of flooding, greater depths of flooding and new areas becoming inundated. It is also noted that in the MRFS scenario, the onset of flooding of properties is the 50% AEP event.

Figure 1-9: Property Damages (Current and MRFS, Uncapped and Capped)

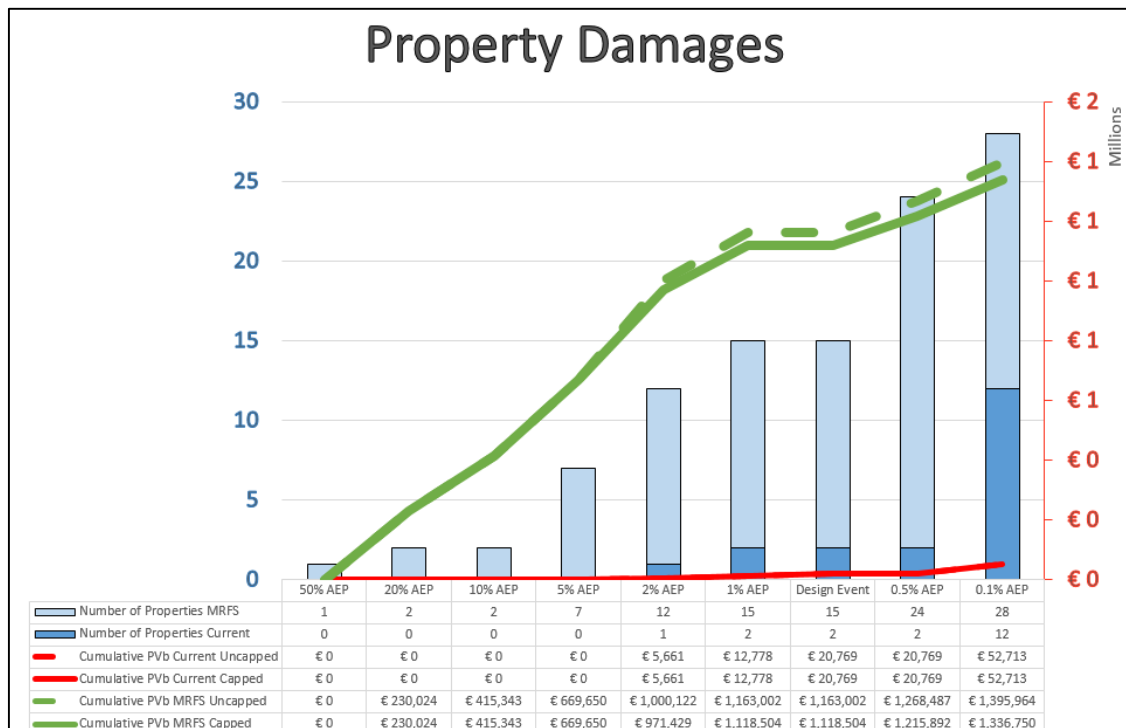
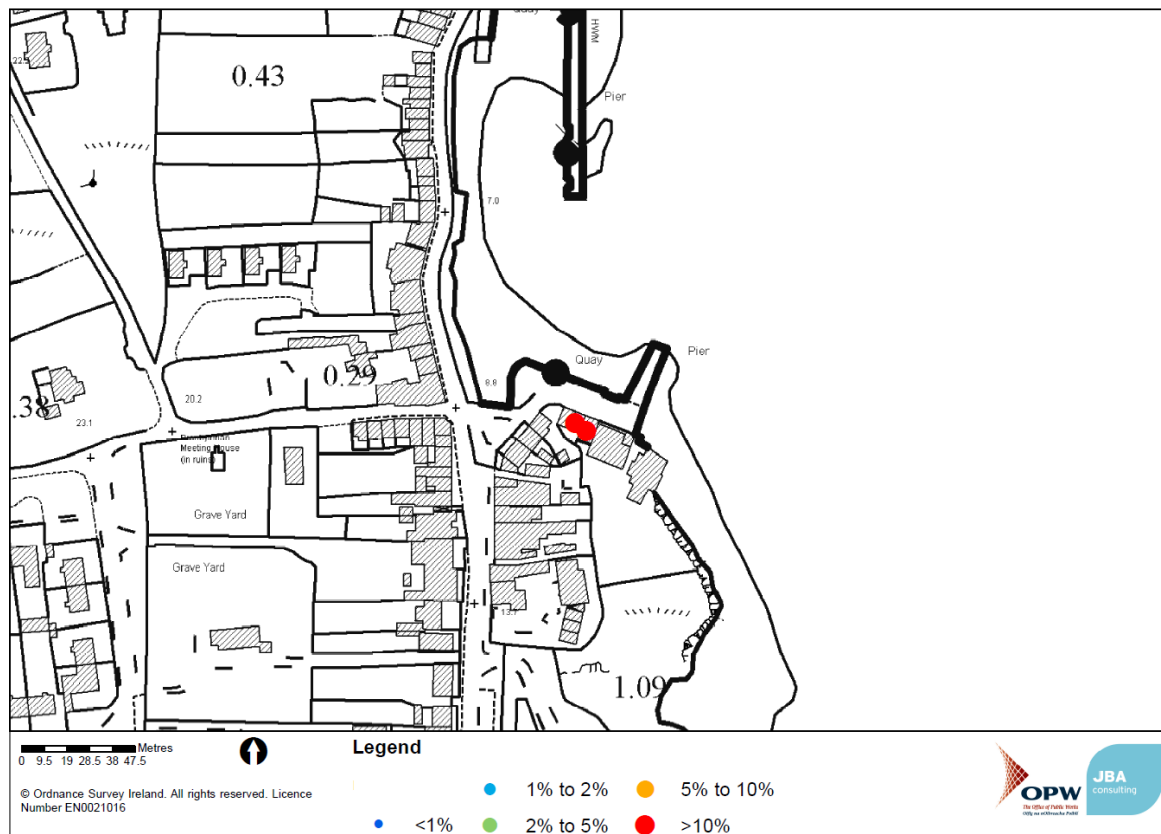


