



South Eastern CFRAM Study UoM17 Preliminary Options Report

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ABBREVIATIONS

AEP	Annual Exceedance Probability
AFA	Area for Further Assessment
BCR	Benefit Cost Ratio
CFRAM	Catchment Flood Risk Assessment and Management
CPI	Consumer Price Index
DD	Drainage District
DEHLG	Department of Environment, Community and Local Government (previously known as the Department of Environment, Heritage and Local Government)
FCERM	Flood or Coastal Erosion Risk Management
FFL	Finished Floor Level
FHRC	Flood Hazard and Research Centre
FRA	Flood Risk Assessment
FRM	Flood Risk Management
FRMP	Flood Risk Management Plan
HA	Hydrometric Area
HEFS	High end future scenario
IRR	Individual Risk Receptor
MCM	Multi Coloured Manual
MPW	Medium Priority Watercourse
MRFS	Mid-range future scenario
OPW	Office of Public Works
PFRA	Preliminary Flood Risk Assessment
pvD	present value Damage
RBD	River Basin District
RMP	Record of Monuments and Places
SAC	Special Area of Conservation
SMR	Sites and Monuments Record
SI	Statutory Instrument
SoP	Standard of Protection
SPA	Special Protection Area
SSA	Spatial Scale of Assessment
UoM	Unit of Management

1 INTRODUCTION

The Office of Public Works (OPW) commissioned RPS to undertake the South Eastern Catchment-based Flood Risk Assessment and Management Study (South Eastern CFRAM Study) in July 2011. The South Eastern CFRAM Study was the third River Basin District (RBD) level CFRAM study to be commissioned in Ireland under the EC Directive on the Assessment and Management of Flood Risks 2007, the EU Floods Directive, (Reference 1) as implemented in Ireland by SI 122 of 2010 European Communities (Assessment and Management of Flood Risks) Regulations 2010 (Reference 2). The South Eastern CFRAM Study will culminate in 2016 with the development of Flood Risk Management Plans (FRMPs) which will include Flood Risk Management Measures designed to deal with identified flood risk.

Unit of Management 17 (UoM17) is located within the South Eastern CFRAM study area (Figure 1.1). The UoM17 Preliminary Options report details the generic methodology for the flood risk assessment and development of flood risk management options to be carried out for all areas being studied in the South Eastern CFRAM Study, also providing the specific findings for the Areas for Further Assessment (AFAs) found in UoM17. The preferred Flood Risk Management Options identified in this report, and the subsequent Flood Risk Management Plan, are recommended to be developed and progressed by more detailed subsequent studies.

1.1 GENERAL INFORMATION ON THE SOUTH EASTERN CFRAM STUDY

As shown in Figure 1.1, the South Eastern CFRAM Study Area covers approximately 12,857 km² and includes six Units of Management; (UoM11 (Owenavorrageh), UoM12 (Slaney and Wexford Harbour), UoM13 (Ballyteigue-Bannow), UoM14 (Barrow), UoM15 (Nore) and UoM17 (Colligan-Mahon). UoM16 (Suir) is covered by the Suir pilot CFRAM Study and covers an area of approximately 3,542 km².

There is historical evidence of a high level of flood risk within certain areas of the South Eastern CFRAM Study area with significant coastal and fluvial flooding events having occurred in the past. A detailed account of historical flooding can be found in the South Eastern CFRAM Study inception reports in which can be downloaded from the South Eastern CFRAM Study website at www.southeastcfframstudy.ie.

The objectives of the South Eastern CFRAM Study are to:

- Identify and map the existing and potential future flood hazard within the Study Area.
- Assess and map the existing and potential future flood risk within the Study Area.
- Identify viable structural and non-structural options and measures for the effective and sustainable management of flood risk within the Study Area.
- Prepare a set of Flood Risk Management Plans (FRMPs) for the Study Area, and associated Strategic Environmental and, as necessary, Habitats Directive (Appropriate) Assessment, that set out the policies, strategies, measures and actions that should be pursued by the relevant bodies, including OPW, Local Authorities and other stakeholders, to achieve the most cost

effective and sustainable management of existing and potential future flood risk within the Study Area, taking account of environmental plans, objectives and legislative requirements and other statutory plans and requirements.

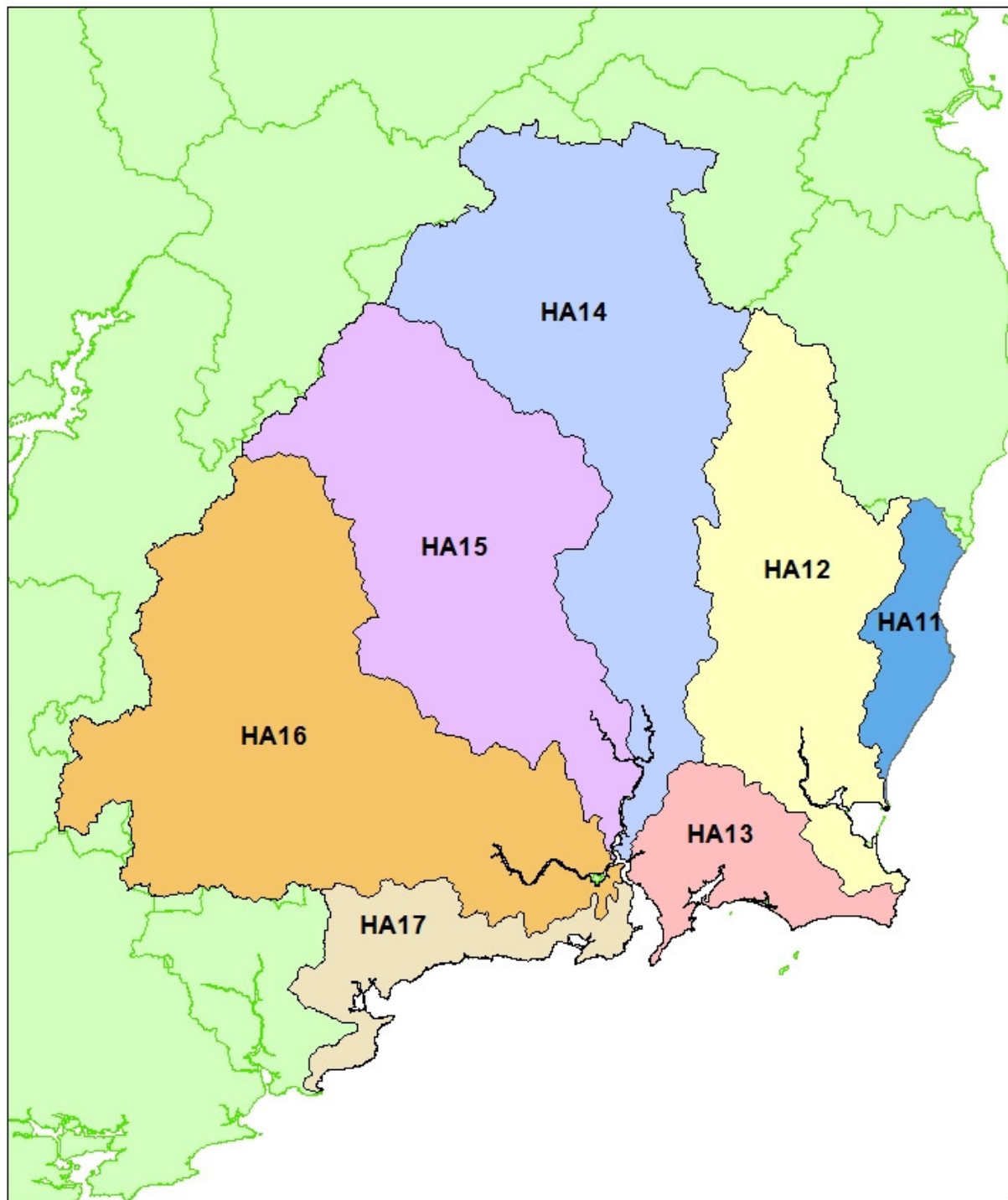


Figure 1.1 - South Eastern CFRAM Study Area

*UoM16 Flood Risk Management Options have been developed under the Suir pilot CFRAM Study

1.2 FLOOD SOURCES

Two flood sources are considered under CFRAM analysis; fluvial and coastal.

1.2.1 Fluvial Flooding

Fluvial flooding occurs when rivers and streams break their banks and water flows out onto the adjacent low-lying areas (the natural floodplains). This can arise where the runoff from heavy rain exceeds the natural capacity of the river channel, and can be exacerbated where a channel is blocked or constrained or, in estuarine areas, where high tide levels impede the flow of the river out into the sea. While there is a lot of uncertainty on the impacts of climate change on rainfall patterns, there is a clear potential that fluvial flood risk could increase into the future.

1.2.2 Coastal Flooding

Coastal flooding occurs when sea levels along the coast or in estuaries exceed neighbouring land levels, or overcome coastal defences where these exist. This flooding mechanism is known as tidal inundation or coastal mechanism 1.

Coastal flooding also occurs when waves overtop the coastline or coastal defences. This flooding mechanism is known as wave overtopping or coastal mechanism 2.

Mean sea levels are rising as a result of climate change, and consequentially coastal flood risk is expected to increase over the coming decades.

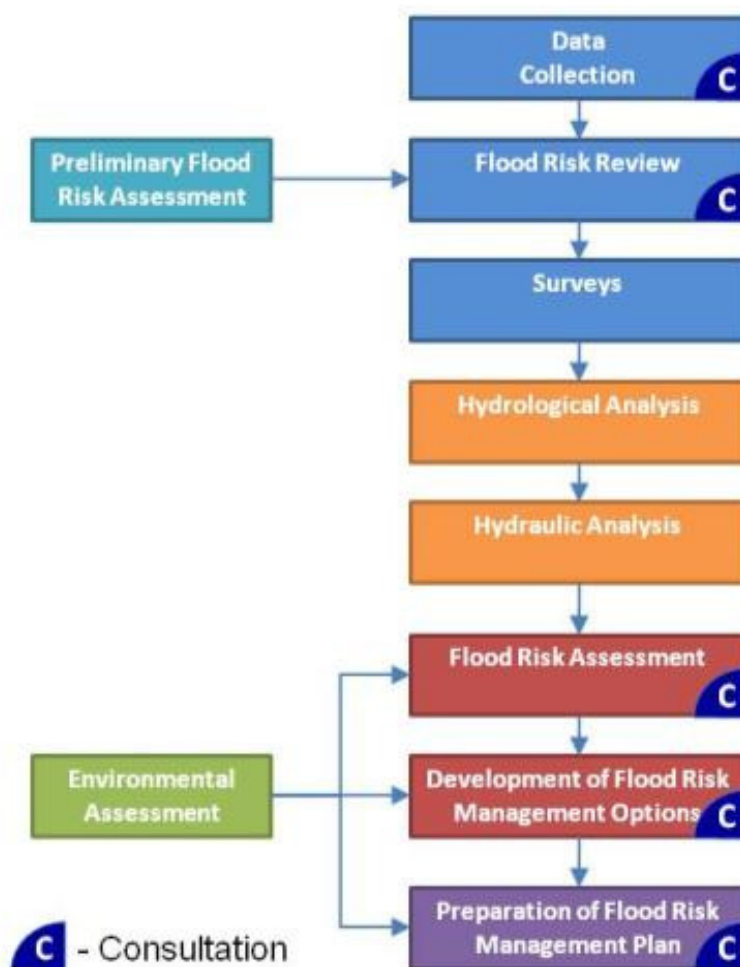
1.3 SOUTH EASTERN CFRAM STUDY ACTIVITIES

To achieve the study objectives the South Eastern CFRAM Study has carried out a range of activities. Each activity, while focusing on a specific task, is connected to and informs the other activities. Figure 1.2 summarises the activities involved in the study and how they relate to each other.

The main outputs and reports associated with the study activities are listed in Table 1.1. An explanation of each activity's output(s) are summarised in sections 1.3.1 to 1.3.11.

Table 1.1 - Outputs of study activities

Activity	Output
Preliminary Flood Risk Assessment	National fluvial flood maps Identification of Areas for Further Assessment
Data Collection	-
Flood Risk Review	Confirmation of Areas for Further Assessment
Surveys	Survey data for all watercourses identified for assessment
Hydrological Analysis	Estimation of flows for all watercourses for all flood events Hydrology report
Hydraulic Analysis	Flood hazard maps Hydraulics report
Flood Risk Assessment	Flood risk maps Preliminary options report
Development of Flood Risk Management Options	Identification of flood risk management measures and options Preliminary options report
Environmental Assessment (including Strategic Environmental Assessment (SEA) & Appropriate Assessment (AA))	SEA Screening Statement, SEA Scoping Report, SEA Environmental Report, SEA Statement AA Screening Statement, Natura Impact Statement
Communications Activities	Influence on draft maps, options and FRMPs Communications synthesis reports
Preparation of Flood Risk Management Plan	Flood Risk Management Plan

**Figure 1.2 – South Eastern CFRAM Study activities**

1.3.1 Preliminary Flood Risk Assessment

In 2011 the OPW completed a Preliminary Flood Risk Assessment (PFRA) in accordance with the EU Floods Directive. The objective of the PFRA is to identify areas where the risks associated with flooding might be significant. The PFRA provides maps showing areas deemed to be at risk. The PFRA identified Areas for Further Assessment (AFAs) which were then taken forward in the CFRAM programme. The documentation associated with the PFRA including the flood maps can be accessed through the national CFRAM website www.CFRAM.ie/pfra.

1.3.2 Data collection

An initial data collection exercise was carried out to capture the relevant information to meet the objectives of the project. The main proportion of this activity was carried out at the start of the project but this activity is also ongoing as new information is made available and new data requirements are identified. Details of the initial data collection process can be found in the South Eastern CFRAM Study inception reports which can be accessed through the South Eastern CFRAM Study website www.southeastcframstudy.ie.

1.3.3 Flood Risk Review

The Flood Risk Review (FRR) was completed in October 2011 for the South Eastern CFRAM Study. RPS was required to review the output of the preliminary flood risk assessment and all other information and knowledge readily available during the initial stages of the South Eastern CFRAM Study. The data was assessed and identified AFAs where potential significant flood risk exists or might be considered likely to exist including areas other than those identified through the PFRA. Areas where significant flood risk does not exist and no further assessment was required were also identified as part of the FRR. The findings of the FRR can be found in the Flood Risk Review Report and maps which can be accessed through the South Eastern CFRAM Study website www.southeastcframstudy.ie.

1.3.4 Surveys

Before progressing to the hydrological and hydraulic analysis activities the topographical data for each watercourse and associated floodplains identified for assessment was required. This activity started in 2011 and was completed in May 2013. The outputs of the survey were LiDAR information of floodplains, river channel cross sections and geometrical data for structures located in the river channel or influencing the hydraulic nature of the river.

1.3.5 Hydrological Analysis

The hydrological analysis encompasses all aspects of flood hydrology including review of historic flood events within the AFAs, flood frequency analysis and design flow estimation. The review of historic flood events and initial flood frequency analysis (to determine the statistical frequency / severity of historic flood events within the AFAs) was completed for the South Eastern study area in June 2012 and is contained within the Inception Reports. The second stage of the hydrological analysis focused on design flow estimation such that design flows for various risk scenarios could be defined and used as inputs for hydraulic modelling. The approach to design flow estimation relied heavily on defining the index flood, equivalent to the statistical median from a series of annual peak flood flows (equivalent to

a 50% chance of occurring in any given year). The design flow estimation included a more detailed flood frequency analysis to define appropriate flood growth behaviour for each catchment / sub-catchment in order to define design events based on scaling of the index flood flow. The hydrological analysis also included consideration of the factors which will affect future changes in flows such as catchment changes and climate change. The hydrological analysis stage overlapped with the hydraulic analysis as design flow estimates were tested and refined through the models against observed data. Details of the hydrological analysis can be found in South Eastern CFRAM Study UoM17 Hydrology Report.

1.3.6 Hydraulic Analysis

Dynamic hydraulic models have been developed for all the areas of assessment. These models simulated how each watercourse will react to various sizes of floods and the interaction with the surrounding floodplain. The output of this analysis is a Hydraulics Report in addition to a series of flood extent, zone, depth, velocity and risk-to-life maps known collectively as flood hazard maps which are generated based on the model results. Details of the hydraulic analysis can be found in the South Eastern CFRAM Study UoM17 Hydraulics Report.

1.3.7 Flood Risk Assessment

The Flood Risk Assessment (FRA) is detailed in this report and its main output is to achieve one of the CFRAM study objectives; assess and map the existing and potential future flood risk within the Study Area. The FRA focuses on the receptors at risk from flooding that are categorised as either social (including risk to people), environmental, cultural heritage or economic receptors.

1.3.8 Development of Flood Risk Management Options

The development of Flood Risk Management (FRM) Options is detailed in this report and its main output is to achieve one of the CFRAM study objectives; identify viable structural and non-structural options and measures for the effective and sustainable management of flood risk within the Study Area. The output of this activity is to present FRM options for the receptors identified during the FRA. This is achieved through a screening process and analysis of the options in order to identify which are the most appropriate in relation to the flood risk management objectives established by national level consultation for the CFRAM programme.

1.3.9 Environmental Assessment

Strategic Environmental Assessment (SEA) is a process to evaluate, at the earliest appropriate stage, the environmental effects of a plan or programme before it is adopted. It also gives the public and other interested parties an opportunity to comment and to be kept informed of decisions and how they were made. The outputs of the process include an SEA Screening Statement notifying the decision to carry out SEA, an SEA Scoping Report outlining the environmental issues considered by the SEA, an SEA Environmental Report outlining the assessment of the potential effects of the measures in the Flood Risk Management Plans on aspects of the environment, and an SEA Statement detailing how the SEA process influenced the development of the Flood Risk Management Plans. Details of the SEA process can be found in the South Eastern CFRAM Study Scoping and supporting environmental reports.

Appropriate Assessment (AA) is a process which ascertains if there are internationally important sites whose integrity could be significantly adversely affected by the implementation of a plan or project. Special Protection Areas (SPAs) and Special Areas of Conservation (SACs) together form the Natura 2000 network of protected areas. Outputs of the process include an AA Screening Statement notifying the decision to carry out AA and a Natura Impact Statement outlining the assessment of the potential effects on Natura 2000 sites of the measures contained in the Flood Risk Management Plans. Details of the AA process can be found in the South Eastern CFRAM Study Screening Statement and supporting assessments.