Table 1-1: Flood cell property damages (current and MRFS)

	Return Period (% AEP)							
	50%	20%	10%	5%	2%	1%	0.5%	0.1%
Current								
No. of properties	0	0	0	0	1	2	2	12
PV Damages (€)	0	0	0	0	5,661	12,778	20,769	52,713
MRFS								
No. of properties	1	2	2	7	12	15	24	28
PV Damages (€)	0	230,024	415,343	669,650	971,429	1,118,504	1,215,892	1,336,750

Figure 1-10: Distribution of property damages

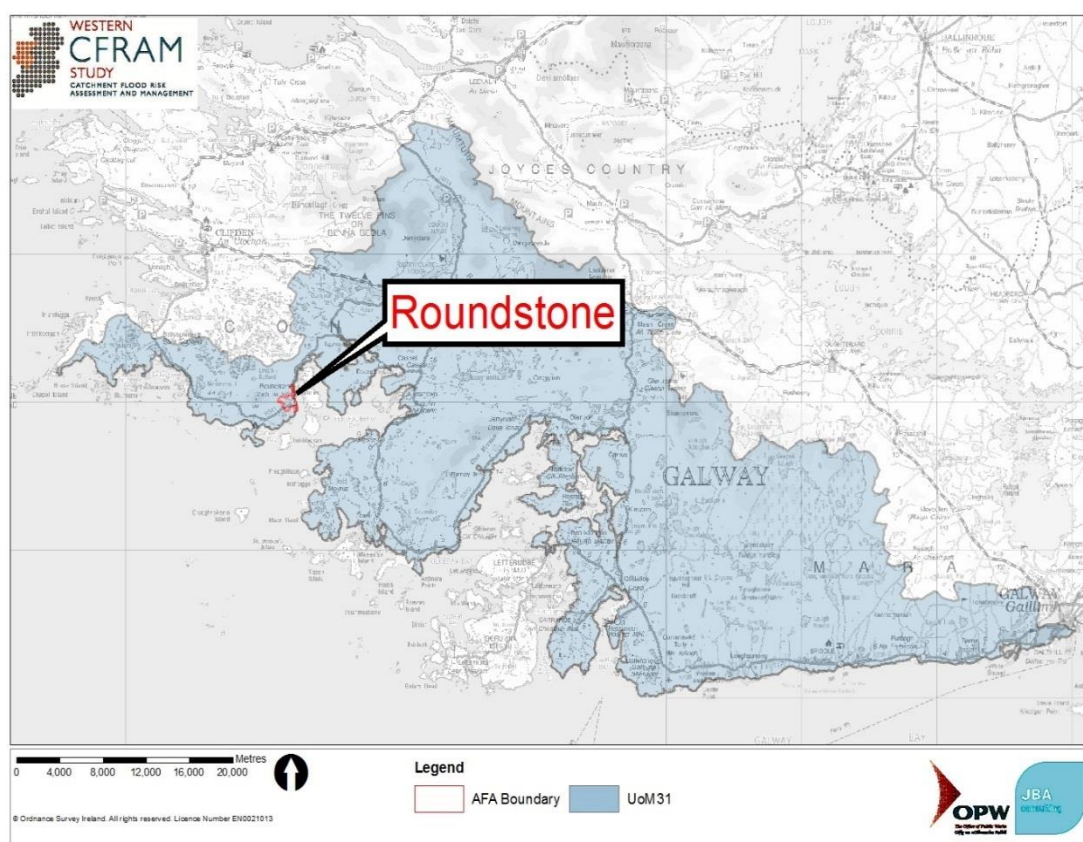


2 Scheme Spatial Scales of Assessment

2.1 Overview

This section documents the analysis of spatial scales of assessment and the identification of flood cells for the Roundstone options appraisal. The interactions between the flood risk, hydrological, hydraulic, economic, social, cultural and environmental aspects of Roundstone have been considered. Figure 2-1 shows the location of Roundstone in relation to other AFAs within the west Galway region. It is also evident that Roundstone is the only AFA within the Galway Bay North UoM 31. 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: Galway Bay North UoMs Overview



2.2 Spatial Scales of Assessment

2.2.1 Unit of Management Spatial Scale

There is only one AFA within the Galway Bay North 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.

2.2.2 Sub-Catchment Spatial Scale – Roundstone Bay

Roundstone is located close to the mouth of Roundstone Bay. There are other AFAs in Galway Bay also affected by tidal flooding; Galway City, Oranmore and Kinvarra. Tidal flooding is predictable and tends to coincide with the scheduled high tide. The OPW has developed a national tide and storm forecasting system. The system was implemented on a trial basis from October 2012 to May 2013. Whilst the cost of flood forecasting would not be feasible for Roundstone alone,

it could be cost beneficial when analysed in conjunction with other AFAs in the general vicinity, such as Oranmore and Galway City.