1.3.10 Communications Activities

Communications activities include elected member briefings, public consultation days, stakeholder workshops, website consultations and consultation with progress group members and other key stakeholders. Stakeholder input influenced the technical review of flood maps, flood risk management options and Flood Risk Management Plans.

1.3.11 Preparation of Flood Risk Management Plan

This is the last activity of the South Eastern CFRAM Study and will follow the Preliminary Options Report. The draft plan will detail the work carried out during the entire study including the outcomes of the PFRA, flood hazard assessment, flood risk assessment, FRM objectives, environmental considerations, FRM options, programme or work and plan monitoring and review. The plan will be finalised taking into consideration the stakeholder consultation feedback on the draft plan.

1.4 PURPOSE OF THE PRELIMINARY OPTIONS REPORT

The main objectives of the preliminary options report are to detail the activities associated with Flood Risk Assessment and the development of Flood Risk Management Options and to present the outcomes of each within UoM17 (Figure 1.3).

The report details the process carried out as part of the FRA and option development in sections 2 - 7.

Sections 8 – 9 of this report detail the decision making process in identifying the most appropriate and feasible FRM options and present details of the options to be taken forward to consultation for UoM17.

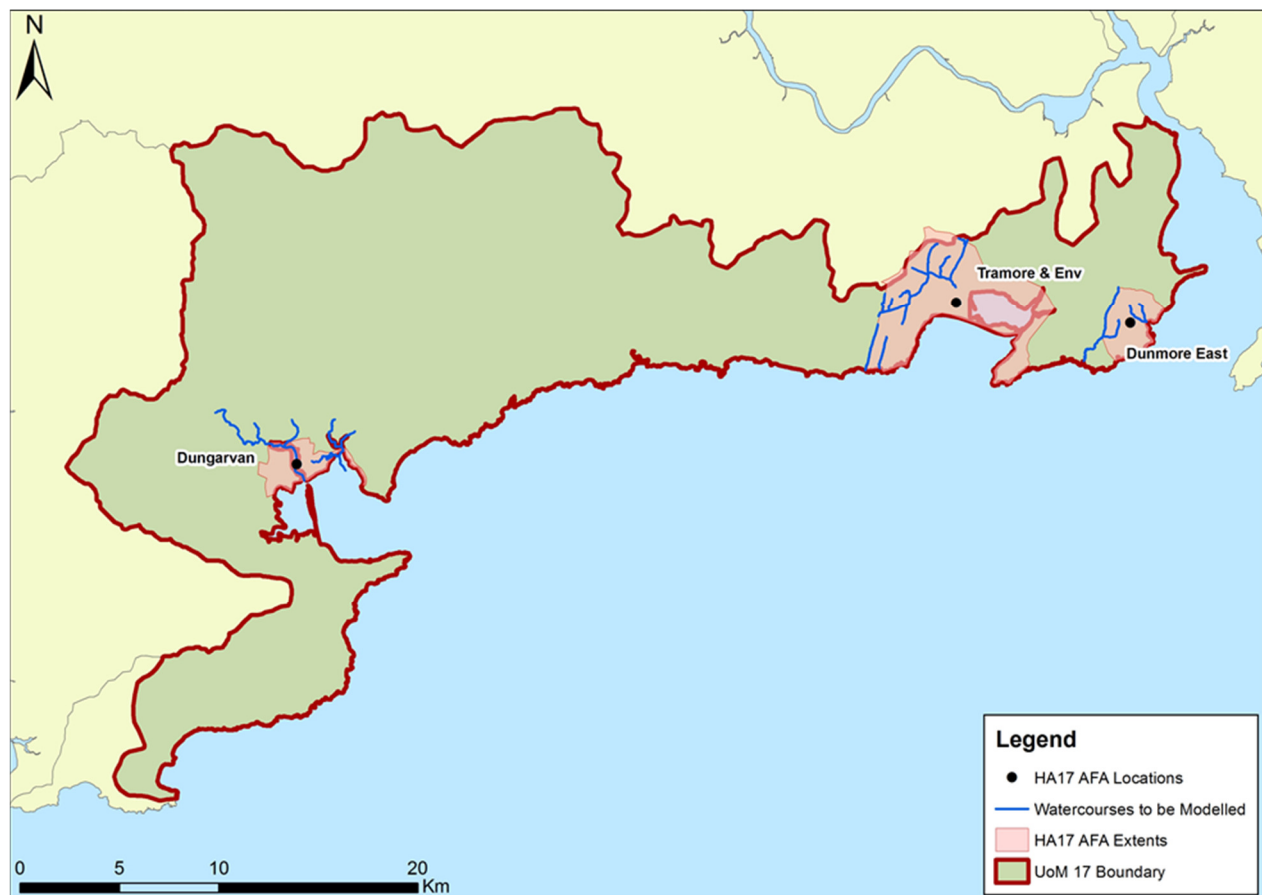


Figure 1.3 - UoM17 AFA Locations and Extents

1.5 INTRODUCTION TO THE OPTIONEERING PROCESS

Optioneering is a process where the flood risk to an area is identified and quantified which informs the choice of the most appropriate FRM options. This is carried out through a series of activities summarised in Figure 1.4.

The activities shown in the blue boxes aim to identify and assess the flood risk. The starting point in this process is to identify the spatial scale of assessment (SSA). The following SSAs are defined:

- Unit of Management SSA - refers to a hydrometric area. There are six Units of Management within the South Eastern CFRAM study area. This report covers UoM17;
- Sub-Catchment SSA - refers to the catchment of the principle river on which multiple AFAs sit;
- AFA SSA - refers to the individual AFA being considered only;
- IRR SSA - refers to Individual Risk receptor outside of an AFA boundary. There are no such IRR identified in the South Eastern CFRAM Study area.

Identifying the SSA informs the FRM method screening process by assuring that only methods appropriate to the spatial scale are considered. FRM methods are considered to be any action that will manage flood risk in some capacity.

The next step in the optioneering process is review of the flood hazard maps output from hydraulic modelling. The flood hazard maps are used to assess the flood risk and produce flood risk maps. The flood risk receptors are assessed in order to ascertain where flood risk management will be required and to what extent. These activities are detailed in Section 4.

On quantifying the flood risk the FRM methods are screened to rule out unacceptable methods. The remaining methods are then developed further and combined to make potential FRM options. This process is described further in Section 7 and illustrated in the orange boxes.

The FRM options are assessed against a set of criteria and objectives and scored in order to identify the preferred options (maroon box). These options are then presented for consultation with the OPW, progress group and steering group (consisting of local authorities and key stakeholders) and the preferred options identified are taken forward to public consultation, thereby allowing the public and stakeholders the opportunity to influence the options (purple box).

Comments from the public consultation are then considered and if appropriate used in updating preferred options which in turn becomes the FRM Measure to be presented in the draft Flood Risk Management Plan (draft FRMP). Environmental assessment (SEA and AA) feeds into the screening of the FRM methods, the development of potential FRM options, the Multi Criteria Analysis (see section 7.3) and consultation activities (green box).

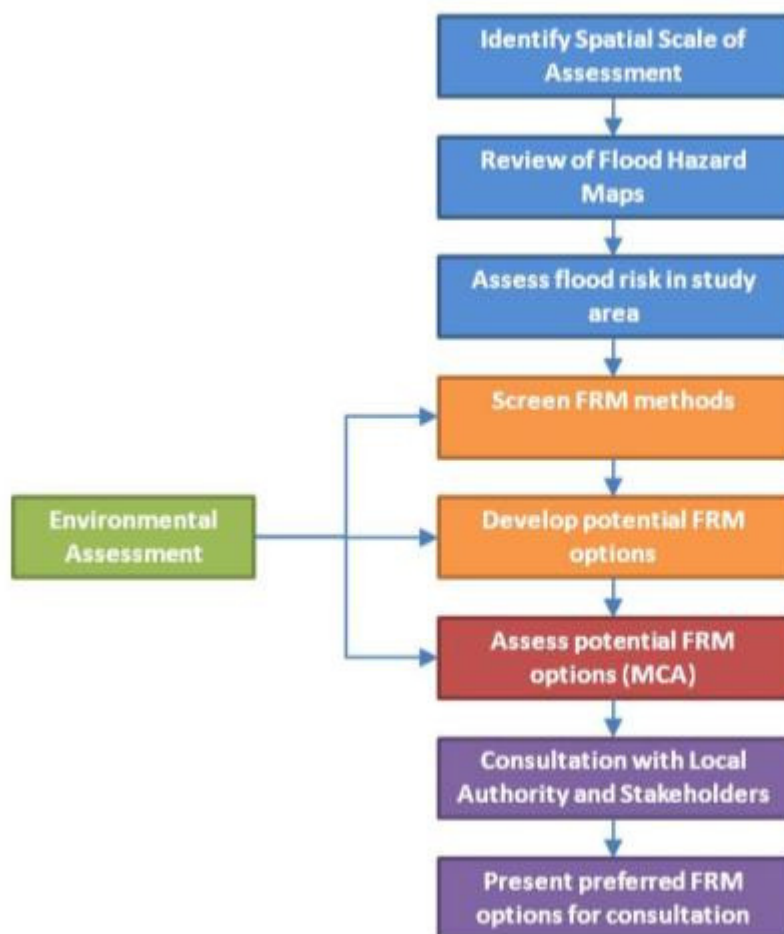


Figure 1.4 - Optioneering process

2 DATA COLLECTION

This section details the data used in the optioneering process. The data was received primarily from the OPW or produced by RPS through the hydraulic analysis within South Eastern CFRAM Study activities. Supplementary data was also received from Local Authorities and stakeholders. The data was received in various formats including GIS, AutoCAD, MS Excel and MS Word. The following sections list the data used for the various activities in the optioneering process.

2.1 BACKGROUND MAPPING

Mapping was used throughout to aid the various tasks. This included assessing the flood risk in the area being studied and identifying the receptors at risk. The maps were used to locate and inform the alignment of proposed FRM options and to reference the options being displayed in the various maps produced. Table 2.1 summarises the mapping that was used.

Table 2.1 - Background Mapping data

Data	Use
OSi 210,000 scale raster map	Various tasks
OSi 50,000 scale raster map	Various tasks
OSi 10,000 scale Digi-City map	Various tasks
OSi 6 inch scale map	Historical review
OSi Ortho Photography	Various tasks
OSi 5,000, scale vector map	Various tasks
OSi 2,500, scale vector map	Various tasks
OSi 1,000, scale vector map	Various tasks
Google maps	Identification of receptors and location of FRM measures
Bing maps	Identification of receptors and location of FRM measures

2.2 RECEPTORS

The following data was used to identify and assess the social, environmental, cultural heritage and economic receptors at flood risk within the area being studied.

Table 2.2 - Receptor data

Data	Use
Primary Schools, Post Primary Schools, Third Level	Flood Risk Assessment
Fire Stations	Flood Risk Assessment
Garda Stations	Flood Risk Assessment

Data	Use
Civil Defence	Flood Risk Assessment
OPW buildings	Flood Risk Assessment
Nursing Homes, Hospitals, Health Centres	Flood Risk Assessment
Geo-Directory (Oct 2010)	Flood Risk Assessment and Damage Assessment
Utility Infrastructure Assets	Flood Risk Assessment
Road	Flood Risk Assessment
Rail	Flood Risk Assessment
Ports	Flood Risk Assessment
Airports	Flood Risk Assessment
Architectural Heritage	Flood Risk Assessment
National Monuments	Flood Risk Assessment
National Heritage Area	Flood Risk Assessment
Proposed National Heritage Area	Flood Risk Assessment
Special Area of Conservation	Flood Risk Assessment
Special Protected Area	Flood Risk Assessment
Pollution Sources	Flood Risk Assessment
Development and Local Area Plans	Assessment of FRM methods
Historical Flood Data	Flood Risk Assessment
OPW Channels	Assessment of FRM methods
OPW Embankments	Assessment of FRM methods
OPW Benefiting Land	Assessment of FRM methods
River Centrelines	Various tasks
Lakes	Various tasks

2.3 FLOOD HAZARD

The output of the hydraulic analysis provides details on the flood extent, depth, velocity, risk to life and flood zones. This was used to inform the flood risk assessment, the screening of FRM methods and in developing and assessing potential FRM options. The following datasets were used.

Table 2.3 - Flood Hazard data

Data	Use
Flood extent raster (50%, 20%, 10%, 5%, 2%, 1%, 0.5%, 0.1% AEP present day flood events)	Establish flood extent and depth for Flood Risk Assessment and developing FRM options
HEFS (10%, 1%, 0.1% AEP flood events)	Developing FRM options
MRFS (50%, 20%, 10%, 5%, 2%, 1%, 0.5%, 0.1% AEP flood events)	Developing FRM options

2.4 SURVEY DATA

Surveys were carried out by CCS for the South Eastern CFRAM Study. This consisted of surveying river cross sections, and specified structures such as culverts, bridges and weirs. Existing defences were surveyed, their geometric data recorded and a visual condition assessment carried out. LiDAR surveys were flown for all relevant areas within the area being studied providing detail of the topography of the flood plain.

Table 2.4 - Survey data

Data	Use
Channel and Structure survey	Flood Risk Assessment and developing FRM options
Defence asset condition survey	Flood Risk Assessment and developing FRM options
Property survey	Flood Risk Assessment
Floodplain survey	Various tasks

2.5 ECONOMIC ASSESSMENT

The following data was used during the economic assessment. This involved assigning damage to receptors during different flood events and providing costs to FRM options.

Table 2.5 - Economic Assessment data

Data	Use
Cost Database	Costing FRM options
Depth Damage Database	Damage Assessment
Consumer Price Index data	Damage Assessment and costing FRM options
Market value of house data	Damage assessment
Purchasing Power Parity	Damage Assessment and costing FRM options
OSi Building polygons	Damage assessment

3 SPATIAL SCALES OF ASSESSMENT

UoM17 contains 3 Areas for Further Assessment (AFAs). These AFAs are all situated along, or in proximity to the coast or the Colligan River. All 3 AFAs within UoM17 have been identified as having some degree of flood risk and therefore risk assessment coupled with optioneering has been undertaken for all these areas.

Through the optioneering process preliminary FRM solution(s) for each AFA will be proposed for UoM17. This could theoretically consist of FRM options within each of the AFAs or one overarching FRM option within UoM17 which benefits all the AFAs. To help assess the solution, Spatial Scales of Assessment (SSA) have been identified. The flood risk within each SSA has been evaluated and optioneered to identify potential FRM measures.

When considering which FRM methods to assess it is accepted that certain methods will be more appropriate at larger spatial scales and others at smaller spatial scales. It is important therefore to define what spatial scale is being assessed at the beginning of the screening process. This is to avoid a situation where the full impact of a FRM method is missed due to the spatial scale of assessment (SSA) being too small, or the FRM method being considered is ineffective as the SSA is too large. OPW have defined SSAs which are described in the following sections.

3.1 UNIT OF MANAGEMENT SSA

The Unit of Management (UoM) SSA refers to a full hydrometric area. For the South Eastern CFRAM UoM17 (Colligan-Mahon) is one of six UoMs

At this scale, methods that could provide benefits to multiple, often all, AFAs within the Unit of Management and other areas should be considered, along with the spatial and temporal coherence of methods being considered at smaller SSAs.

FRM methods and options that might typically be applicable at this scale might include (but are not necessarily limited to):

- Policy requirements;
- Flood forecasting and warning systems;
- Land Use Management, where applicable;
- Methods implemented under other legislation;
- Methods which offer potential benefit to multiple UoMs/Sub-catchments and/or AFAs such as tidal barrages;
- Requirements for additional monitoring (rain and river level / flow gauges)
- Public awareness and education campaigns.

3.2 SUB-CATCHMENT SSA

The sub-catchment SSA refers to the catchment of the principal river on which multiple AFAs sit, including areas upstream and areas downstream to the river's discharge into another, larger river or into the sea.

At this scale, methods that could provide benefits to multiple AFAs within the sub-catchment and other areas should be considered, such as storage or conveyance improvement, along with the spatial and temporal coherence of methods being considered at smaller SSAs.

3.3 AFA SSA

The AFA SSA refers to an individual AFA; such areas would include towns, villages, areas where significant development is anticipated and other areas or structures for which the risk that could arise from flooding is understood to be significant. At this scale, methods benefitting only the particular AFA in question are considered, even if the implementation of a given method includes works or activities outside of the AFA, i.e., elsewhere in the sub-catchment or UoM. Examples of where this might apply would be storage options upstream of the AFA, or flood forecasting and warning systems, that provide benefits to no other AFAs than the AFA under consideration.

3.4 SPATIAL SCALES OF ASSESSMENT FOR UOM17

A review was carried out for UoM17 to identify the SSAs which would require optioneering. This was based on the flood risk to each AFA. Only AFAs with a present day flood risk were considered when identifying Sub Catchment SSAs. The principal flood mechanism was also considered to ensure that any FRM Methods being assessed would have the potential to benefit all the AFAs within the Sub Catchment identified. UoM and Sub Catchment SSAs were delineated using the hydrological catchment boundaries. Table 3.1 and Figure 3.1 detail the SSAs for UoM17.