Any structural methods located in Roundstone Bay to protect Roundstone from flooding are likely to directly impact upon the environment (SACs and SPAs).

2.2.3 AFA Spatial Scale - Roundstone

Localised structural methods will be assessed on an AFA scale. This will include analysing the suitability of flood containment methods. Any containment methods in Roundstone will not have an effect on water levels in other AFAs due to its secluded location within Roundstone Bay. Any flood method within the bay is likely to impact on the Cregduff Lough and Connemara Bog Complex SACs.

Roundstone is a standalone AFA as it is affected by coastal flooding only so there is no upstream or downstream AFA affected. An AFA option to protect tidal inundation in the pier area will need to protect the area in its entirety otherwise flood defences would be bypassed.

2.3 Key environmental, social and cultural constraints

This section summarises the social, cultural and environmental issues relating to flood risk in Roundstone and the spatial scales they relate to. It is noted that this will be covered in greater depth as part of the SEA, however to inform the initial screening assessment work it is worthwhile providing an overview of the key constraints at an early stage.

2.3.1 West of Ireland (Mayo, Galway, Sligo)

Roundstone is on the Wild Atlantic Way and is nestled amongst the Twelve Bens, in the heart of Connemara. In the town the quay has numerous pubs, cafes and craft shops that maximise the scenic location and are located close to the waterfront. Flooding is likely to impact upon visitor numbers as there is only one approach road from Galway City (R341) and the depths of flooding expected would make this road impassable for most traffic.

Connemara is a world-renowned area of natural beauty and attracts thousands of tourists every year. Flooding is unlikely to impact on the profile of Connemara as a tourist destination, but flood management methods that significantly alter the landscape of the environs or damage local habitats could potentially reduce visitor numbers.

Flooding in Roundstone is unlikely to have a notable economic or social impact on the rest of Ireland. Connemara Bog Complex and Cregduff Lough are designated SACs and the Natura 2000 designated sites are important internationally, so any negative impacts to habitats or species could potentially have a significant influence on a European scale.

2.3.2 West Galway/Galway Bay North

Roundstone is identified as an 'Other Settlements & the Countryside' in the Galway County Development Plan 2015-2021. Other Settlements are defined as settlements that are predominantly rural in nature. They provide an important, limited service to the local community through existing facilities such as national schools, post offices etc. The growth and development of these 'Other Settlements' is important to facilitate the needs of local communities.

The R341, which runs through Roundstone, is a designated route on the Wild Atlantic Way and is the primary connection between Galway City and southern Connemara. The R341 is within the 0.5% AEP tidal flood extent and flood risk to it will increase with climate change in the future scenarios. There is an alternative approach into the village from the north, however, it is no more than a botharín and could only accommodate small, single-lane traffic. The R341 is an important transport link for the area and the future vulnerability of network links 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.

2.3.3 Roundstone Bay

Roundstone Bay is bounded by four SACs: Connemara Bog Complex, Rosroe Bog, Cregduff Lough and Dog's Bay. 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 Roundstone has many pubs, cafes and shops that line the pier and main street. Flooding is likely to affect this trade due to impassable access roads, as will disruption during construction of any structural methods. Its location and scenic views is an essential amenity of the village and its tourist trade is reliant on these picturesque views being maintained. The local library, which serves a dual function as a community centre, also is affected by flooding.

Access from the north of the village to Dog's Bay, a renowned stretch of beach, is affected by flooding. Many visitors' primary reasons for travelling to Roundstone is to visit this beach.

3 Screening of Possible Methods and Options

3.1 Introduction

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 assessment 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 assess the existing scenario. Currently, the OPW issues high tide advisory. 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. This high tide warning is issued to local authorities. As a result of this and other warning indicators such as the local news, reviewing tide tables etc. flood resilience methods may be put in place.

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 Roundstone in the current and the future scenario. Along the pier and southern extent of the AFA, risk levels are classified as significant danger to most. An economically, environmentally and socially acceptable solution to alleviate flooding is sought to protect the town.

Figure 3-1: Risk to Life (Current)