Table 3.1 – List of SSAs in UoM17

SSA	Name	AFAs within SSA
UoM	UoM 17	All
AFA	Dungarvan	
AFA	Dunmore East	
AFA	Tramore	

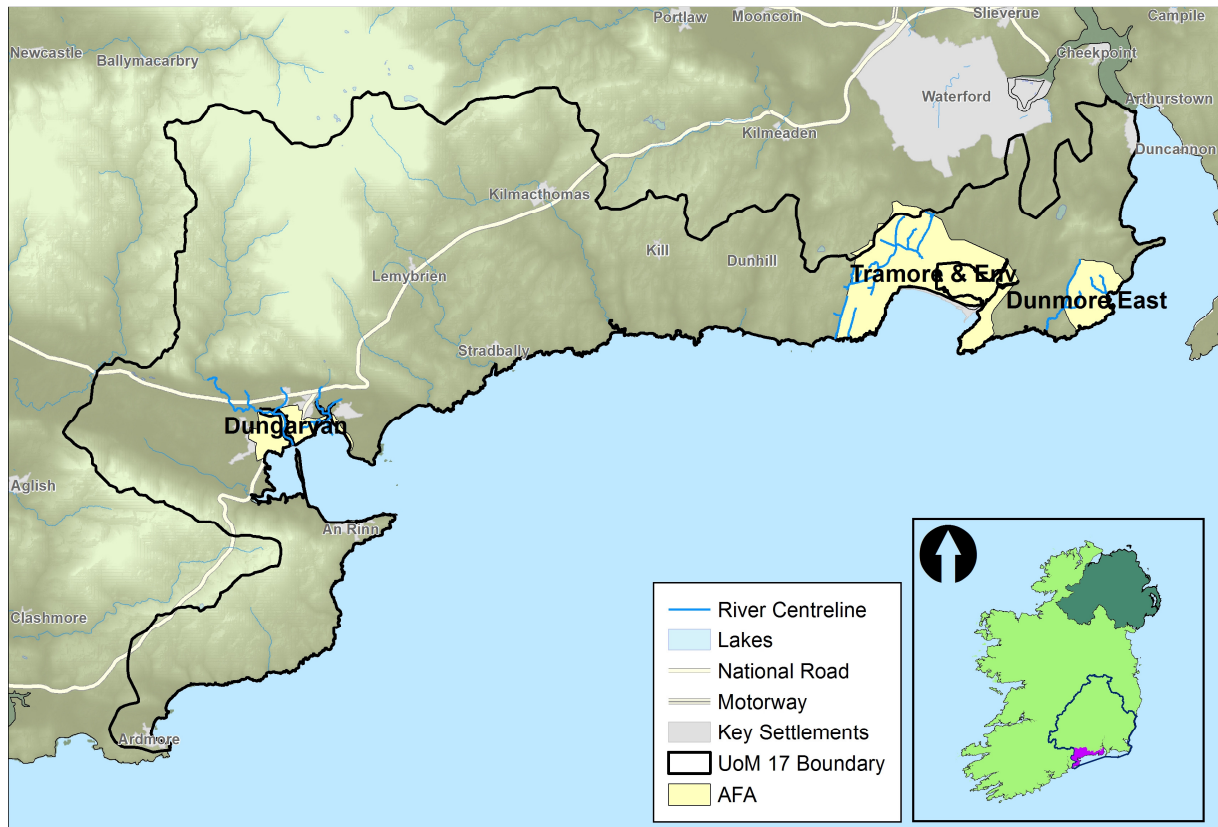


Figure 3.1 – UoM17 SSAs

4 FLOOD RISK ASSESSMENT

The aim of the Flood Risk Assessment is to assess and map the potential adverse consequences (risk) associated with flooding in the area being studied. The assessment identifies how flooding occurs, i.e. its flooding mechanism, and the consequence of the flooding to the receptors affected. This process helps to identify the applicability of an FRM method for each SSA being considered.

The level of flood risk is assessed using four receptor groups as described in Table 4.1. The risk to a receptor can be affected by its location within the flood extent or the proportion of the receptor within the flood extent, the depth to which it floods, the velocity of the water adjacent to the receptor and the receptors' vulnerability to flooding.

Table 4.1 - Flood risk receptor groups

Flood Risk Receptor Group	Receptor Dataset	Indicator
	Residential Properties	Location and number of residential properties
	Residential Homes (children, disabled, elderly)	Location, type and number
	Prisons, Schools (primary, post-primary, third level education), fire stations, garda stations, civil defence, ambulance stations, hospitals, health centres, OPW buildings, government buildings, local authority buildings.	Location, type and number
	Social amenity sites	
	Residential and Commercial Properties	Location, type, number, depth-damage data
	ESB power stations, ESB HV substations, Board Gais assets, Eircom assets, Water supply, Data centres	Location, type and number
	Road networks, Rail networks & Stations, Ports and Harbours	Location, type, number and length
Environment	Special Area of Conservation, Special Protected Area, Groundwater Abstraction for Drinking Water, Pollution Sources, Recreational water including bathing water	Location, extent and nature
Cultural Heritage	Architectural Heritage, National Monuments, National Heritage Area, Proposed National Heritage Area, Sites and Monument Records, Record of Monuments and Places	Location, type and number

The flood risk to the four receptor groups in each of the AFAs within UoM17 is summarised in Table 4.2.

Table 4.2 Flood Risk Analysis UoM17

Type of Risk	Flood Risk for Design AEP (%) Event		
	Dungarvan AFA	Dunmore East AFA	Tramore AFA
Current Scenario (Present Day)			
Event Damage (€)	2,635,991 Fluvial 4,240,103 Coastal 1 2,692,743 Coastal 2	753,027 Fluvial 0 Coastal 1	432,273 Fluvial 0 Coastal 1
No. Residential Properties at Risk	24 Fluvial 39 Coastal 1 38 Coastal 2	8 Fluvial 0 Coastal 1	4 Fluvial 0 Coastal 1
No. Business Properties at Risk	1 Fluvial 20 Coastal 1 5 Coastal 2	0 Fluvial 0 Coastal 1	2 Fluvial 0 Coastal 1
No. Utilities at Risk	0 Fluvial 1 Coastal 1 8 Coastal 2	0 Fluvial 0 Coastal 1	0 Fluvial 0 Coastal 1
No. Major Transport Assets at Risk	4 Fluvial 1 Coastal 1 8 Coastal 2	5 Fluvial 5 Coastal 1	6 Fluvial 0 Coastal 1
No. Highly Vulnerable Properties at Risk	0 Fluvial 0 Coastal 1 0 Coastal 2	0 Fluvial 0 Coastal 1	0 Fluvial 0 Coastal 1
No. of Social Infrastructure Assets at Risk	24 Fluvial 36 Coastal 1 48 Coastal 2	3 Fluvial 0 Coastal 1	15 Fluvial 0 Coastal 1
No. Environmental Assets at Risk	4 Fluvial 4 Coastal 1 5 Coastal 2	2 Fluvial 0 Coastal 1	9 Fluvial 0 Coastal 1
No. Potential Pollution Sources at Risk	0 Fluvial 0 Coastal 1 0 Coastal 2	0 Fluvial 0 Coastal 1	0 Fluvial 0 Coastal 1
Mid-Range Future Scenario			
Event Damage (€)	3,213,278 Fluvial 74,145,879 Coastal 1 32,565,353 Coastal 2	2,136,847 Fluvial 0 Coastal 1	559,048 Fluvial 0 Coastal 1
No. Residential Properties at Risk	31 Fluvial 388 Coastal 1 298 Coastal 2	16 Fluvial 0 Coastal 1	5 Fluvial 0 Coastal 1
No. Business Properties at Risk	1 Fluvial 58 Coastal 1 25 Coastal 2	3 Fluvial 0 Coastal 1	2 Fluvial 0 Coastal 1
No. Utilities at Risk	0 Fluvial 3 Coastal 1 0 Coastal 2	0 Fluvial 0 Coastal 1	0 Fluvial 0 Coastal 1
No. Major Transport Assets at Risk	9 Fluvial 6 Coastal 1 51 Coastal 2	6 Fluvial 5 Coastal 1	7 Fluvial 0 Coastal 1

Type of Risk	Flood Risk for Design AEP (%) Event		
	Dungarvan AFA	Dunmore East AFA	Tramore AFA
No. Highly Vulnerable Properties at Risk	0 Fluvial 1 Coastal 1 1 Coastal 2	0 Fluvial 0 Coastal 1	0 Fluvial 0 Coastal 1
No. of Social Infrastructure Assets at Risk	45 Fluvial 84 Coastal 1 118 Coastal 2	3 Fluvial 0 Coastal 1	17 Fluvial 0 Coastal 1
No. Environmental Assets at Risk	6 Fluvial 5 Coastal 1 8 Coastal 2	2 Fluvial 0 Coastal 1	9 Fluvial 0 Coastal 1
No. Potential Pollution Sources at Risk	0 Fluvial 0 Coastal 1 0 Coastal 2	0 Fluvial 0 Coastal 1	0 Fluvial 0 Coastal 1
High-End Future Scenario			
Event Damage (€)	3,499,625 Fluvial 164,012,346 Coastal 1 85,605,346 Coastal 2	2,228,077 Fluvial 0 Coastal 1	812,570 Fluvial 1,021,861 Coastal 1
No. Residential Properties at Risk	38 Fluvial 613 Coastal 1 465 Coastal 2	22 Fluvial 0 Coastal 1	6 Fluvial 25 Coastal 1
No. Business Properties at Risk	3 Fluvial 94 Coastal 1 39 Coastal 2	3 Fluvial 0 Coastal 1	2 Fluvial 3 Coastal 1
No. Utilities at Risk	0 Fluvial 4 Coastal 1 0 Coastal 2	0 Fluvial 0 Coastal 1	0 Fluvial 0 Coastal 1
No. Major Transport Assets at Risk	10 Fluvial 11 Coastal 1 63 Coastal 2	6 Fluvial 5 Coastal 1	11 Fluvial 1 Coastal 1
No. Highly Vulnerable Properties at Risk	1 Fluvial 1 Coastal 1 1 Coastal 2	0 Fluvial 0 Coastal 1	0 Fluvial 0 Coastal 1
No. of Social Infrastructure Assets at Risk	108 Fluvial 121 Coastal 1 142 Coastal 2	3 Fluvial 0 Coastal 1	19 Fluvial 0 Coastal 1
No. Environmental Assets at Risk	7 Fluvial 7 Coastal 1 8 Coastal 2	2 Fluvial 0 Coastal 1	9 Fluvial 0 Coastal 1
No. Potential Pollution Sources at Risk	0 Fluvial 0 Coastal 1 0 Coastal 2	0 Fluvial 0 Coastal 1	0 Fluvial 0 Coastal 1

4.2 FLOOD RISK MAPS

The clearest way to present the flood risk within an area being studied is through flood risk maps. These maps detail the source of the risk and the receptors at risk. The following flood risk maps were produced:

- Social Risk map
- Environmental Risk map
- Cultural Heritage Risk map
- Economic Risk map
- Economic Activity map
- Economic Risk Density map
- Number of Inhabitants map

The social, environmental, cultural heritage and economic risk maps display the various receptors within each AFA. Their proximity to the flood extents and therefore the level of risk can be ascertained by these maps. Figure 4.1 presents an example of a cultural heritage risk map in Portlaoise.

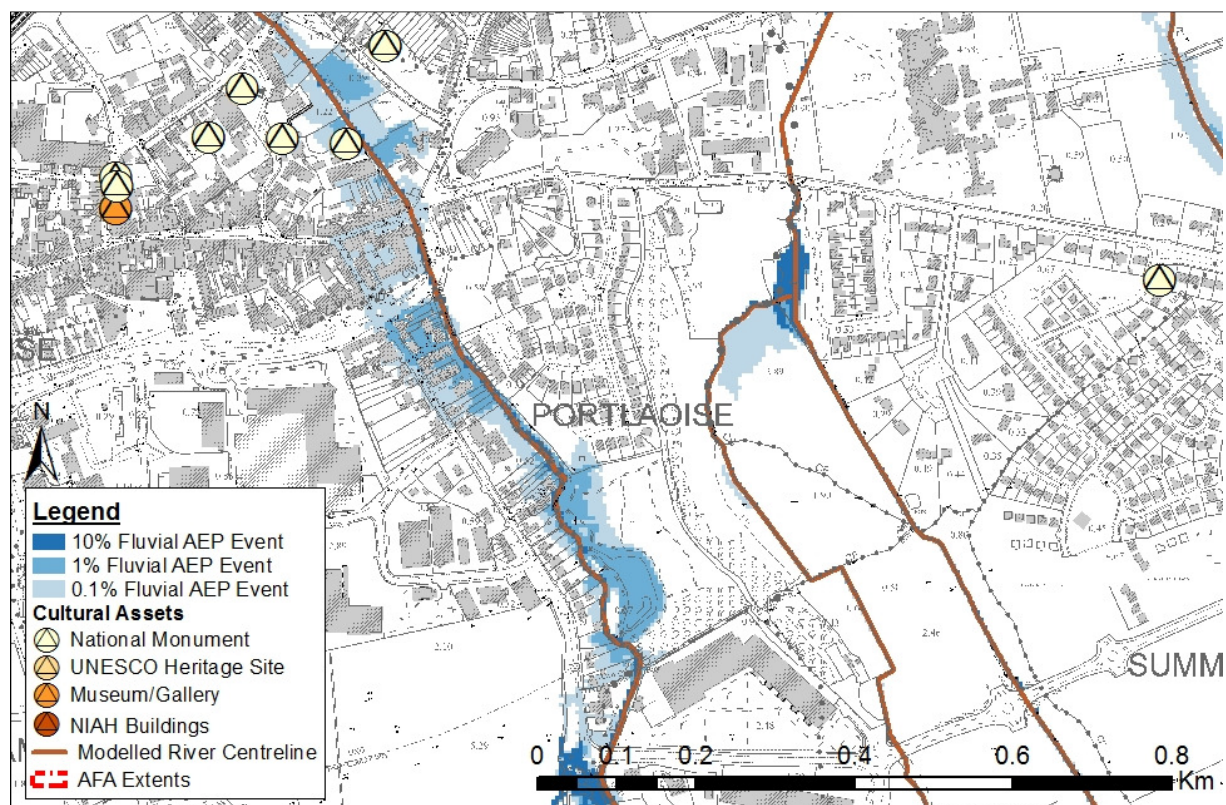


Figure 4.1 - Extract from cultural heritage risk map

The economic activity maps present the nation's economic activity in four categories; property (residential properties), infrastructure (transport and utilities), rural land use and economic (commercial properties). Where an economic activity is at risk in any AFA it is highlighted on the map. Figure 4.2 presents an example of an economic activity map.

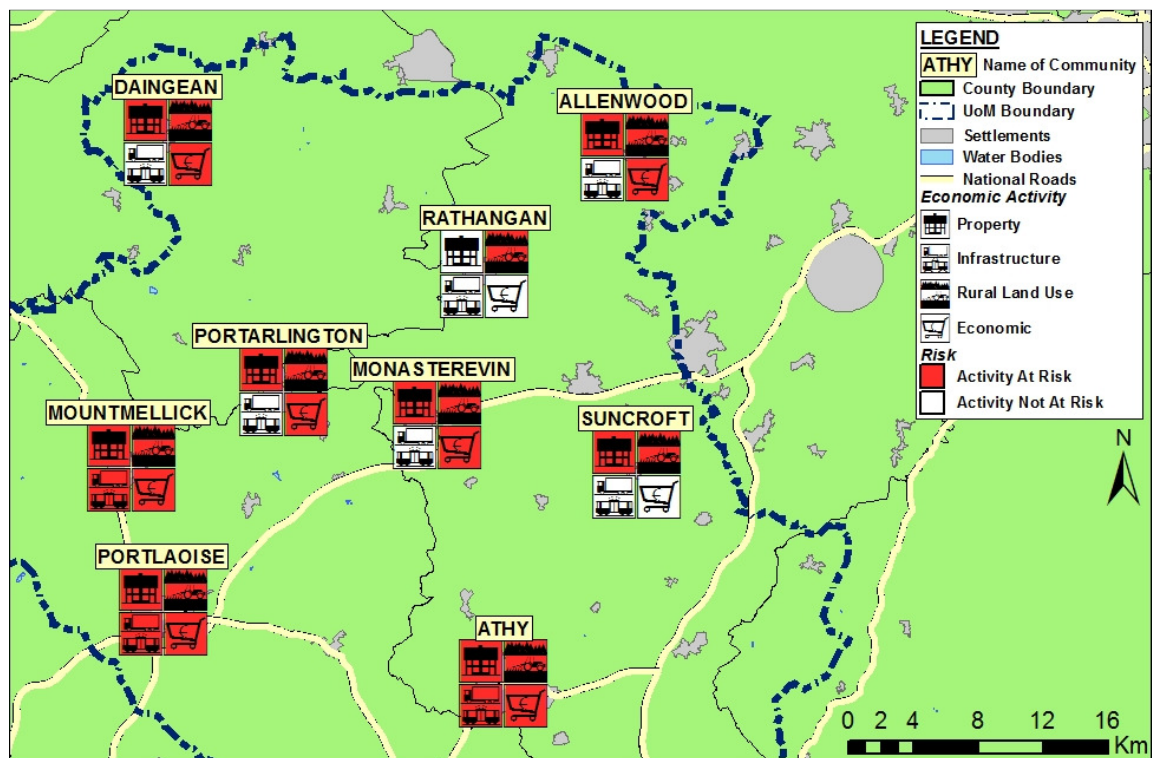


Figure 4.2 – Extract from economic activity map

The economic risk density maps and number of inhabitants maps present their data in the form of grid squares, 100m x 100m. Depending on the annual average damage (AAD) or the number of inhabitants within each grid square the square is assigned a colour format. An example of an Economic Risk Density map is shown in Figure 4.3. The flood risk within the UoM17 AFAs is summarised within Section 8.

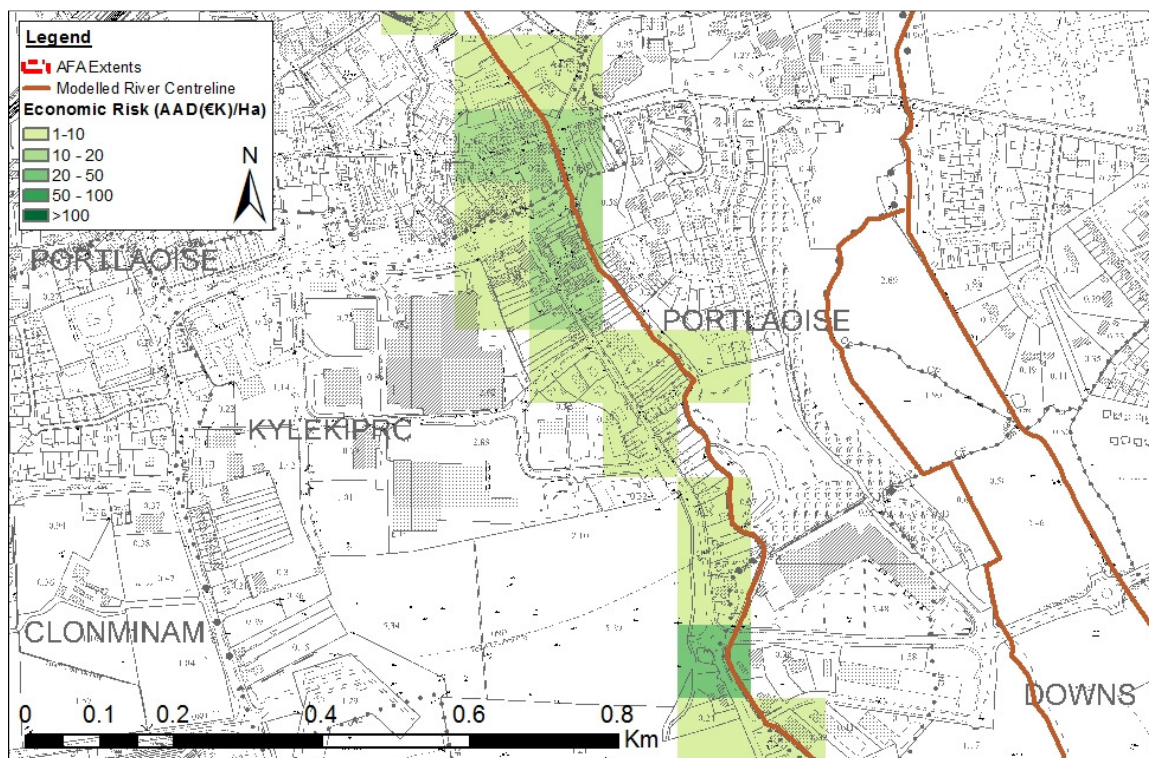


Figure 4.3 - Extract from economic risk density maps

4.3 FLOOD CELLS

It is recognised that the preferred method in one part of the AFA may not be the preferred method in another part. This may be due to location specific factors such as the flood source, the flooding mechanism or the receptors being affected including the potential benefit available from protecting them. Therefore before FRM methods are screened for their suitability within any given AFA a review was carried out, considering the above factors, to identify sub-areas of the AFA, referred to as “flood cells”.

A further assessment of these flood cells was carried out to ascertain how a change within a flood cell would likely impact on another flood cell. Where flood cells were deemed likely to affect other AFAs or where the flood cell contains the majority of the AFA risk they were considered complex. Where flood cells were discrete areas with relatively little risk they were considered local.

Where flood cells were interdependent the FRM methods considered in these flood cells were screened together so as to ensure that no adverse effect was imposed on any given flood cell. All other flood cells were screened independently.

When all flood cells for an AFA have been screened the suitable FRM methods are taken forward to develop FRM options for the AFA as a whole. Section 8, which details the screening process for each AFA, includes the findings of the flood cell review within UoM17.

In identifying flood cells it is recognised that the complex cells contain the majority of the risk and the methods that are proposed will have the biggest impact to the town or area in question. For this reason it is important that all suitable methods in complex cells are considered and developed into potential options for analysis. Local flood cells represent discrete areas of flooding remote from the main flood risk area within the town or area in question and have a relatively low risk. There are often numerous local cells scattered around an AFA and it is preferable to identify, and discretely select, the most suitable method/s to address the flood risk before developing the options. Otherwise a large number of potential options will be identified which will represent only minor variations of the same option dealing with the main risk area. A qualitative review of suitable methods has therefore been carried out for local cells where the technical, economic, social and environmental implications are considered based on professional judgement. These considerations are similar to the objectives set out in the multi criteria analysis (MCA) details of which are given in section 7.3.

5 DAMAGE ASSESSMENT

As part of the economic risk assessment a monetary damage is assigned to certain receptors at risk. This damage represents the costs to the nation if the flood events being considered were to occur. The following receptors are assigned a monetary damage value:

- Residential properties
- Commercial properties
- Utility infrastructure

The total damage to an area being studied is used to quantify the economic risk and provide the amount of potential benefit that would accrue if a FRM measure is put in place which would prevent the damage from occurring.

5.1 DAMAGE ASSESSMENT GUIDELINES

The damage assessment methodology for the CFRAM study follows the guidance in "The Benefits of Flood and Coastal Defence: A Manual of Assessment Techniques" (Flood Hazard Research Centre, Middlesex University, UK, 2005). This document is often referred to as the Multi Coloured Manual (MCM).

The MCM results from research carried out by Middlesex University Flood Hazard Research Centre and provides data and techniques for assessing the benefits of flood risk management in the form of flood alleviation. The MCM has focused on the benefits that arise from protecting residential property, commercial property, and road disruption amongst other areas as experience has shown that these sectors constitute the vast majority of the potential benefits of capital investment.

Based on this research the MCM provides depth damage data for both residential and commercial properties. For certain depths of flood water a damage has been assigned to a property type. This damage is a combination of the likely items within the building and the building structure itself. The damage to each property is dependent on the property type, as such the MCM has categorised both the residential and commercial properties. An example of depth damage data is shown in Figure 5.1.

Components of damage	DETACHED LAND USE CODE 11 2010 PRICES FLOOD DURATION MORE THAN 12 HOURS																
	DEPTH ABOVE UPPER SURFACE OF GROUND FLOOR																
	-0.3	0	0.05	0.1	0.2	0.3	0.6	0.9	1.2	1.5	1.8	2.1	2.4	2.7	3		
1 Paths and paved areas	0	54.32	58.38	73.32	162.24	360.86	413.33	455.09	503.6	604.25	695.98	824.35	859.62	902.05	949.92		
2 Gardens/fences/sheds	0	0	102.7	202.5	705.95	1308.73	2248.7	2948.95	3755.38	5856.54	6811.11	8088.28	9415.97	10109.3	10487.34		
3 External main building	935.51	1223.52	1430.1	1763.94	2321.56	2647	3129	3808.85	4520.47	5913.69	8082.01	9828.87	12058.9	15251.18	19279.72		
4 Plasterwork	176.84	487.74	1124.95	1712.61	2592.26	3917.47	4739.55	5016.94	5913.36	7178.64	8142.19	9363.46	9918.23	10305.43	10860.2		
5 Floors	0	1756.48	6399.48	7457.37	8453.96	9270.39	9344.44	9418.48	9455.5	9603.59	9751.68	9899.77	9899.77	9899.77	9899.77		
6 Joinery	0	357.66	1572.85	4443.87	6055.64	7510.61	7534.94	7853.8	7951.63	8025.14	8220.27	11396.54	11396.54	11396.54	11396.54		
7 Internal decorations	209.19	241.8	374.99	1716.8	2753.95	2833.64	2931.01	3104.93	3234.52	3348.56	3462.6	3480.28	3480.28	3480.28	3480.28		
8 Plumbing and electrical	0	0	962.99	1726.05	2669.08	4106.08	4395.48	4395.48	4395.48	4395.48	4395.48	4395.48	4395.48	4395.48	4395.48		
Building Fabric Damage	1321.54	4121.52	12026.44	19096.46	25714.63	31954.78	34736.44	37002.52	39729.95	44925.9	49561.33	57277.02	61424.8	65740.04	70749.25		
1 Domestic appliances	0	0	2.76	194.14	903.63	1657.79	1798.06	1906.38	1907.06	1907.74	1910.12	1911.61	1911.61	1911.61	1911.61		
2 Heating equipment	0	0	35.91	68.21	118.1	161.3	697.84	955.69	1149.08	1149.08	1149.08	1149.08	1149.08	1149.08	1149.08		
3 Audio/video	0	0	163.71	479.77	686.43	959.78	1287.64	1682.48	1718.91	1718.91	1718.91	1718.91	1718.91	1718.91	1718.91		
4 Furniture	0	0	194.6	334.79	2140.23	2175.78	2207.94	2251.35	2335.43	2361.77	2361.77	2361.77	2361.77	2361.77	2361.77		
5 Personal effects	0	0	57.37	143.14	281.24	430.58	642.4	785.56	859.81	974.85	1058.12	1058.12	1058.12	1058.12	1058.12		
6 Floor coverings/curtains	0	0	1360.09	1432.05	1432.05	1474.94	1654.79	1667.42	1688.06	1702.99	1702.99	1702.99	1702.99	1702.99	1702.99		
7 Garden/DIY/leisure	0	0	32.38	96.52	126.4	203.42	233.81	266.64	269.59	277.21	278.09	278.09	278.09	278.09	278.09		
8 Domestic clean-up	0	0	4820.2	4820.2	5915.8	5915.8	6884.9	6884.9	6884.9	6884.9	6866.9	6866.9	6866.9	6866.9	6866.9		
Household Inventory Damage	0	0	6667.02	7568.82	11603.87	12979.4	15407.39	16400.42	16812.85	16977.46	18845.97	18847.46	18847.46	18847.46	18847.46		
Total Damage	1321.54	4121.52	18693.46	26665.28	37318.5	44934.18	50143.83	53402.95	56542.8	61903.35	68407.3	76124.49	80272.26	84587.5	89596.71		
Total Damage/Square Metre	17.07	52.5	247.12	353.18	495.36	597.03	666.9	711.58	751.92	821.18	908.61	1013.84	1068.33	1123.67	1188.23		

Figure 5.1 - MCM's depth damage data for detached houses

For properties identified at risk from coastal flooding an additional 10% was added onto the damage figure attributed to building fabric, which is made of up several components as shown in Figure 5.1. This percentage was set by the OPW to account for increased repair costs related to property inundation from seawater.

5.2 RECORDING DAMAGE ASSESSMENT DATA

The damage assessment is carried out in order to quantify the economic risk to the area being studied. This requires details to be recorded such as background data, interim calculations and final damage results. As such RPS have created geo-referenced shapefiles, known as economic risk shapefiles, with the relevant data recorded in the attribute tables, an example is shown in Figure 5.2.

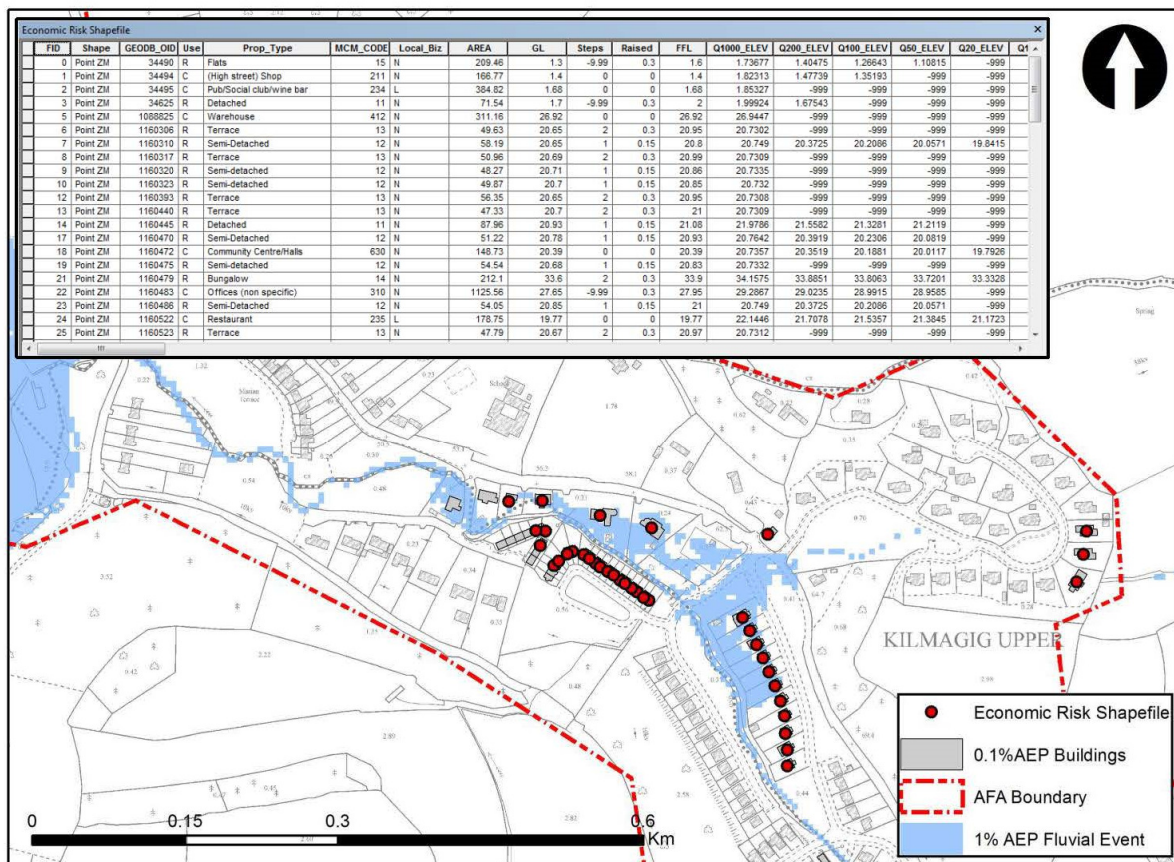


Figure 5.2 - Example shapefile with attribute table showing damage assessment data

The damage data for residential properties and commercial properties has been grouped into a single point file for each area being studied. The following sections detail the key steps in the damage assessment and the data that is recorded during various processes within the shapefile attribute tables.

5.3 CATEGORISATION OF PROPERTIES

Properties were categorised according to MCM guidelines. A complete list of the property types and MCM codes utilised is included in Table 5.1. The MCM assigns a code to each property type to aid the

damage calculations where a number can more readily be used in calculations rather than a description in text format.

Table 5.1 - MCM property types

Property Type	MCM code	Property Type	MCM code
Detached House	11	Leisure	51
Semi Detached House	12	Hotel	511
Terrace House	13	Boarding House	512
Bungalow	14	Caravan Mobile	513
Flat	15	Caravan Static	514
Shop/Store	21	Self-catering Unit	515
(High Street) Shop	211	Hostel (including prisons)	516
Superstore/Hypermarket	213	Bingo hall	517
Retail Warehouse	214	Theatre/Cinema	518
Showroom	215	Beach Hut	519
Kiosk	216	Sport	52
Outdoor market	217	Sports Grounds and Playing Fields	521
Indoor Market	218	Golf Courses	522
Vehicle Services	22	Sports and Leisure centres	523
Vehicle Repair Garage	221	Amusement Arcade/Park	524
Petrol Filling Station	222	Football Ground and Stadia	525
Car Showroom	223	Mooring/Wharf/Marina	526
Plant Hire	224	Swimming Pool	527
Retail Services	23	Public Building	6
Hairdressing Salon	231	School/College/University/Nursery	610
Betting Shop	232	Surgery/Health Centre	620
Laundrette	233	Residential Home	625
Pub/Social club/wine bar	234	Community Centres/Halls	630
Restaurant	235	Library	640
Café/Food Court	236	Fire/Ambulance station	650
Post Office	237	Police Station	651
Garden Centre	238	Hospital	660
Office	3	Museum	670
Offices (non-specific)	310	Law court	680
Computer Centres (Hi-Tech)	311	Church	690
Bank	320	Industry	8
Distribution/Logistics	4	Workshop	810
Warehouse (including store)	410	Factory/Works/Mill	820
Land Used for Storage	420	Extractive/heavy Industry	830
Road Haulage	430	Sewage treatment works	840
Warehouse (electrical goods)	411	Laboratory	850
Warehouse (ambient goods)	412	Miscellaneous	9
Warehouse (frozen goods)	413	Car Park	910
		Public Convenience	920
		Cemetery/Crematorium	930

Property Type	MCM code	Property Type	MCM code
		Bus Station	940
		Dock Hereditament	950
		Electricity Hereditament	960

For each area being studied all properties found within the 0.1% AEP flood extent were categorised. This was carried out using data gained from site visits, surveys, OSi mapping, An post geo-directory and online mapping. The OSi building polygon layer was used initially to locate all the properties and provide their floor area. GIS software was used to select all properties whose outlines intersected flood extents. This selection was tailored depending on the hydraulic model used to produce the flood extents. For rectangular mesh models, the buildings were represented by 5m grid squares orientated on the north-south axis. These building grid squares were selected where they intersected with the various flood extents. The selected building grid squares were then used to overlay and select the OSi buildings. Hydraulic models utilising a flexible mesh represented the building using the OSi building footprint. The OSi building polygons were therefore used to select the properties that intersected the various flood extents. Further details of which hydraulic model type was used in each AFA are available in the South Eastern CFRAM Study, UoM17 Hydraulics Report.

Sheds and garages have no depth damage data in the MCM guidelines and therefore required removal from the properties to be assessed. Using the An post geo-directory spatial dataset it was possible to identify those properties without any information. These properties were checked to ensure they were garages or sheds before removal, or where information did not exist for buildings that were to be included RPS manually filled in the missing data required.

All remaining buildings were then categorised, with information collected under the headings in Table 5.2.

Table 5.2- Categorisation of properties data

Data type	Attribute name	Data details
Property ID	GEODB_OID	An Post geo-directory database ID
Property Use and Basement Present	Use	"R" for residential "RB" for residential with basement "C" for commercial "CB" for commercial with basement "CC" for commercial cellar
MCM code	MCM_CODE	As per MCM guidelines
Local Business	Local_Biz	"L" for local business "N" for not local business
Building Floor Area	AREA	Area (m ²), calculated using the OSi building polygon in ArcGIS

5.4 PROPERTY FLOOR LEVEL

The damage assigned to a property relates to the depth of water above the finished floor level. In the absence of surveyed flood levels for every property at risk, online mapping and site visits were utilised to collect data which could be used to provide a more accurate estimate of property floor levels. This included the number of steps into each property and whether basements were present.

The property ground levels were extracted from LiDAR datasets for each building, where the minimum level on the building footprint was acquired. This provided a conservative level on which to add the height of the steps. The LiDAR survey carried out captured the ground level to an accuracy of 0.2m.

As a general rule most properties are constructed with the floor level raised 300mm above the adjacent ground level, with two steps at entrances. For this reason each step was assigned a 150mm height, and where an entrance was not visible it was assumed to have the standard 300mm rise. This was assumed for the South Eastern CFRAM Study and is consistent with the assumptions made in the MCM. For the purposes of this study a conservative approach was assumed where a basement was found, where the threshold level was dropped 2.5m below ground level.

These details were attributed to each property and the finished flood level calculated accordingly. Table 5.3 shows the details recorded in the damage assessment shapefile.