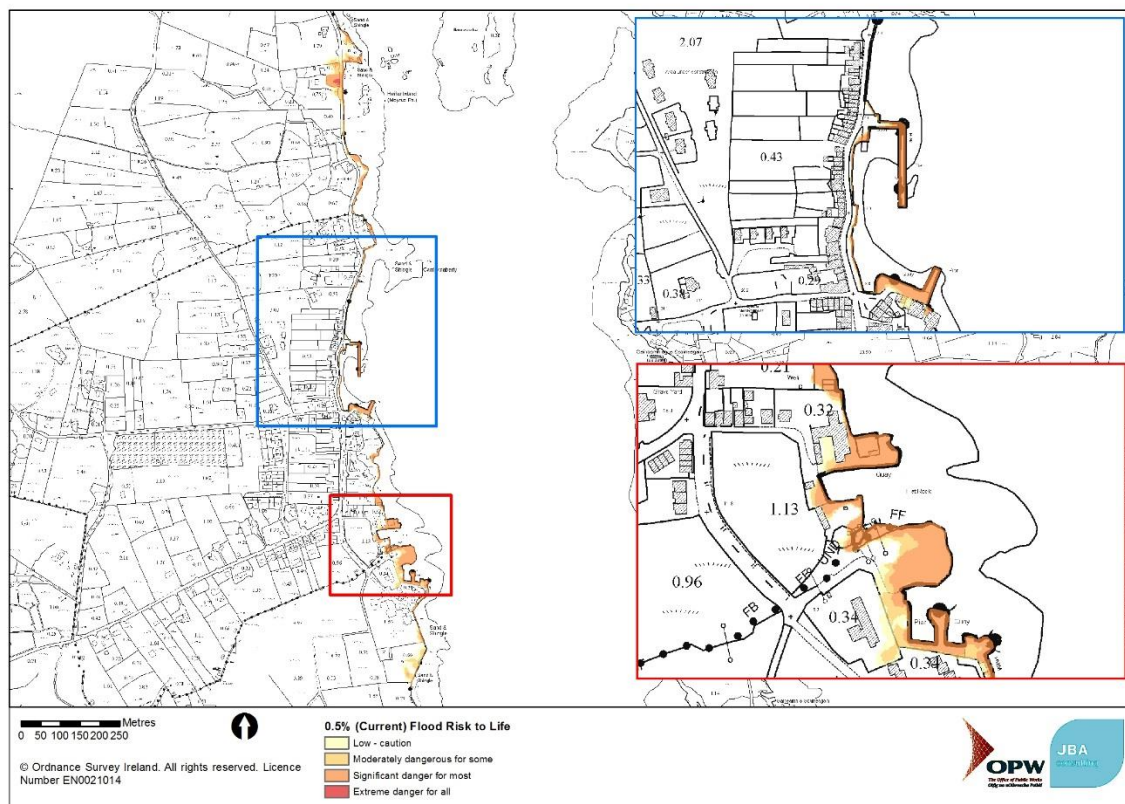
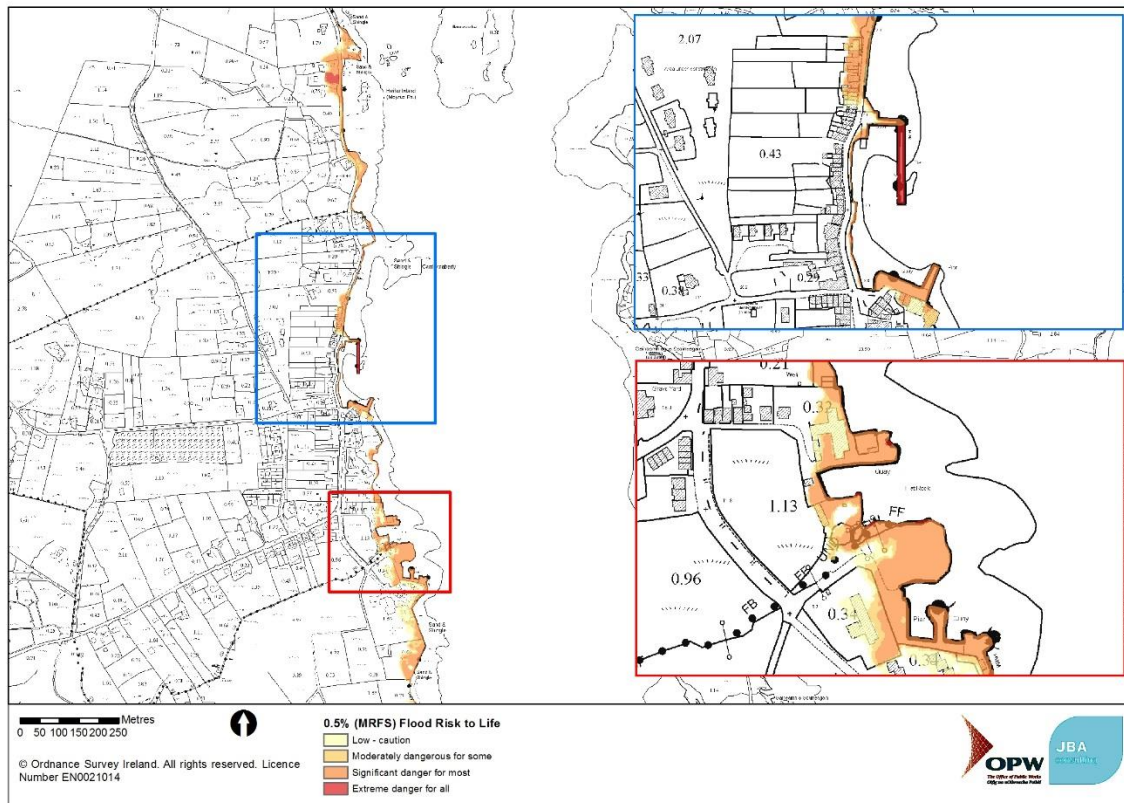


Figure 3-2: Risk to Life (MRFS)



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. In the current Scenario the area is affected by coastal flooding only, therefore, only coastal methods have been screened.
- **Economic** - Technically feasible methods have been reviewed for economic viability. As noted previously, approximate benefits associated with the 0.5% AEP coastal event are €20,769, 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 method may have a detrimental impact on an environmentally or culturally valuable or protected site which would result in the need an Imperative Reasons of Overriding Public Interest (IROPI) 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. Roundstone is significantly affected by the effects of climate change with estimated benefits increase from €20,769 in the current scenario to €1,225,955 in the MRFS. Any methods preferred for the village will have to be sustainable and adaptable to the potential impacts of climate change.

Table 3-1: FRM Method Screening

Possible Flood Risk Management Method	Technical	Economic	Health and Safety	Initial Screening Result	Comment
Non - Structural Methods					
Do Existing	Pass	Pass	Pass	Viable	There is a moderate-high risk to society and where feasible this risk should be reduced by the implementation of methods be that structural or non-structural methods. The long term viability of the existing situation is an issue given the significant risk to life in future scenario
Coastal Methods					
Tidal Barrier	Pass	Fail	-	Not Viable	A barrier would have to be placed across Roundstone Bay, which is part of the Connemara Bog Complex and Dog's Bay SACs. The cost of a barrier is estimated to be close to €7million making it an uneconomically feasible option for either present day scenario or future scenario.
Flood Containment Methods					
Walls	Fail	-	-	Not Viable	Flood walls are impractical options for protecting properties at risk on the pier and quay as the walls would prevent access to the quayside. It is a working pier and construction of a permanent flood wall is not feasible, even a partial wall to reduce demountable length would hinder access to the pier and prevent vehicular access for the pier. Further walls would be required in the south of the AFA in the MRFS.
Embankments	Fail	-	-	Not Viable	In Roundstone the road is adjacent to the quay so there is insufficient space for embankments
Demountable Walls	Pass	Fail	-	Not Viable	This method would require a 50m demountable section to be raised in times of high risk. The demountable would need to be 1.2m in height. A flood forecasting system would be needed to tie into national tide storm surge system, which would provide adequate lead time. Demountable walls are estimated to cost €481,006 and are not economically viable.
Road Raising	Fail	-	-	Not Viable	The raising of road is not feasible within Roundstone. Roads levels in the village are determined by finished floor levels and cannot be altered.
Individual Property Protection Methods					
Relocation of Properties	-	-	-	Not Applicable	Relocation of properties is stressful for the owners and is preferred where there are no alternative viable options. The current frequency of flooding within Roundstone does not justify consideration of this method.

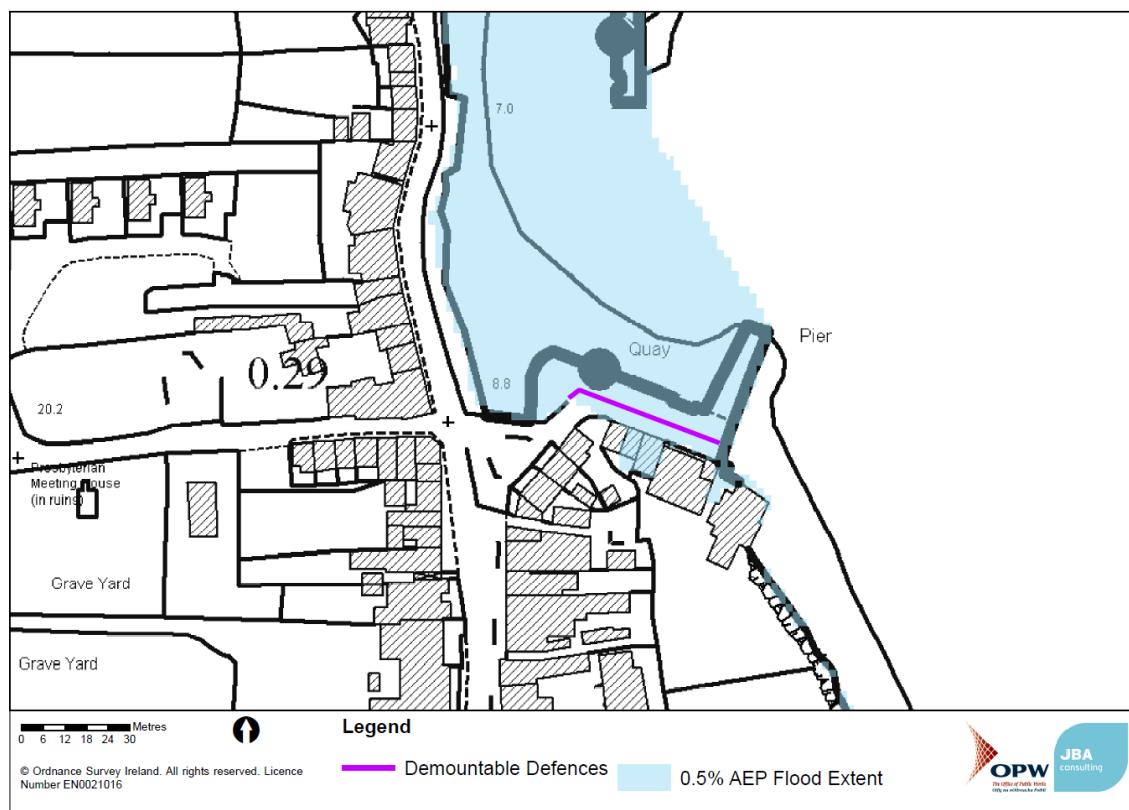
3.4 Screening for possible options

Pulling together the individual methods discussed above, Table 3-2 details the management options for Roundstone. The preferred option is demountable defences along the pier. The screening assessment has found no economically viable structural methods for Roundstone. The options assessed are presented in Table 3-2 and Figure 3-3.