Table 5.3- Property threshold data

Data type	Attribute name	Data details
Ground Level	GL	LiDAR data extracted at each property, measured in mOD
How many steps into property	Steps	Number of steps into property entrance. Where details of property entry are unknown “-999” value recorded.
Is ground floor raised	RAISED	Calculated from “Steps” column. Each step to be 0.15m, on basis of 0.3 standard entry to a property. Where “-999” value recorded the 0.3m standard entry is assumed.
Finished Floor Level	FFL	Ground level plus raised value. For properties with basements FFL is calculated to be ground level minus 2.5m.

5.5 FLOOD DEPTH OF PROPERTIES

To estimate the damage to a property the depth that it floods was required. This will vary depending on the size of the flood event. As part of the South Eastern CFRAM Study the depths to which the properties flood during the 50%, 20%, 10%, 5%, 2%, 1%, 0.5% and 0.1% AEP flood events were calculated. The depth of flooding was calculated by finding the difference between the flood water elevation and the FFL.

To achieve this, the maximum flood depth at each property was required. It is recognised that as flood water passes around a structure such as a building the water will build up against the upstream face and be forced around the structure. This creates an uneven distribution of water levels around the

structure. This was simulated in the hydraulic analysis where buildings were placed in the floodplain forcing the modelled flood to flow around them. To maintain a conservative approach the maximum flood level adjacent to the building was extracted and recorded in the attribute table of the economic risk shapefile. This process was achieved by carrying out analysis in ArcGIS and was carried out for each property and for each flood event. As the water was deflected around buildings and not through them no flood elevation data was located within the building footprint. The flood elevation rasters were therefore buffered through an interpolation tool within GIS placing flood elevation data inside buildings. This also ensured that buildings close to the margins of the floodplain were included in the analysis where appropriate. The maximum flood elevation was then extracted from the raster and assigned to the relevant building. Table 5.4 shows the details recorded within the economic risk shapefile attribute tables.

Table 5.4 - Flood depth of properties data

Data type	Attribute name	Data details
Flood level for all flood events	Q1000_ELEV, Q200_ELEV, Q100_ELEV, Q50_ELEV, Q20_ELEV, Q10_ELEV, Q5_ELEV, Q2_ELEV.	The maximum flood level adjacent to the building (mOD)
Flood depth for all flood events	Q1000_Dp, Q200_Dp, Q100_Dp, Q50_Dp, Q20_Dp, Q10_Dp, Q5_Dp, Q2_Dp.	Difference between the flood level and FFL

5.6 FLOOD DAMAGE TO PROPERTIES

Once the depths of flooding are known the damage can be calculated using the MCM depth damage data. This is known as principal direct damage in that the flooding directly damages assets, it does not account for indirect damages such as heating costs to dry out the house, etc. For each property type a typical damage based on historical data has been assigned to a depth of flooding, an example of which is shown in Figure 5.3.

	DETACHED LAND USE CODE 11														
	2010 PRICES														
	FLOOD DURATION MORE THAN 12 HOURS														
Components of damage	DEPTH ABOVE UPPER SURFACE OF GROUND FLOOR														
	-0.3	0	0.05	0.1	0.2	0.3	0.6	0.9	1.2	1.5	1.8	2.1	2.4	2.7	3
1 Paths and paved areas	0	54.32	58.38	73.32	162.24	360.86	413.33	455.09	503.6	604.25	695.98	824.35	859.62	902.05	949.92
2 Gardens/fences/sheds	0	0	102.7	202.5	705.95	1308.73	2248.7	2948.95	3755.38	5856.54	6811.11	8088.28	9415.97	10109.3	10487.34
3 External main building	935.51	1223.52	1430.1	1763.94	2321.56	2647	3129	3808.85	4520.47	5913.69	8082.01	9828.87	12058.9	15251.18	19279.72
4 Plasterwork	176.84	487.74	1124.95	1712.61	2592.26	3917.47	4739.55	5016.94	5913.36	7178.64	8142.19	9363.46	9918.23	10305.43	10860.2
5 Floors	0	1756.48	6399.48	7457.37	8453.96	9270.39	9344.44	9418.48	9455.5	9603.59	9751.68	9899.77	9899.77	9899.77	9899.77
6 Joinery	0	357.66	1572.85	4443.87	6055.64	7510.61	7534.94	7853.8	7951.63	8025.14	8220.27	11396.54	11396.54	11396.54	11396.54
7 Internal decorations	209.19	241.8	374.99	1716.8	2753.95	2833.64	2931.01	3104.93	3234.52	3348.56	3462.6	3480.28	3480.28	3480.28	3480.28
8 Plumbing and electrical	0	0	962.99	1726.05	2669.08	4106.08	4395.48	4395.48	4395.48	4395.48	4395.48	4395.48	4395.48	4395.48	4395.48
Building Fabric Damage	1321.54	4121.52	12026.44	19096.46	25714.63	31954.78	34736.44	37002.52	39729.95	44925.9	49561.33	57277.02	61424.8	65740.04	70749.25
1 Domestic appliances	0	0	2.76	194.14	903.63	1657.79	1798.06	1906.38	1907.06	1907.74	1910.12	1911.61	1911.61	1911.61	1911.61
2 Heating equipment	0	0	35.91	68.21	118.1	161.3	697.84	955.69	1149.08	1149.08	1149.08	1149.08	1149.08	1149.08	1149.08
3 Audio/video	0	0	163.71	479.77	686.43	959.78	1287.64	1682.48	1718.91	1718.91	1718.91	1718.91	1718.91	1718.91	1718.91
4 Furniture	0	0	194.6	334.79	2140.23	2175.78	2207.94	2251.35	2335.43	2361.77	2361.77	2361.77	2361.77	2361.77	2361.77
5 Personal effects	0	0	57.37	143.14	281.24	430.58	642.4	785.56	859.81	974.85	1058.12	1058.12	1058.12	1058.12	1058.12
6 Floor coverings/curtains	0	0	1360.09	1432.05	1432.05	1474.94	1654.79	1667.42	1688.06	1702.99	1702.99	1702.99	1702.99	1702.99	1702.99
7 Garden/DIY/leisure	0	0	32.38	96.52	126.4	203.42	233.81	266.64	269.59	277.21	278.09	278.09	278.09	278.09	278.09
8 Domestic clean-up	0	0	4820.2	4820.2	5915.8	5915.8	6884.9	6884.9	6884.9	6884.9	6866.9	6866.9	6866.9	6866.9	6866.9
Household Inventory Damag	0	0	6667.02	7568.82	11603.87	12979.4	15407.39	16400.42	16812.85	16977.46	18845.97	18847.46	18847.46	18847.46	18847.46
Total Damage	1321.54	4121.52	18693.46	26665.28	37318.5	44934.18	50143.83	53402.95	56542.8	61903.35	68407.3	76124.49	80272.26	84587.5	89596.71
Total Damage/Square Metre	17.07	52.5	247.12	353.18	495.36	597.03	666.9	711.58	751.92	821.18	908.61	1013.84	1068.33	1123.67	1188.23

Figure 5.3 - The MCM's depth damage data for a detached house

Depth of flooding and therefore damage is measured relative to the FFL of the property in question. Damages start at a threshold value of -0.3m for residential properties and at 0m for non-residential, as provided in the MCM. In accordance with OPW guidance for residential properties the property type was considered for calculating damages, but not the property age, social class or size. Contrary to this the property type and size (floor area) have been considered for calculating non-residential property damages, where the floor area was derived from the OSi building polygon layer.

A GIS tool has been developed which provides the direct damage in each flood event for each building in pound sterling 2010 as provided in the MCM. These direct damage figures were then updated from 2010 pound sterling prices to 2013 euro rates applicable to Ireland, using the OECD's purchasing power parities (PPP) records and CSO Ireland's consumer price index (CPI). The overall adjustment factor used in the South Eastern CFRAM Study was 1.344, the conversion rates are shown in Tables 5.5 and 5.6.

Table 5.5 - Converting pound sterling to euro using the PPP 2010 values from OECD website

	PPP
US - UK	0.667
US - Ire	0.853
UK - Ire	1.279

Table 5.6 - Conversion rates to current year prices using CPI from CSO Ireland website

	CPI
2006	100
2010	101.2
Apr-13	106.4
2010 - 2013	1.051

The following details of the information and calculations described above were recorded within the economic risk shapefile attribute tables:

Table 5.7 - Flood damage to properties data

Data type	Attribute name	Data details
Direct damage per meter square	Q1000_M2Dm, Q200_M2Dm, Q100_M2Dm, Q50_M2Dm, Q20_M2Dm, Q10_M2Dm, Q5_M2Dm, Q2_M2Dm.	Damage per meter square to each property according to the depth of flooding from each flood event as per MCM data. Values in pound sterling updated to 2010 costs and for non-residential properties only.
Direct Damage to property over full floor area	1000_Dm£10, Q200_Dm£10, Q100_Dm£10, Q50_Dm£10, Q20_Dm£10, Q10_Dm£10, Q5_Dm£10. Q2_Dm£10	For residential properties calculations are based on property type and flood depth. For non-residential properties calculations are based on property type, flood depth and floor area.
Principal Direct Damage conversion to euro and 2013 prices	1000_PDD, Q200_PDD, Q100_PDD, Q50_PDD, Q20_PDD, Q10_PDD, Q5_PDD, Q2_PDD.	Conversion rate (1.344) applied to damage to property over full floor area.

5.7 INTANGIBLE DAMAGES, UTILITY AND EMERGENCY COSTS

Apart from the material damages to the building structure and the goods inside the property, it is recognised that there are monetary damages associated with clean-up costs, temporary accommodation, stress, etc. To account for this, it is OPW policy to assign intangible damages to all residential properties equal to the direct damages. No intangible damages are assigned to commercial properties as these costs do not apply at the same level with the exception of small family run businesses. To achieve this, a survey was carried out identifying these small businesses and an intangible damage equal to the direct damage assigned to those properties as well.

An economic damage relating to infrastructure utility assets will be incurred in flood events. Examples of these may include electrical sub-stations and telecommunications assets. A percentage of 20% of the principal direct damage has been applied to account for these damages, which have been set based on the analysis of damages from historical flooding in the UK.

A cost will be associated with emergency services dealing with the flood events. Following the MCM guidance, the OPW have set the emergency costs at 8.1% of the principal direct damages which has been adopted in this study. The following details were recorded within the economic risk shapefile attribute tables:

Table 5.8 - Intangible damages and emergency cost data

Data type	Attribute name	Data details
Intangible Damage	Q1000_IntD, Q200_IntD, Q100_IntD, Q50_IntD, Q20_IntD, Q10_IntD, Q5_IntD, Q2_IntD.	Set equal to the present direct damage of residential properties and small family run businesses.
Utility costs	1000_Util, Q200_Util, Q100_Util, Q50_Util, Q20_Util, Q10_Util, Q5_Util, Q2_Util.	Equal to 20% of the present direct damage for all properties.
Emergency costs	1000_Emerg, Q200_Emerg, Q100_Emerg, Q50_Emerg, Q20_Emerg, Q10_Emerg, Q5_Emerg, Q2_Emerg.	Equal to 8.1% of the present direct damage for all properties.
Event damage	1000_EvDam, Q200_EvDam, Q100_EvDam, Q50_EvDam, Q20_EvDam, Q10_EvDam, Q5_EvDam, Q2_EvDam.	Summed damage of any one event. This is the total of the present value damage, utility damage, emergency costs and intangible damage.
Event damage for MCA	1000_EvMCA, Q200_EvMCA, Q100_EvMCA, Q50_EvMCA, Q20_EvMCA, Q10_EvMCA, Q5_EvMCA, Q2_EvMCA.	Sum of the present value damage and emergency costs. The multi-criteria analysis requires economic damages which only account for these contributors.

5.8 ANNUAL AVERAGE DAMAGE AND PRESENT VALUE DAMAGE

Thus far in the process, damages have been assigned to each property for each flood event. In order to gain an appreciation of the economic risk the overall damage needs to be calculated. This is represented by assessing the likelihood of each of these flood events occurring in any given year and applying this as a percentage to the damage, this is known as the Annual Average Damage (AAD). This can then be taken over the lifetime of the project which has been set at 50 years and discounted back to present day costs, this is known as present value damage (PvD).

Calculating the AAD can best be described by considering the graph shown in Figure 5.4. The points shown represent the flood events where the damage has been calculated. Their position on the graph

is dictated by the damage caused and by the frequency of the flood event occurring in any given year. These points are joined together to create a damage curve. This curve represents all the other flood events that could occur in between the flood events shown, for example the damage that would occur in a 33%AEP event can be estimated by the damage curve that is drawn from the 50%AEP event to the 20%AEP event.

The area under the curve is therefore a function of the damage and the frequency and gives the AAD. It can be seen then that for many areas being considered the majority of the damage occurs from the smaller, more frequent flood events rather than the larger flood events that appear at first glance to contribute most to the flood damage. Because the AAD is calculated by the area under the damage curve the more flood events included in the assessment the more accurate the AAD figure will be. A minimum of three events are required to create a curve but the less events there are the more likely the AAD will be overestimated. It is also essential to identify the threshold event. This is the event where damage starts to occur. Failure to do this will cut the damage curve short and reduce the area under the graph. The events that were considered for this study were the 50%, 20%, 10%, 5%, 2%, 1%, 0.5% and 0.1% AEP flood events.

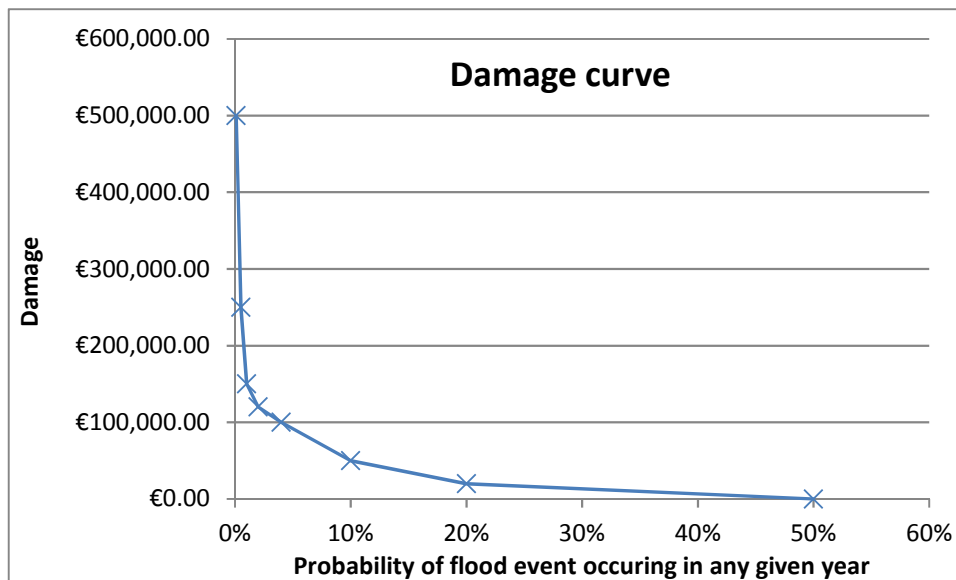


Figure 5.4 - Example damage curve

Once the AAD is found the present value damage is calculated. The present value damage calculation sums the AAD that is expected to occur for each of the 50 years being considered in this study. However in order for the damage value in each year to be comparable with each other they are discounted to represent the equivalent present damage value. Discounting damage values in the future is based on the principle that generally people prefer to receive goods or services now rather than later. This is known as time preference. The cost therefore of providing a flood management option will also be discounted to present day values. It is therefore best practice to discount the AAD figure for any given year by the distance in years it is away from the present day. The OPW has set this discount rate at 4% and this figure has been used in this study. Over the 50 years being considered this amounted to factoring the AAD by 21.482. A separate AAD figure was calculated

specifically for use in the multi-criteria analyses process, which only included principal direct damage and emergency services costs.

The following details were recorded within the economic risk shapefile attribute tables:

Table 5.9 - AAD and PvD data

Data type	Attribute name	Data details
Annual Average Damage	AAD	The equation to calculate the AAD is as follows: $(((Q2_EvDam+[Q5_EvDam])/2*(0.5-0.2)+([Q5_EvDam]+[Q10_EvDam])/2*(0.2-0.1)+([Q10_EvDam]+[Q20_EvDam])/2*(0.1-0.05)+([Q20_EvDam]+[Q50_EvDam])/2*(0.05-0.02)+([Q50_EvDam]+[Q100_EvDam])/2*(0.02-0.01)+([Q100_EvDam]+[Q200_EvDam])/2*(0.01-0.005)+([Q200_EvDam]+[1000_EvDam])/2*(0.005-0.001))$
Present value damage	PvD	The AAD factored by 21.482
Annual Average Damage*	AAD_MCA	The equation to calculate the AAD is as follows: $(((Q2_EvMCA+[Q5_EvMCA])/2*(0.5-0.2)+([Q5_EvMCA]+[Q10_EvMCA])/2*(0.2-0.1)+([Q10_EvMCA]+[Q20_EvMCA])/2*(0.1-0.05)+([Q20_EvMCA]+[Q50_EvMCA])/2*(0.05-0.02)+([Q50_EvMCA]+[Q100_EvMCA])/2*(0.02-0.01)+([Q100_EvMCA]+[Q200_EvMCA])/2*(0.01-0.005)+([Q200_EvMCA]+[1000_EvMCA])/2*(0.005-0.001))$

*As the MCA requires only AAD the present value damage (PvD) was not required to be calculated.

5.9 COASTAL FLOODING

Where properties were identified to be at risk of coastal flooding, an additional 10% was added onto the building fabric damage. RPS created a GIS tool mirroring that for the fluvial damages which accounted for the additional building fabric damage. Where properties were at risk from coastal mechanisms 1 and/or 2, this tool was used for damage calculations.

5.10 DEFENDED FLOOD DAMAGES

In the defended scenario a copy of the economic risk shapefiles were made, where properties were protected up to the 1% fluvial or 0.5% coastal AEP. Any properties with extracted flood depths up to the standard of protection were removed and the damages calculations rerun to provide a defended AAD and PvD. An assumption was made that when defences were overtopped any damage in events that exceed the standard of protection would be the same as when no defence was in place.