Table 3-2 Summary of options for Roundstone

	Option 1	Option 2
Present day	Do Existing - Individual Property Resilience This option would continue the existing scenario and provide simple resilience methods only such as raising awareness and the potential for individual property protection.	The provision of demountable defences at times of flood risk.
In the future	This option will delay flood risk management methods for Roundstone until further information on climate change and its implications becomes available.	The defence heights could be extended to accommodate climate change flows.
Conclusions	This option does not provide a design standard of protection for the present day but allows future management of flood risk to be considered.	This option provides protection to the 1% design standard. The demountables would maintain access to the working harbour.
CBR	Not applicable	0.04

Figure 3-3: Locations of flood mitigation methods



A breakdown of the estimated costs for the options for Roundstone 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 A. Individual method costs are detailed in Appendix B.

Table 3-3: Indicative screening costs

Option 1- Do Existing		€
Do Existing - No Costs Involved		
Option 2- Demountable Walls		€
Construction costs		
Demountable Barriers (1.2m high for 50m)		56,100
Construction costs - Subtotal		56,100
Preliminaries	32%	17,952
Capital costs - Subtotal		74,052
Optimism Bias	50%	37,026
Capital costs - Total		111,078
Operation and maintenance net present value		
Demountable O&M Cost		222,634
Event Costs		23,985
Operation and maintenance - Subtotal		246,619
Optimism Bias	50%	123,310
Operation and maintenance costs - Total		369,929
Option cost for cost benefit analysis		481,007

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 Climate Change

Within Roundstone there is a significant risk associated with increasing sea levels as a result of climate change. The predicted flooding will result in a significant increase in the number of properties at risk of inundation and increases in depths in those properties already prone to flood.

Because the bulk of the risk is in the future, no cost beneficial management option has been put forward to manage flood risk in the current FRMP. The predicted risk has not yet materialised so the justification to manage that risk is not there and funding for such a scheme would have a very low priority. It is, however, also not appropriate to ignore the fact that there are significant increases in flood risk likely to occur. Therefore, whilst the proposed options do not include for methods to manage this risk, the following summarises considerations for the management of this risk into the future.

Of primary consideration for Roundstone is the balance between preserving the amenity benefits for the town associated with the harbour front against the significant increase in flood risk to life that is going occur with climate change.

Options not currently viable in Section 3.4 may become cost effective with increasing sea level rise but they will also reduce in effectiveness. To continue to manage flood risk, the scale of the proposed options will also need to increase. In the HEFS with an increase in sea level of 1m predicted, raised defences are likely to be excessive and more unconventional options such as relocation of properties may need to be considered.

3.6 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) - 23rd of September 2015

On September 23rd 2015 a public consultation was held at the Roundstone Community Centre to outline possible methods for the town.

This PCD was attended by no (zero) people.

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 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.

Full discussions on non-structural methods have 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 Roundstone.

Non-Structural Methods

Planning Development and Control

Spatial Planning and Impacts on Development

Roundstone falls within the Galway County Development Plan, and does not have a separate Local Area Plan. The Galway County Plan included a Screening SFRA which identifies and plots a series of flood risk indicators. No specific, or more detailed, SFRA has been carried out.

Current zoning within the County Development Plan SFRA are based on PFRA flood maps and should be updated to consider CFRAM Flood Zones.

There is an increased future risk of flooding in the northern section of Roundstone during a 1% AEP flood event with areas within the town centre and southern section experiencing extension of Flood Zone A & B.

Further detail on flood risk and land zoning objectives under both current and future scenarios is provided in Section 4 of the UoM331 Overarching Report.

Sustainable Drainage Systems

The coastal nature of Roundstone which is developed in a ribbon along the coast limits the necessity for SuDS as flood risk management methods, however they provide important water quality functions for the receiving coastal and groundwater bodies. There is however, a high level of pluvial risk behind the current sea walls and SuDS methods can help alleviate this.

Due to the even distribution of runoff routes from the hills there is little potential for regional attenuation of runoff to reduce surface water flood risk in Roundstone.

More detail on the applicability of SuDS in Roundstone, and indicative storage volumes, are provided in Section 4 of the UoM31 Overarching Report

Flood Preparedness Methods

Flood Forecasting and Warning Systems

In Roundstone the current risk is from tidal flooding. There is potential to tie into the national storm surge model developed by the OPW. The resolution is high in Galway Bay but is currently only operated for winter and autumn months.

Emergency Response Planning

Until such time as a scheme is built in Roundstone 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.

As Roundstone is a tourist destination many of the residents may be unaware of the flooding risk. It is imperative that the locals develop and implement an evacuation plan at time of high risk.

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 limited attendance to both the flood mapping and POR Public Consultation Days (PCD) in the town. Public awareness through education schemes or increased awareness by the relevant authorities is need to ensure that the residents of the area are aware of the risk.

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. Flood depths currently in Roundstone Pier are greater than 600mm so resilience is currently preferred to individual property protection 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 as is the case in some properties. For the three properties affected permanent individual property protection is a feasible solution, as flood depths in the 0.5% AEP event are less than 0.5m. The effectiveness of this option will decrease in the future and the 0.5% AEP design standard may not be met as flood depths in excess of 0.75m are expected for the MRFS 0.5% AEP coastal event in some properties.

Maintenance

Ongoing maintenance of the sea walls, coastal structures and surface water drainage network and outfalls is critical to maintaining the level of flood risk management provided to Roundstone.

5 Conclusion

The hydraulic modelling demonstrated that there is flood risk to properties along the coast at Roundstone as a result of coastal flooding, with still-water level being the primary mechanism of flooding.

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 Roundstone, the proposed individual property protection 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. These should be utilised as viable methods to reduce risk in the short term and 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	
Roundstone	€ 150,000	€ 150,000	€ 150,000	€ 150,000	€ 150,000	Roundstone

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

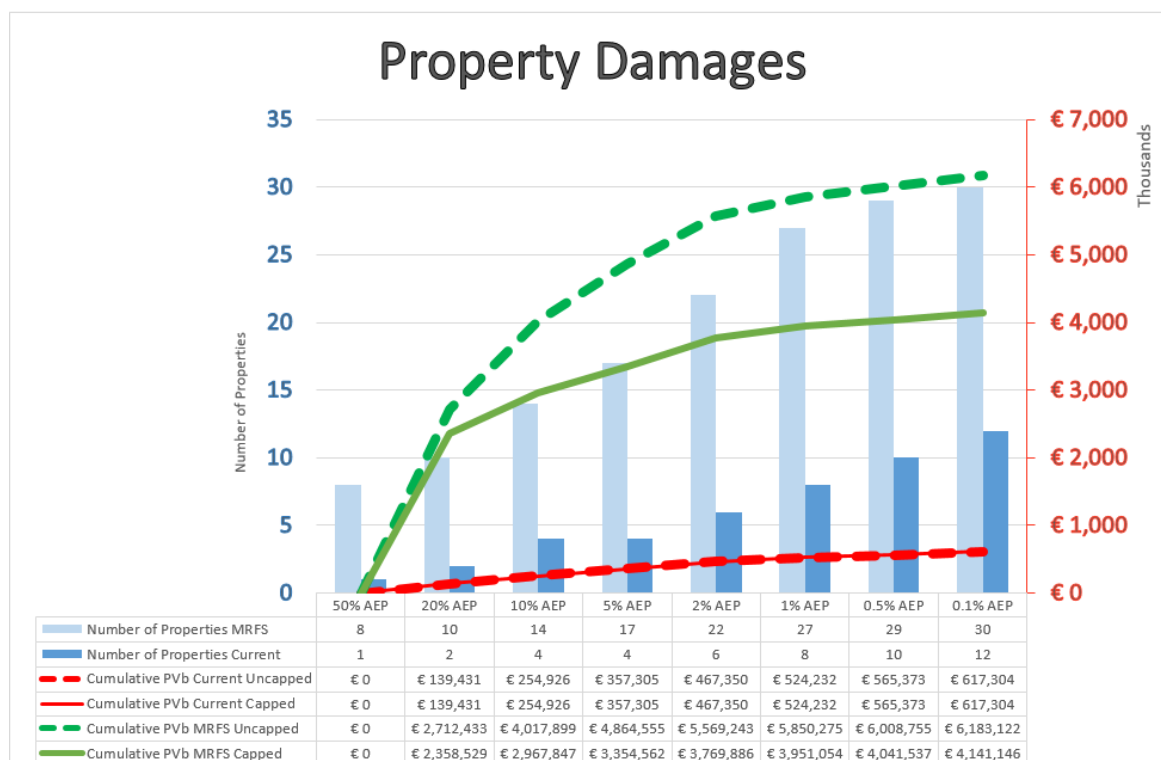
Property type	Rateable value per m ² (€)
Retail	161
Office	115
Warehouse	51
Leisure & Public	37
Industry	41

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 Damages)



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-5 and details of the constituent parts provided in the following sections.

Table A-5: Screening costs (Sample 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-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 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 - Demountable Defences

Demountable defences (50m @1.2m high)

Single Method Capital Cost Tool	
Demountable Type	For Supply and Ground beam installation
Material	Imported
Barrier Length (m)	50
Barrier Height (m)	1.2
Span (m)	5
Barrier unit rate (€/m)	€ 1,020
Over-ride unit rate (€/m)	
Total costs (€)	€51,000
Apply update to unit rate (CPI) if appropriate (€) (1.0)	€ 51,000
Enter other applicable costs (€)	-
Total capital cost (€)	€ 51,000
Consider amendments based on site issues/constraints (€) (Method factor 10%)	€56,100
Preliminaries (32%)	€ 17,952
Total capital cost (€)	€ 74,052

Operation and Maintenance Cost Tool	
Barrier length total (m)	50
Total annual O&M costs (€)	€10,432
Present value O&M costs (€)	€ 222,634

Event Costs	
Barrier length total (m)	50
Total individual event costs (€)	€4,272
Present value event costs (€) (Assumes events once every five years to allow for practice and event costs) ³	€ 23,985 ⁴

Summary

Total PV Cost	
Total capital costs (€)	€ 74,052
Total Maintenance Costs	€222,634
Total Event costs	€23,985
Total PVc costs (€)	€ 320,671
Optimism bias rate (%)	50%
Total Cost including Optimism Bias (€)	€ 481,006

⁴ Breakdown of costs shown below (4,272 every five years discounted at 4% is €23,985) Below includes both operation and maintenance (10,432 annually discounted at 4% is €222,634) and event once every 5 years costs.