5.11 BENEFIT

The economic benefit derived from a flood alleviation measure is the difference in present value damages before and after the measure is put in place. A separate shapefile was created in which the benefit was found. AAD and PvD figures from the current scenario and the defended scenario were extracted and the difference calculated, which provided the defended uncapped present value benefit and the defended annual average damage.

Table 5.10 - Capping damages data

Data type	Attribute name	Data details
Present Value Economic benefit of providing required standard of protection	PvB_DEF	Difference between PvD for the current and defended scenarios. This value is uncapped.
Annual average benefit of providing required standard of protection	AAD_DEF	The AAD factored by 21.482

5.12 CAPPING BENEFIT

It is recognised that for certain properties the overall damage associated with it can far exceed the market value of the property. This can be due to either the depth to which it floods or the frequency with which it floods or more likely a combination of both. Where such a situation occurs it is necessary to cap the damages at the market value. The market value was calculated at a regional level with the market value data sourced from the Central Statistics Office.

Residential properties affected have been assigned a market value of €257,462 which is the national average market value of second hand properties in Ireland taken during the last quarter of 2013. The capping value was set at twice this value to account for the market value and the intangible costs, giving a final national capping value of €514,924. For non-residential properties the capping value was set according to the Multi Coloured Manual guidelines. This used the rateable value for various commercial property types, and was factored by the floor area to account for the property size. Due to the variable methods which Local Authorities calculate the rates of commercial properties this method, which is based on UK rate data, was found to produce inconsistent results and could not be used. Therefore an equivalent region in the UK, the south west of England, was considered and the rates for commercial property types used. The rateable values were sourced from the UK government website, **GOV.uk**. These values were converted from pound sterling to euros.

Damage to commercial properties was reviewed to ascertain the proportion any individual commercial property has on the overall damage. For properties contributing 1% of the total damage or more a detailed assessment was carried out. This involved confirming the amount of floor area that would flood and the FFL assumed.

The approach taken in this study is to cap the benefit as opposed to any damage contribution earlier in the process. The following details were recorded within the benefit shapefile attribute tables:

Table 5.11 - Capping damages data

Data type	Attribute name	Data details
Capping value of each property	CAP_CODE	For residential properties the value is given as twice the national market value of €257,462, derived from CSO. Residential MCM codes were related to property types with rate values in South West England, as were found to correlate well with Irish rate values.
Capping value of each property	CapVal	Residential CapVal was set as twice the rateable value. Commercial property values were based on 10 * Area* Rateable value per metre.
Capped present value benefit	PvB_DEF_C	Any benefit greater than the CapVal calculated was capped at the CapVal. Any benefit less than the CapVal was let equal the original present value benefit.

5.13 DAMAGE ASSESSMENT REVIEW

A review of the damage assessment was carried out to quality check the data being used. This was carried out by reviewing the properties that contribute over 1% of the capped PvD. The review consisted of checking the property type and the finished floor level including split levels, the footprint areas and the depth damage being applied.

6 FLOOD RISK MANAGEMENT METHODS

There are various ways to manage the flood risk within any area being studied. These methods can be grouped into four types of method.

- Permit methods - accept that flooding will occur. Methods include doing a minimal amount of additional maintenance.
- Prevent methods - avoid future flood risk. Methods include planning and development control.
- Protect methods - reduce the likelihood of flooding. Methods include flood walls, flow diversion and storage.
- Prepare methods - reduce the impact of flooding. Methods include individual property protection, flood forecasting and public awareness campaigns.

The CFRAM study has set an objective to identify viable structural and non-structural options and measures for the effective and sustainable management of flood risk within the area being studied. With this being said it is an aspiration of the study to provide the highest standard of flood risk management that is cost beneficial. This would, in general, entail providing 'protect' methods over 'prepare' methods and avoiding 'permit' methods where possible. Prevent methods, which consider future flood risk, should always be included.

6.1 STANDARD OF PROTECTION

The standard of flood risk management is also dependant on the design standard being applied i.e. the maximum level of protection that the FRM methods provide. The preferred design standard for this study is the 1% AEP event for fluvial flood risk and the 0.5% AEP event for coastal flood risk or the appropriate combination for areas of joint fluvial-coastal influence. The FRM method achieving the design standard must also have provision for adaptability to the mid-range future scenario (MRFS) flood risk (refer to section 7.5).

Where there is a clear technical, economic, social or environmental case as to why the preferred standards would not be appropriate or acceptable, or where the adoption of alternative standards would provide significant additional benefit in relation to costs and impacts, this is also considered.

6.1.1 Residual Risk

No FRM measure can totally eliminate the flood risk to an area, as a flood event greater than the design standard can occur, this is referred to as residual risk. In calculating residual damage it is assumed that for any design standard less than the 0.1% AEP flood event, residual damage will occur. In most cases the design standard will be to the 1% AEP event and there will therefore be residual damage for the 0.5% and 0.1% AEP flood events. For the purposes of this study it is assumed that for FRM methods that contain the flow within the river channel, such as flood walls, the residual damage for flood events greater than the design standard will be the same as the present day current damages.

For FRM methods that reduce the flow, such as upstream storage, the benefit provided during flood events greater than the design standard event was calculated.

6.2 LIST OF FRM METHODS

Table 6.1 lists the FRM methods being considered in the South Eastern CFRAM Study. This list is not exhaustive and additional FRM methods may become apparent which are specific to an area being studied. Where this is the case the additional FRM methods will be added to the long list of methods to be screened under the title “other works”.

Table 6.1 FRM Methods

FRM Method	Method type	Description
Do Nothing	Permit	Stopping the current maintenance regime
Additional Maintenance	Permit	Continue and augment existing flood risk management practices, such as maintenance and inspection, based on review of the existing regime.
Do Minimum	Permit	Clearance of channels and locating isolated/single issue which can be easily addressed in order to reduce the flood risk
Planning and Development Control	Prevent	Zoning of land for flood risk appropriate development, prevention of inappropriate incremental development, review of existing Local Authority policies in relation to planning and development and of inter-jurisdictional co-operation within the catchment.
Building Regulations	Prevent	Regulation relating to floor levels, flood proofing, flood resilience, sustainable drainage systems, prevention of reconstruction, or redevelopment in flood risk areas.
Catchment Wide SuDS	Prevent	Managing runoff rates to watercourses from new development. Ensuring that required features and infrastructure is included in development plans to maintain the existing greenfield runoff rate.
Land Use Management	Protect	Changing how the land is used in order to store or slow surface water runoff and slow in channel and out of bank flow along the river in order to store flood water in suitable locations. This may consist of the creation of wetlands, restoring river meanders, increasing the amount of boulders and vegetation in channel, perpendicular hedges or ditches in the floodplain, tree rows and planting in floodplain to either slow flow or direct flow, planting along banks parallel to flow, fencing off livestock from riparian strip, changing agricultural practices to decrease soil compaction and increase water infiltration.
Strategic Development Management	Prevent	Management of necessary floodplain development (proactive integration of structural measures into development designs and zoning, regulation on developer-funded communal retention, drainage and/or protection systems.
Storage	Protect	Large scale dam and reservoir, offline washlands (embanked areas of floodplain to store water during larger flood events.
Improvement of Channel Conveyance	Protect	Deepening of channel bed, widening of channel, realigning long section profile, removal of constraints, lining or smoothing channel.
Hard Defences	Protect	Reinforced concrete walls, earth embankments, demountable barriers.

FRM Method	Method type	Description
Relocation of Properties	Protect	Abandoning flood risk area and properties within and providing alternative properties in suitable area.
Culverting	Protect	Routing the watercourse underground through culvert to prevent out of bank flooding along a specific stretch.
Diversion of Flow	Protect	Removing flow from the watercourse via a diversion and discharging to a suitable river or coastline or reintroducing the flow further downstream. This may consist of a culvert or an open channel.
Flood Warning/Forecasting	Prepare	Installation of flood forecasting and warning system and development of emergency flood response procedures.
Public Awareness Campaign	Prepare	Informing public who live, work or use a flood risk area on risks of flooding and how to prepare for flooding.
Individual Property Protection	Prepare	Flood protection and resilience measures such as flood gates, vent covers, use of flood resilient materials, raising electrical power points, etc.
Other Works	-	Other specific methods not listed above.

6.3 BASELINE CONDITION

The existing regime is considered the baseline condition which incorporates activities such as monitoring, inspection and clearance. This represents the current scenario which all other scenarios, created by the implementation of other FRM methods, are compared to. This is realised by the reduction in receptors at risk, as described in Section 4, and the reduction in monetary damage (see Section 5) also known as benefit.

The review of the existing maintenance regime considers all activities currently carried out which may play a part in the management of flood risk. The level and frequency of maintenance is considered, along with inspection, and any other specific activity (for example the operation of locks, barrages, sluice gates and valves). There may be many organisations / stakeholders involved in maintaining the existing regime within a unit of management. Apart from ad-hoc maintenance undertaken by local authorities, which is discussed in relation to each AFA in Section 8, the activities discussed in the following sections may significantly contribute to maintaining the existing regime across multiple AFAs within UoM17.

6.3.1 Drainage Districts (Local Authorities)

There is one Drainage District located within UoM17:

- Shandon DD

Drainage Districts represent areas where the Local Authorities have responsibilities to maintain watercourse channels and therefore contribute to maintaining the existing regime. None of modelled watercourses are located within the Shandon Drainage District in UoM17 and as such the activities within Drainage Districts are not considered to significantly contribute to the maintenance of the existing regime affecting the AFAs however they do contribute to the maintenance of the existing regime in other parts of UoM17.

6.3.2 Arterial Drainage (OPW)

The Brickey Arterial Drainage Scheme was undertaken by the OPW between 1965 and 1967, under the 1945 Arterial Drainage Act however this does not include any of the modelled watercourses within UoM17. The OPW continues to have statutory responsibility for inspection and maintenance of the Scheme, which includes much of the main channel. While the primary focus of arterial drainage schemes is not for flood relief but for the improvement of agricultural land, there is undoubtedly reduced fluvial flood risk in certain parts of UoM17.

7 ASSESSMENT OF FRM METHODS

In order to ensure a consistent approach across the South Eastern CFRAM study area, a process to assess the FRM methods for each SSA has been standardised as summarised in the flow chart in Figure 7.1.

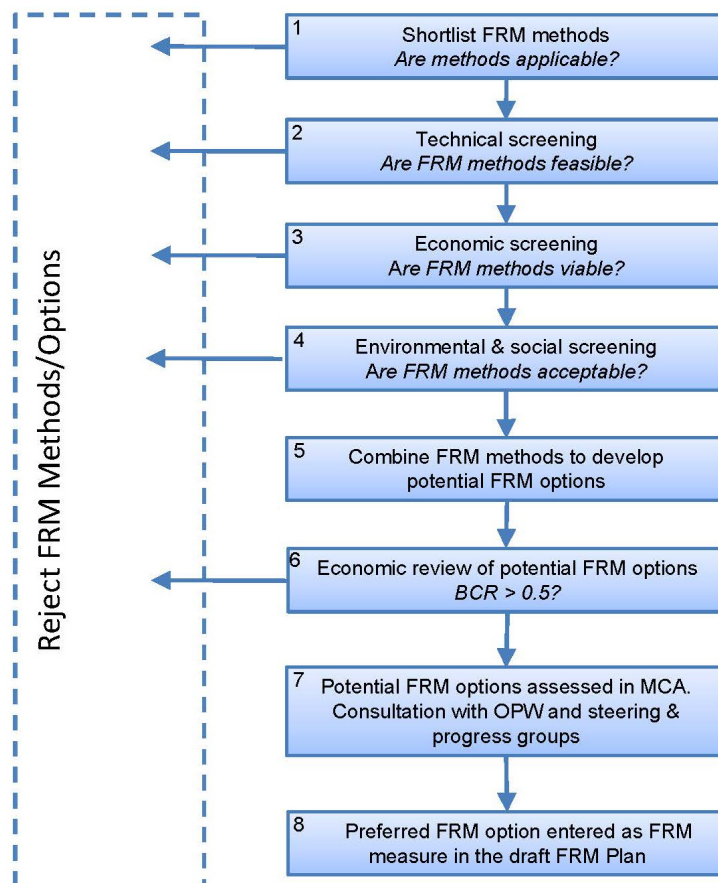


Figure 7.1 - Assessment of FRM methods flow chart

The flow chart summarises in boxes 1 to 4 how the screening of FRM methods was carried out. Boxes 5 and 6 describe how the FRM methods that came through the screening were developed into potential FRM options and box 7 shows how the potential FRM options were assessed to identify the preferred FRM options. This process was carried out in consultation with the OPW and the steering group and progress groups of the South Eastern CFRAM Study.

The preferred FRM option/s will be taken forward to public consultation and, if required, updated to reflect the comments and issues raised before presenting the final FRM measure in the FRM Plan as shown in box 8. Section 8 provides a record of the assessments and decisions made when this process was applied to the South Eastern CFRAM Study SSAs.

7.1 SCREENING FRM METHODS

The aim of the screening process was to ensure the widest possible range of FRM methods were considered in the assessment process while the rejection of any methods was robust and with clear and transparent reasoning. The following section details how the screening process achieved this.

7.1.1 Shortlisting FRM Methods

A long list of FRM methods (Table 6.1) has been developed by OPW and RPS and includes FRM methods which accept that flooding occurs (permit methods), reduce the likelihood of flooding (protect methods), reduce the impact of flooding (prepare methods) and avoid future flood risk (prevent methods).

This long list was reviewed for each SSA in terms of applicability. Methods which were not applicable to the specific SSA were rejected and a shortlist of FRM methods created to be considered further. An example of this is considering flood forecasting at an AFA SSA. If the flood forecasting were to benefit multiple AFAs, the full benefit of the FRM method would not be captured at an AFA scale of assessment and should therefore be considered at UoM scale.

7.1.2 Technical Screening

Although an FRM method may be applicable, it may not be feasible from a technical point of view. This may be due to the method providing no reduction in flood risk. An example of this is where a high level of maintenance and operation is currently being carried out on a watercourse and to implement the "do minimum" method, (a reduction on maintenance and operation) would result in increased flood risk with little cost savings. Where such methods were identified they were rejected at this stage and not considered any further in the process.

Other methods may have little impact in reducing the flood risk. This was ascertained through hydraulic modelling and reviewing the effect of the method or through reviewing the flooding mechanisms, for example a channel conveyance method will have little impact if the flood mechanism is the back water effect from the coast or a different river.

The technical screening also identifies methods which would be excessively complex to implement. This may be due to restrictions on construction methods or obstacles such as bridges and underground services. These methods may be effective in reducing the flood risk but due to their complex nature they do not merit further consideration until all other more straightforward methods have been exhausted.

The following sections detail how each of the FRM methods have been technically screened.

7.1.3 Do Nothing

This method was considered at AFA scale, in situations where the existing regime involves operation/maintenance which might be stopped without increasing flood risk. This could apply either to the operation/maintenance of an existing flood defence/watercourse in an area where the flood risk has

been reduced sufficiently due to other works, or where receptors have become flood resilient or moved out of the flood plain.

7.1.4 Additional Maintenance

This method was considered at AFA scale, the aim of the technical review was to identify where additional maintenance works (in comparison to the current level of maintenance) would be effective. A review was carried out to assess the likelihood of the maintenance issues, such as vegetation, debris and culverts susceptible to blockages causing an increased flood risk. Where this was identified targeted maintenance methods have been proposed.

Where dense vegetation and debris was deemed to be influencing water levels during flood events the technical feasibility of this method was assessed by considering the hydraulic model sensitivity. The friction values used in the model were adjusted in order to represent the reduction in channel roughness associated with vegetation removal. Where a noticeable reduction in water levels was observed this method was considered technically feasible, where the reduction in water levels was negligible the method was considered technically unfeasible. Where this method was identified as feasible targeted maintenance methods have been proposed.

Where potential culvert blockage was deemed to be influencing water levels during flood events, trash screens were considered and where this method was found effective it was considered technically feasible and targeted maintenance methods have been proposed.

7.1.5 Do Minimum

This method was considered at AFA scale, the aim of the technical review was to identify localised areas where, due to a restriction or pinch point, the flood risk is increased and where minimal construction works would remove the restriction. These activities would be considered relatively straightforward, discrete and low cost.

7.1.6 Sustainable Planning and Development Management

This method was considered at UoM scale as it is a policy level measure to prevent significant increased risk for, or due to, new development.

In November 2009, the Guidelines on the Planning System and Flood Risk Management, jointly developed by DECLG and the OPW, were published under Section 28 of the Planning Acts. These Guidelines provide a systematic and transparent framework for the consideration of flood risk in the planning and development management processes, whereby:

- A sequential approach should be adopted to planning and development based on avoidance, reduction and mitigation of flood risk.
- A flood risk assessment should be undertaken that should inform the process of decision-making within the planning and development management processes at an early stage.
- Development should be avoided in floodplains unless there are demonstrable, wider sustainability and proper planning objectives that justify appropriate development and where the

flood risk to such development can be reduced and managed to an acceptable level without increasing flood risk elsewhere (as set out through the Justification test).

The proper application of the Guidelines by the planning authorities is essential to avoid inappropriate development in flood prone areas, and hence avoid unnecessary increases in flood risk into the future. The flood mapping provided as part of the FRMP will facilitate the application of the Guidelines.

In flood-prone areas where development can be justified (i.e. re-development, infill development or new development that has passed the Justification Test), the planning authorities can manage the risk by setting suitable objectives or conditions, such as minimum floor levels or flood resistant or resilient building methods.

The following methods are encompassed within the Sustainable Planning and Development Management method and were considered at UoM scale as they are policy level measures to prevent significant increased risk for, or due to, new development:

- Planning and Development Control
- Building Regulations
- Sub-catchment Wide SuDs
- Strategic Development Management.

7.1.7 Land Use Management

Floods can be attenuated (i.e. the flood slowed down, the peak flow reduced and the flood volume spread over a longer period of time) by interventions along the river and throughout the catchment, e.g. increasing channel and floodplain roughness (introducing impediments to flow in the river, or on floodplains, such as by increasing riparian vegetation or planting hedgerows) or by restoring meanders. Such methods are often referred to as Land Use Management (LUM), Natural Water Retention Measures (NWRM) or Natural Flood Management (NFM). This method has been shown to reduce flood flows with the greatest influence on smaller, more frequent floods. However this reduction in flow has been difficult to quantify and further research is required on this matter. In addition to reducing flood risk such measures can have significant benefits for environmental enhancement, such as contributing to the objectives of the Water Framework Directive or increasing biodiversity.