Discount rate:	4.0%	Present Value Factor:		22.341		Total PVc (€):	€320,671
Cash sum		€0	€74,052	€511,168	€51,264	€636,484	€320,671
year	Discount Factor	Cost Elements				TOTALS:	
		Enabling	Capital	Maint.	Event	Cash	PV
0	1.000	0	74,052			74,052	74,052
1	0.962			10,432	4,272	14,704	14,138
2	0.925			10,432		10,432	9,645
3	0.889			10,432		10,432	9,274
4	0.855			10,432		10,432	8,917
5	0.822			10,432	4,272	14,704	12,086
6	0.790			10,432		10,432	8,245
7	0.760			10,432		10,432	7,927
8	0.731			10,432		10,432	7,623
9	0.703			10,432	4,272	14,704	10,331
10	0.676			10,432		10,432	7,047
11	0.650			10,432		10,432	6,776
12	0.625			10,432		10,432	6,516
13	0.601			10,432	4,272	14,704	8,831
14	0.577			10,432		10,432	6,024
15	0.555			10,432		10,432	5,793
16	0.534			10,432		10,432	5,570
17	0.513			10,432	4,272	14,704	7,549
18	0.494			10,432		10,432	5,150
19	0.475			10,432		10,432	4,951
20	0.456			10,432		10,432	4,761
21	0.439			10,432	4,272	14,704	6,453
22	0.422			10,432		10,432	4,402
23	0.406			10,432		10,432	4,233
24	0.390			10,432		10,432	4,070
25	0.375			10,432	4,272	14,704	5,516
26	0.361			10,432		10,432	3,763
27	0.347			10,432		10,432	3,618
28	0.333			10,432		10,432	3,479
29	0.321			10,432	4,272	14,704	4,715
30	0.308			10,432		10,432	3,216
31	0.296			10,432		10,432	3,093
32	0.285			10,432		10,432	2,974
33	0.274			10,432	4,272	14,704	4,030
34	0.264			10,432		10,432	2,749
35	0.253			10,432		10,432	2,644
36	0.244			10,432		10,432	2,542
37	0.234			10,432	4,272	14,704	3,445
38	0.225			10,432		10,432	2,350
39	0.217			10,432		10,432	2,260
40	0.208			10,432		10,432	2,173
41	0.200			10,432	4,272	14,704	2,945
42	0.193			10,432		10,432	2,009
43	0.185			10,432		10,432	1,932
44	0.178			10,432		10,432	1,857
45	0.171			10,432	4,272	14,704	2,517
46	0.165			10,432		10,432	1,717
47	0.158			10,432		10,432	1,651

48	0.152			10,432		10,432	1,588
49	0.146			10,432		10,432	1,527

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.

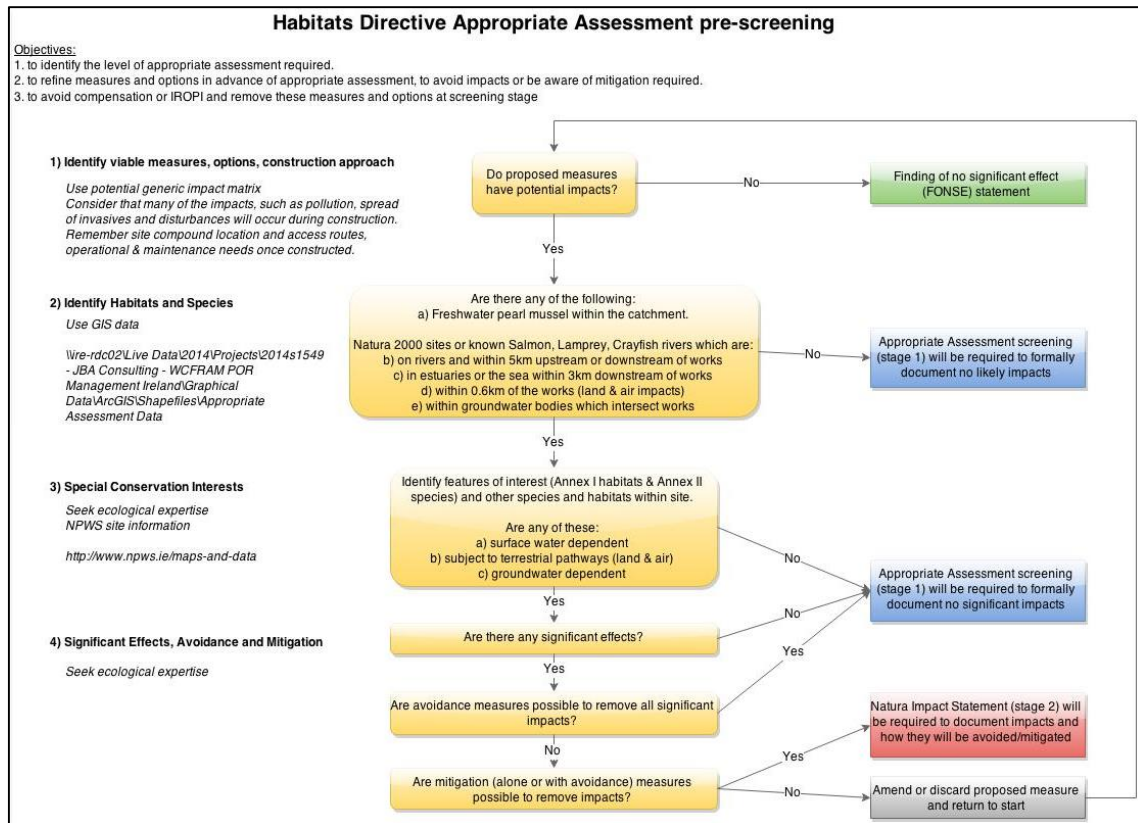
Table C-4: Environmental considerations

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-6.

Figure C-6: Habitats Directive Appropriate Assessment pre-screening



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