Whilst these methods require piloting in an Irish context to determine their practicality, it is considered appropriate to assess their application to areas with a relatively limited degree of flooding which might be addressed by marginal hydrological modification, and where current land use suggests that such methods have potential to be implemented and are therefore technically feasible, economically viable, environmentally beneficial and socially acceptable. The plan-level assessment did not consider land owner buy-in.

A national screening was carried out whereby the land's potential for rainfall runoff reduction was quantified. This screening was carried out to ascertain the potential effectiveness of natural flood management measures in a catchment. The factors that were considered were:

- Land cover – Key land use and practices were identified which give rise to the greatest hydrological impacts.
- Soil – Soils were identified and their vulnerability to soil structural degradation assessed.
- Slope – Shallow to steep slopes were identified and scored on their sensitivity to runoff.
- Rainfall – The standard annualised average rainfall was identified to find areas experiencing greater or lesser runoff.

These four factors were combined to create a sensitivity classification from 1 to 4. A classification of 1 identified areas where NFM measures would have little impact in reducing the runoff and a classification of 4 identified areas where NFM measures would have a significant impact in reducing the runoff. The screening was carried out for UoM17 and a raster dataset of 20m grid squares with each grid square having its own classification developed. This was converted to a GIS shapefile to facilitate its potential use and interaction with other receptor datasets. This output was used as an initial screening tool in order to identify AFAs with a potential for Land Use Management.

The aim of the technical review was to identify suitable pilot areas to implement natural flood management through management of land use practices upstream of flood risk areas. This method was considered at UoM and sub-catchment scale initially to assess potentially suitable areas, and refined at AFA scale to determine where the measure would be suitable to pilot either standalone or in combination with other measures. At AFA scale a review of the area in question was carried out and an assessment made on its suitability for a pilot study. The following factors were considered:

- The size of the catchment. Smaller catchment will be more easily monitored and will have less landowners and stakeholders to liaise with.
- Land cover. This was considered using the Corine land use dataset and an assessment made its ability to reduce runoff should the land use be changed. Bog areas were considered to have little ability to reduce the runoff as rewetting drained bogs would have limited hydrological benefit and undrained bogs would already attenuate runoff. Urban areas were also considered difficult to retrospectively change in order to reduce runoff as the space to do so is generally limited. Agricultural and forested land, including scrubland, was considered to offer relatively better scope for runoff reduction as there may be space to apply measures.
- Catchment slope. A general assumption was made that steep catchments have a good potential in reducing the runoff and slowing the flood down. Flat catchments have little potential to do this.

7.1.8 Storage

The aim of the technical review was to identify areas of land suitable to store flood water in order to attenuate river flows and reduce the existing flood risk. This method was considered at both Sub-catchment and AFA scales.

At AFA scale the effect of storage was assessed by a hydraulic analysis. The general approach was to estimate the volume of water required to be stored, identify suitable storage areas and to hydraulically model the effects of storage during the design flood event. Estimating the volume of

water required to be stored involved reviewing the simulated hydrographs produced from the existing hydraulic models. By comparing a high frequency flood event where there is no or little risk to the low frequency design flood event an estimation of the volume can be made over the duration of the flood. While this does not account for lag times caused by a storage dam it provides an initial estimate. Following this suitable storage areas were identified using LiDAR survey data that provided the required storage volume. These areas were then screened for suitability, areas found unsuitable due to receptors within or in proximity to them were removed. Where storage areas were identified and found suitable the effects of placing the storage areas in the watercourse network were modelled.

At Sub-catchment scale an estimate of the hydrological affects was undertaken where it was not possible to model the effects of storage areas outside the hydraulic model extents. Initial flood flows were estimated in part by accounting for the river's catchment characteristics. By estimating the change to these characteristics resulting from the inclusion of storage areas, post-storage flood flows were estimated. The catchment characteristic that changed as a result of increased storage areas was FARL (Flood Attenuation by Reservoirs and Lakes). Depending on the percentage of the catchment changed to flood storage areas, the FARL value changed accordingly. This in turn changed the estimated flood flow which was used to estimate the reduction in flood risk.

7.1.9 Improvement of Channel Conveyance

The aim of the technical review was to identify reaches of watercourse suitable for improved conveyance and to estimate how effective the improvement would be in reducing the flood risk. This method was considered at both Sub-catchment and AFA scales.

Conveyance can be improved because there are existing restrictions to flow, such as undersized culverts. Or conveyance can be improved through altering the existing channel's characteristics such as width, depth and slope.

The general principle applied when attempting to improve conveyance was to remove restrictions, and increase channel capacity either through changing width, depth and/or slope. However, there are certain scenarios where this would not be possible such as where an existing structure limits the width or depth that the channel can be changed by, or where the flooding originates from downstream and backs up the watercourse making any conveyance improvement techniques ineffective.

The risk areas and flooding mechanisms were identified and the suitability of channel conveyance assessed. The effects of removing restrictions to the 1%AEP flow were modelled such as upgrading culverts or removing weirs. An estimation of how the channel could be changed to convey the 1%AEP flow was carried out where the channel was found to have insufficient capacity. This was estimated using the Manning's equation which allows for width, depth and slope to be changed and the resulting flow capacity calculated. A review of the channel long section was undertaken to establish what length of the channel would need to be upgraded to ensure the required conveyance extended past the risk area. For steep watercourses this length would be relatively short, whereas flat watercourses would require a relatively long reach to be upgraded.

7.1.10 Hard Defences

The aim of the technical review was to identify where, what type and to what extent hard defences would be required to provide the required standard of protection. This method was considered mainly at AFA scale, however where the presence of a tidal barrage form of defence would benefit several UoMs/Sub-catchment/AFAs (generally at the downstream extent of a UoM) a UoM scale assessment was undertaken.

The assessment was carried out by reviewing the existing flood extent and delineating where hard defences would be required. As a general rule hard defences were kept as far from the watercourses as possible to ensure the maximum amount of floodplain would be retained. On establishing the position of hard defences a hydraulic model was run to assess the affects and to establish the flood water level against the defences. This was sometimes an iterative process as the presence of hard defences would push the flood water upstream or downstream causing flooding elsewhere. In these cases additional hard defences would be added and the model run again and again until the required SoP was achieved.

In some cases the model showed that the hard defences needed to provide the required standard of protection would be excessively high making it unfeasible. Where such a situation occurred hard defences were technically screened out.

7.1.11 Relocation of Properties

The aim of the technical review was to identify suitable properties for relocation, which in effect means abandoning the flood prone asset and finding a similar facility in a non-flood prone area. This localised method was considered at AFA scale.

While there are many circumstances where relocation of properties was technically possible this review considered the following as unsuitable:

- Where the properties were interspersed amongst other properties. This occurred when overland flow affected some properties but not others as it progressed. Due to the uncertainty of the model and the effect of local structures such as garden walls this method was considered technically unfeasible.
- Where the property was placed in a strategic position and cannot be removed without removing a vital service.

7.1.12 Diversion of flow

The aim of the technical review was to identify suitable locations where flow could be diverted from a watercourse causing flood risk and to identify suitable discharge locations. This may be to another river, a coastline or a point further downstream on the same river. High level review determined that there were no suitable UoM or Sub-catchment scale diversion routes, and this method was considered at AFA scale.

The review estimated the size of the diversion needed in order to convey sufficient flow such that flood risk was removed or reduced along the watercourse in question. For each AFA, locations for flow

diversions were identified. These locations would be located upstream of where flood risk occurs and free from structures that might impede the diversion. If suitable locations were found to be available a diversion route was identified. This relied on the topography of the surrounding land to provide a path which falls from the diversion inlet to its outlet and on there being no barriers located across the potential diversion route such as properties.

If a diversion location was identified an estimation of how much flow it would have to convey was made. This was carried out by an analysis of the existing hydraulic model for the AFA in question. The in-channel flow was compared with the peak flow during the flood event at the risk area being considered and how much flow would need to be diverted calculated. This would depend of the location of the flow diversion to the risk area and how much lateral in-flow would take place in between these two locations. Following this a diversion channel size was calculated using the Manning's equation.

7.1.13 Flood Warning/Forecasting

The aim of the technical review was to identify catchments which would afford suitable warning time to receptor owners or emergency response teams to allow them to prepare for an oncoming flood by defending the property from flooding or moving contents out of flood risk areas. This method was considered at UoM scale initially to assess the rainfall and flow monitoring requirements, as it is considered that there are potential operational and infrastructural benefits at UoM scale. Where relevant the assessment was refined at sub-catchment and AFA scale to determine where the measure would be suitable either standalone (to support resilience) or in combination with other measures, such as individual property protection.

Flood warning and forecasting can be driven by different mechanisms. River gauges which monitor flow provide the most accurate estimate of a flood event but are more restricted in the warning time available depending on the river's catchment characteristics. Rain gauges may also be used as the basis for the warning system or in conjunction with a hydrological model. Rainfall based systems are generally less accurate as a prediction needs to be made between rainfall and river flow however a longer warning time can be provided. This type of forecasting lends itself to a large area where multiple catchments and rivers would benefit.

When this method was considered at AFA level, in most cases it was found that small catchments would require a minimal amount of gauging infrastructure to be implemented. Generally a river gauge was required at the risk area and at the forecasting area along with some rainfall gauges in the upper catchment. It was assumed that a correlation between the rainfall gauges and the river gauge at the forecasting location would provide the decision making time in order to issue a warning. The warning time available was based on the travel time of the flood event from the river gauge at the forecasting location to the risk area. This was estimated by calculating the flood wave travel time within the hydraulic model and applying an average speed to the distance between the river gauges. A minimum warning time of 2 hours was set to allow people to react to the flood events, otherwise the flood warning and forecasting method was considered technically unfeasible.

For larger areas, more rainfall gauges would be required in order to accurately represent the catchment. A minimum density of 1 gauge per 100km² would be required as per the World Meteorological Organization guidelines, however this rate would be increased depending on the distribution of smaller catchments within the main catchment and when the catchment itself is relatively small. River gauges would also be required throughout the catchment to provide river flow/water level data at identified risk areas and at locations upstream which would provide the required warning time. River gauges would also be added at strategic locations along the watercourses and at significant tributaries depending on the distribution of flows. The warning time would be estimated in a similar method to the small catchments where only one AFA is located using the hydraulic models results to calculate this time.

7.1.14 Public Awareness Campaign

This method was considered at UoM scale and is based on the risk in any given area and what other methods are being proposed. This method aims to make the public aware of the current flood risk their property and surrounding area is in and how residents might take necessary precautions to reduce the risk and damage to themselves and their property. This information would be tailored to the level of risk, whether the areas have an FRM option and what level of protection the option will provide. This information might be relatively generic where protect methods are being proposed however where permit and prepare methods are being proposed this information might be tailored so that the public are equipped to make their property more flood resilient, such as changing floor and wall materials to be flood resilient, or how to monitor the available flood forecasting information.

7.1.15 Individual Property Protection

This method was considered at AFA level, aiming to protect individual properties by the provision of flood gates and other items which prevent the ingress of flood waters into a property. This method is considered to have limited effectiveness as there could still be flood damage to the building structure and surrounding land and it relies on human intervention to put the defence in place every time a flood occurs. For this reason 20% of the damage was assumed to be avoided over the life time of the scheme. Where the flood depth to a property is greater than 0.6m this method was considered technically infeasible as the risk of structural damage to the property is high.

7.1.16 Other Works

These methods were considered at AFA level, and would be specific to the area being assessed or the flooding that occurs. One example is where pumping would be required to make an option technically feasible, for example assisting fluvial drainage against tidal controls.

The methods considered applicable to each SSA are summarised in Table 7.1.

Table 7.1: Summary of FRM Applicability to SSA

Method	UoM	AFA
Do Nothing	x	✓
Additional Maintenance	x	✓
Do Minimum	x	✓
Planning and Development Control	✓	x
Building Regulations	✓	x
Catchment Wide SuDs	✓	x
Land Use Management	✓	✓
Strategic Development Management	✓	x
Storage	x	✓
Improvement of Channel Conveyance	x	✓
Hard Defences	x	✓
Relocation of Properties	x	✓
Diversion of Flow	x	✓
Flood Warning/Forecasting	✓	✓
Public Awareness Campaign	✓	x
Individual Property Protection	x	✓
Other Works	x	✓

7.1.17 Economic Screening

The economic screening ensured that only methods likely to be cost beneficial progressed to the more detailed assessment. This was carried out by calculating the benefit available in the SSA and comparing that to the cost of implementing the method (the benefit available was quantified through the damage assessment as described in Section 5). As mentioned in Section 4.2 the screening was applied within flood cells when considering AFAs. Whilst discrete areas within the AFA have discrete flood risk and therefore potential benefit, the cost of a method being considered in a flood cell was compared with the benefit to the whole AFA. This is because the cost benefit ratio is taken for the whole AFA and even though a method may not be cost beneficial at any given flood cell there could be enough benefit elsewhere in the AFA to carry that method through the process. Therefore the economic screening considered the total AFA benefit.

7.1.17.1 Construction costs

The cost of constructing FRM methods was calculated using the OPW unit cost dataset. This data was based on previous schemes using real costs and was presented as rates to be applied to the FRM methods depending on the quantities involved.

As such the first stage in this process was to quantify the FRM methods. This information included wall lengths and heights, lengths of culvert, volume of excavation, etc. This was carried out by hydraulic modelling and using the GIS software ESRI ArcMap. The location and extent of FRM methods were delineated in GIS using OSi mapping with consideration of the flood risk receptors. Once the quantities were calculated, the unit construction rates could be applied to estimate the construction cost.

Additional costs were added to the construction costs to account for other work items outside of construction and to account for unknown factors that may add to the total cost of the scheme. Costs for preliminary items were added based on a percentage of the construction cost. These items would generally apply to the whole scheme, not just an individual asset within the scheme. This would include items like temporary fencing, haul roads, site cabins, road sweeping, etc. The preliminaries can range from 32% - 6% of the construction costs where cheaper construction costs have a larger percentage for preliminaries and expensive construction costs have a smaller percentage for preliminaries. In addition to this other items were also included and are presented in Table 7.2.

A maintenance cost was estimated over the life span of the scheme, which has been set at 50 years. These costs were estimated from the OPW unit cost database as yearly costs and discounted over the 50 years.

Once the construction costs, preliminaries, other item costs and maintenance were calculated an optimism bias was added to give the total cost of the FRM method. The optimism bias accounts for unknowns, factors that could occur which if they did would add to the cost of the scheme. These factors include, for example, design complexity, ground conditions, services, public relations. A summary of FRM method costs are presented in Table 7.2. The FRM method costs for potential options are summarised in Section 8 for each AFA.

Table 7.2 - Additional costs to FRM options

Item	% of construction cost
Preliminaries	32 - 6
Detailed design (design fees)	13
Allowance for archaeological and/or environmental monitoring/exploration	10-15
Cost of land acquisition/compensation	10-15
Allowance for art	€0 - €2.55m = up to €25,500 €2.55m - €6.3m = €38,000 €6.3m - €12.7m = €51,000 >€12.7m = €64,000
Maintenance	-
Optimism Bias	70 - 10

7.1.18 Environmental and Social Screening

It is important to ensure that methods being brought through the assessment process will not have significant detrimental environmental or social/cultural impacts.

AFAs were screened for proximity to European Sites and World Heritage Sites and the potential hydraulic linkages to these sites from FRM methods. At screening stage areas sensitive to development were avoided if possible. Methods that were technically and economically feasible were visualised and reviewed from an environmental and social perspective to determine if there was any early positional improvement that could be undertaken to minimise potential negative impacts. The assessment assumed unmitigated methods but that the construction of the options will be undertaken

by competent contractors in accordance with current best working practice and construction works will be undertaken outside of seasons that may have environmental sensitivities. For some SSAs the environmental feedback resulted in the development of refined FRM options based on existing technically and socially feasible options.

Mitigation noted through the screening, and subsequent more detailed environmental and social MCA process, are ideally brought through into the SEA Environmental Report, AA Stage 2 and adopted / committed to in the FRMP.

7.2 DEVELOPING POTENTIAL FRM OPTIONS

All FRM methods that were found suitable in the screening process detailed in Section 7.1 were developed into options. Options consist of a single or multiple methods which manage the flood risk to the entire SSA. This was carried out by identifying all possible combinations of FRM methods, assessing their effectiveness and undertaking a benefit cost analysis.

7.2.1 Identifying possible FRM options

When a number of FRM methods were found suitable for an SSA they were assessed both as standalone methods and in combination with other methods. There were certain circumstances where methods could not be combined such as where one method is not complemented by another, for example relocation of properties is not suitable to consider with another method which manages the risk in the same area. Once all suitable combinations were identified the resulting potential options were proposed.

7.2.2 Option effectiveness

A quantitative assessment of how effective the options could be was carried out by hydraulic simulation. This assessment considered how different methods would interact with each other. For example where a storage method and a hard defence method were combined the reduction in the hard defence length and height was calculated due to the attenuation from the storage. Details of each option are presented in Section 8.

7.2.3 Benefit Cost Analysis

The cost of each option was calculated by combining the construction and maintenance costs of the FRM methods making up the option and then applying a cost for preliminaries, other items and optimism bias as detailed in section 7.1.17. Using the benefit, as detailed in section 5, a benefit cost ratio (BCR) was calculated. Options with a BCR or 0.5 or greater were considered potential options and continued in the assessment. The BCR threshold of 0.5 was set to allow options which are apparently not cost beneficial to progress with a view that if they are considered during a detailed study the options costs may be reduced as uncertainties in relation to site specific conditions are ruled out or mitigated.

The primary FRM methods which were progressed through the technical, environmental, social and economic screening were combined to create potential FRM options. Most methods, while providing significant reductions in flood risk, will not manage the flood risk entirely by themselves. Methods were therefore required to be combined into options so that they would manage the flood risk and achieve the objectives set by the study.

In most cases the FRM options were required to provide a design standard of the 1% AEP flood event although this could vary depending on the requirements of the SSA. All suitable combinations of FRM methods were considered as potential FRM options, however, only options that could provide the required design standard were progressed further.

7.3 ASSESSMENT OF POTENTIAL FRM OPTIONS (MCA PROCESS)

The development of options stage identified potential FRM options. From these options an assessment was required to identify preferred option(s). This was carried out with a multi criteria analysis (MCA).

Historically the assessment of FRM options has been primarily based on economic costs and benefits, with an EIA undertaken to minimise negative impacts on the environment, and public consultation undertaken to ensure social acceptability. The National Flood Policy Review (OPW, 2004) set a broader range of objectives for flood risk management in Ireland that was subsequently reinforced by the EU 'Floods' Directive [2006/60/EC].

The MCA framework was developed to broaden the range of potential impacts associated with flooding and the implementation of FRM options considered in the development and selection of FRM options and strategies, and their subsequent prioritisation. It was based on the numeric, but non-monetarised, assessment of options against a range of objectives. Indicators were used to assign scores for each objective on the basis of the degree to which the option being appraised goes beyond a specified basic requirement for that objective towards meeting a specified aspirational target for that objective. Weightings were applied globally (nationally) for each objective, with local weightings applied to reflect the local importance of that objective in the context of the respective SSA, and these weightings were applied to the scores derived as described above.

The sums of the weighted scores, set against the total costs of their achievement, represented the preference for a given option (using all criteria) or the net benefits of an option (using only the economic, social and environmental criteria). These total scores can be used to inform the decision on preferred option(s) selection for a given location and the prioritisation of potential schemes between locations.

The following section describes the MCA process in more detail.

7.3.1 Criteria and Objectives

Each option was assessed against four criteria; Social, Economic, Environmental and Technical. Scoring against these criteria helps to achieve the CFRAM Study objective of achieving the most cost effective and sustainable management of existing and potential future flood risk within the area being studied. A set of objectives, associated with each criteria, are an expansion on the requirements of the National Flood Policy Review and the EU Floods Directive. The degree to which an option achieves each objective is an indication of the success of the option in managing the flood risk, the more the option achieves across all the objectives, the greater preference it will be given.

Generally each objective focused on a flood risk receptor type and how the flood risk was to be reduced with the exception of the technical objectives which focused on how the options would be constructed and operated during their lifetime. In some cases the flood risk receptor type was wide reaching and sub-objectives were required to focus on a specific group within the receptor type. Table 7.3 presents the objectives and sub-objectives set for each of the criteria in the MCA.

Table 7.3 - Criteria and Objectives of the MCA

Criteria	Objective	Sub-Objective
		Minimise risk to human health and life of residents
		Minimise risk to high vulnerability properties
		Minimise risk to social infrastructure and amenity
		Minimise risk to local employment
	Minimise economic risk	Minimise economic risk
	Minimise risk to transport infrastructure	Minimise risk to transport infrastructure
	Minimise risk to utility infrastructure	Minimise risk to utility infrastructure
	Manage Risk to agriculture	Manage Risk to agriculture
	Support the objectives of the WFD	Provide no impediment to the achievement of water body objectives and, if possible, contribute to the achievement of water body objectives
	Support the objectives of the Habitats Directive	Avoid detrimental effects to, and where possible enhance, Natura 2000 network, protected species and their key habitats, recognising relevant landscape features and stepping stones.
	Avoid damage to, and where possible enhance, the flora and fauna of the catchment	Avoid damage to or loss of, and where possible enhance, nature conservation sites and protected species or other know species of conservation concern.
	Protect, and where possible enhance, fisheries resource within the catchment	Maintain existing, and where possible create new, fisheries habitat including the maintenance or improvement of conditions that allow upstream migration for fish species
	Protect, and where possible enhance, landscape character and visual amenity within the river corridor	Protect, and where possible enhance, visual amenity, landscape protection zones and views into / from designated scenic areas within the river corridor
		Avoid damage to or loss of features, institutions and collections of architectural value and their setting.
		Avoid damage to or loss of features, institutions and collections of archaeological value and their setting.
	Ensure flood risk management options are operationally robust	Ensure flood risk management options are operationally robust
	Minimise health and safety risks associated with the construction, operation and maintenance of flood risk management options	Minimise health and safety risks associated with the construction, operation and maintenance of flood risk management options
	Ensure flood risk management options are adaptable to future flood risk, and the potential impacts of climate change	Ensure flood risk management options are adaptable to future flood risk, and the potential impacts of climate change

7.3.2 Scoring Options

A scoring system was devised for the MCA to assess each option in a robust, clear and transparent way. A score was given for how well an option achieved an objective but also accounts for the importance of the objective relative to other objectives and how important the receptors within the area being studied are relative to the receptor group being considered.

To enable the scoring of the objectives, indicators were set. Indicators are parameters, measurable and numeric where possible, by which the success of the option in meeting a particular objective can be gauged. For example a social objective is to "minimise risk to human health and life of residents" and the indicator is "the number of residential properties at risk from flooding during the 0.1% AEP event". The difference that the option being assessed makes to the number of residential properties at risk can be calculated as a percentage and applied to the maximum achievable score value to give the actual option score.

The success of the option in achieving the particular objective in question is quantified by how much it goes beyond a specified basic requirement and achieves a specified aspirational target. As such basic requirements and aspirational targets have been set in terms of the defined indicator.

The basic requirement represents a neutral status or 'no change', whereby an option has no impact on the matter the objective relates to, or meets what might be termed for some objectives, minimum requirements for acceptability. If an option performs less well than the basic requirement, i.e. has a negative impact (a dis-benefit) or does not meet the minimum requirements for acceptability, it will score a negative-value score for that objective, but might still be considered further, depending on the degree of the dis-benefit or failure to meet the requirements. The basic requirement is therefore not an absolute minimum requirement for acceptability, but a benchmark to define positive versus negative impacts or performance.

The aim of an objective is defined by the aspirational target, whereby an option would be deemed as performing optimally with respect to the given objective if it were to meet the aspirational target. Typically this may represent complete removal of a risk, or the full achievement of another benefit, and it will be rare that any option will meet such aspirational targets for even one, let alone all, objectives. The aspirational targets are therefore not requirements that must be met, and it should be noted that very effective options may still fail to meet the aspirational targets.

The following rules have been applied to the MCA scoring:

- An option achieving the basic requirement is given a score of zero.
- An option meeting the aspirational target is given a score of five. Options achieving more than the aspirational target still score a maximum of five.
- An option achieving somewhere in between the basic requirement and the aspirational target is given a score proportional to the degree to which it achieves the objective beyond the basic requirement towards meeting the aspirational target.

- An option failing to meet the basic requirement is given a negative score of -1 to -5 depending on the impacts associated with the option.
- Where the performance or impact of the option becomes unacceptable a score of -999 is given and the option is rejected from further consideration.

Justification for each objective score has been included within the MCA tables providing the rationale for each score.

7.3.3 Weighting objectives

It is considered that some objectives are more important than others and to give them all equal importance would not reflect the significance of the benefit, or lack thereof, achieved. For example, an objective considering risk to life is more important than one considering social amenity sites. To reflect this in the scoring a global weighting has been applied. This gives an objective more or less weight in the overall assessment of the suitability or value of the option. Global weightings will remain constant nationally and were derived following consultation carried out at national stakeholder level between the OPW and a number of stakeholders.

It is also appreciated that for any given objective its importance will depend on the SSA and the type of receptor it is considering. For example, an objective considering the impact to environmentally designated sites may have more significance if the site is of international importance than of local importance. To account for this a local weighting is applied to the objective. The local weighting has been determined either numerically according to the degree of risk (e.g. annual average damage, number of properties) or by professional judgment including input from stakeholders and the public. Details of the local weighting rationale are included within the MCA tables.

7.4 PREFERRED FRM OPTIONS

Identification of the preferred FRM options is based on the following:

- **Criteria Scores:** Once the MCA has been applied, each option will have a weighted score for each objective. For each option, the scores for each of the four criteria have been summed to provide the Criteria Scores.
- **MCA Benefit Score:** To derive the MCA Benefit Score, the scores for the economic, social and environmental Criteria Scores have been summed. This score represents the net benefits of the option.
- **Option Selection MCA Score:** To derive the Option Selection MCA Score, the scores for all four of the criteria have been summed. This score compliments the MCA Benefit Score with the Technical Criteria Score, and hence includes all of the aspects that have been taken into account in considering the preferred option for a given location.

- **MCA Benefit – Cost Ratio (BCR):** The MCA Benefit Score has been divided by the cost of the option to provide a numerical, but non-monetarised, MCA Benefit - Cost Ratio that provides an indication of the overall benefits that can be delivered per Euro invested.
- The **Economic Benefit – Cost Ratio (BCR)** has been calculated using the more traditional techniques (i.e., the FHRC Multi-Coloured Manual, rather than the option appraisal MCA set out herein).
- **Consultation:** Consultation with the OPW, steering group and stakeholder group.

Preliminary FRM options have been reviewed by OPW and the South Eastern CFRAM Study progress group and steering group members. Professional judgement and stakeholder comment is required to identify the preferred options as some options may have a good monetary BCR but a poor overall net benefit/cost or vice versa and comparison between options may not always be clear. Recommendations can be made at this point to improve the options and preferred options identified for incorporation in the Flood Risk Management Plan.

7.4.1 No potential options

In certain cases, no potential options were identified; this was mainly due to technical or economic reasons. Where this occurred an alternative SoP was considered i.e. the options with the best potential were assessed against a different design event. This was usually a 2% AEP flood event for fluvial flood risk and a 1% AEP flood event for coastal. The reduction in construction cost was compared with the reduced benefit that results from considering a lower SoP. Any options with a BCR ≥ 0.5 were continued in the optioneering process as a potential option. In addition to this all feasible methods identified at UoM or Sub Catchment level were included for each AFA. Where no potential options were identified the baseline condition was taken as the preferred option.

7.5 FUTURE CHANGE ASSESSMENT ALONGSIDE OPTION DEVELOPMENT

To address the challenge of climate change and other factors potentially affecting future flood risk, the OPW, as lead agency for flood risk management in Ireland, has adopted an approach in relation to assessing and providing for the potential impacts of future change for the Flood Risk Management Programme. This approach is aimed at the effective and efficient provision for the potential impacts of climate change and other factors in the management of existing, and particularly potential future, flood risks.

The approach requires that the possible impacts of future change, and the associated uncertainty in projections, shall be considered at all stages of activity under the national Flood Risk Management Programme, and the development, design and implementation of all policies, strategies, plans and measures for, or related to, flood risk management must be sustainable and should adopt an adaptive approach (i.e. including provision for future amendment or enhancement) or, where appropriate, an assumptive approach (i.e. including relevant allowances) with respect to such impacts.

FRM options are designed to perform for 50 years and during this option's lifetime it is expected that, flood events will become more severe and an option's subsequent design SoP will be reduced. The implications for flood risk change and the requirement for further measures and expenditure to maintain the SoP over this timescale may be significant. A phased future change review was therefore carried out alongside the hazard, risk and option development assessments to determine how sensitive hazard and risk are likely to be in particular AFAs, and, to assess potential option's ability to achieve the objective of adaptability.

A "sensitivity to future change" review was carried out using the hydrological and hydraulic analysis to ascertain the change in flood hazard and risk. This established the consequences of future change in any given area, whereby the number of additional properties was determined along with the AAD that may occur under the Mid Range Future Scenario (MRFS) or the High End Future Scenario (HEFS). The degree of change in future damages, compared to present day values, was assessed to qualitatively identify the vulnerability of communities (either; highly-sensitive - requiring outline future change assessment for measures during the CFRAM option development stage, or; less-sensitive requiring adaptation assessment to be undertaken at a later, detailed design, stage). The following rules were applied to assess the vulnerability:

- Low vulnerability: AAD change <25% & <€1m
- Moderate vulnerability: AAD change >25% & <€1m or AAD change < 25% & >€1m
- High vulnerability: AAD change >25% & >€1m

Within highly-sensitive AFAs a "future change adaptability" review was carried out, using qualitative expert engineering judgement supported by quantitative information obtained by modelling simulations of methods and options under consideration. The methods being proposed as preliminary option(s) were assessed in order to give an indication as to how readily they could be adapted and the likely design approach to provide additional protection (namely the Adaptive Approach, the Assumptive Approach or No Physical Provision).

This assessment was dependent on:

- the methods themselves, for example an embankment can be relatively readily added to or a channel could be dredged further but a culvert cannot provide more capacity readily.
- the watercourse's sensitivity to additional flow with the method in place. For example, when walls are being considered the additional height required is related to how close or set back they are from the watercourse or the effect of a downstream control structure such as a weir or culvert.
- the characteristics of the upstream catchment. For example some methods/options can be made adaptive by the addition of complementary measures or interventions at a future stage, such as Land use management or phased resilient living and retreat.

The review considered how potential measures/options could be made more adaptive (incorporating low or no-regrets decisions) by qualitatively assessing adjustments to reduce vulnerability, make space for water, deliver co-benefits, build-in flexibility and consider deferring, removing or abandonment.

As part of the detailed assessment of the method/option, the alterations/interventions envisaged to develop from the present day's requirements to the likely future method/option considered the following:

- how the method could be adapted (e.g. add to its length, replace with a larger culvert, widen the channel, etc)
- what additional length, heights, capacity, etc would be required,
- what restrictions there are preventing this (e.g. where an existing structure would prevent a channel or bridge from being widened)
- what considerations would be required early in the design stage to accommodate the adaptation later (e.g. would a flood wall require a larger foundation to allow for additional height later).

The review was concluded with a statement of the method's ability to adapt and which options would be considered the most adaptable. Methods, that do not form part of any particular options, were also considered as an alternative way to provide additional protection also. This assessment of adaptability enabled the option to be scored under objective 4c in the MCA appraisal process and will also be reported in the FRMPs.

8 OPTIONEERING OF UOM17 SPATIAL SCALE OF ASSESSMENTS

The following sections detail the findings of the optioneering process applied to the various areas within the two SSAs in UoM17.

8.1 UOM17 UOM

8.2 DUNGARVAN AFA

8.3 DUNMORE EAST AFA

8.4 TRAMORE AFA

8. OPTIONEERING OF SSA'S

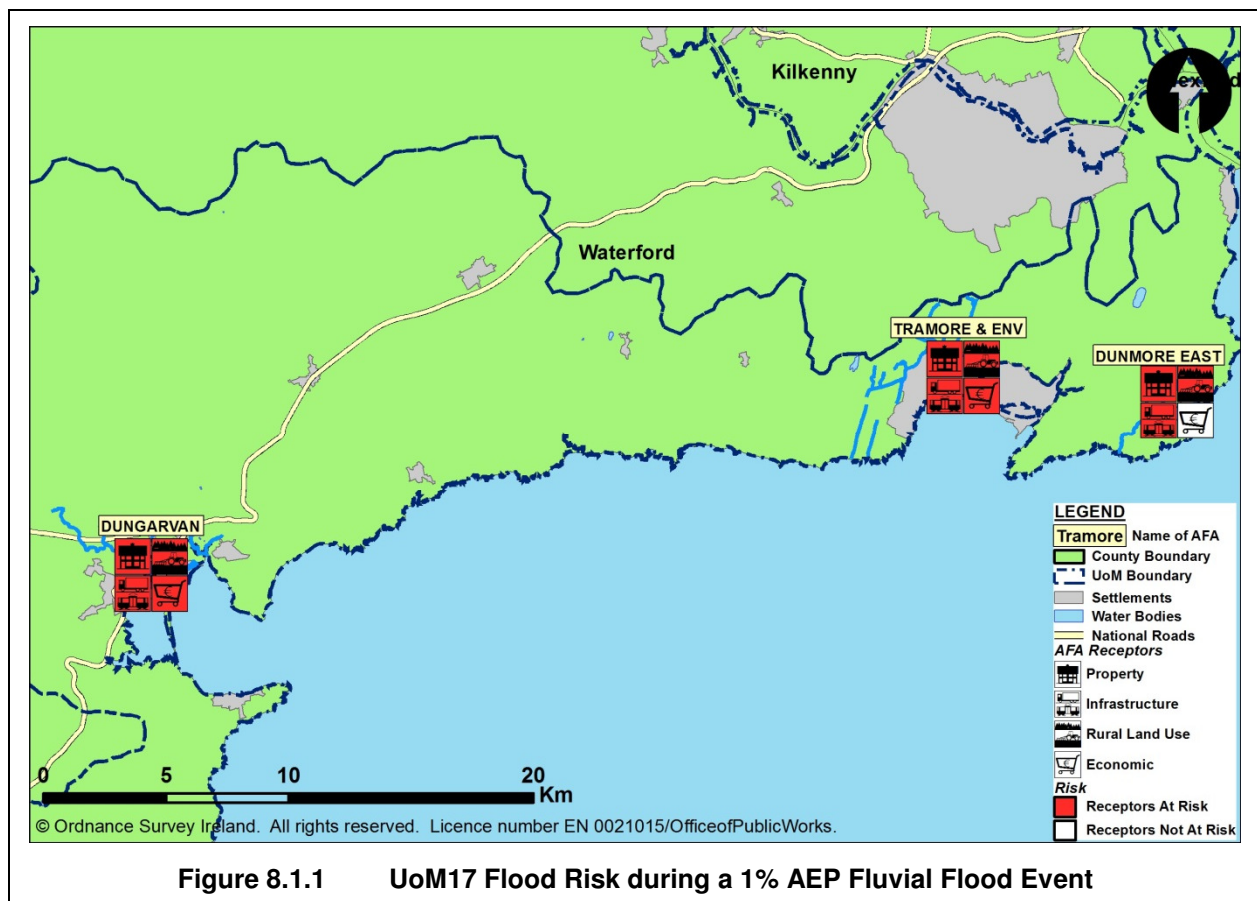
8.1 UoM17 Optioneering of FRM Options

Name	Local Authority	SSA	Status	Date
UoM17	Waterford <ul style="list-style-type: none"> Dungarvan AFA Dunmore East AFA Tramore AFA 	UoM	Final	08/06/2016

8.1.1 Source of flooding

Fluvial	Coastal Mechanism 1	Coastal Mechanism 2
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8.1.2 Summary of Flood Risk within SSA boundary



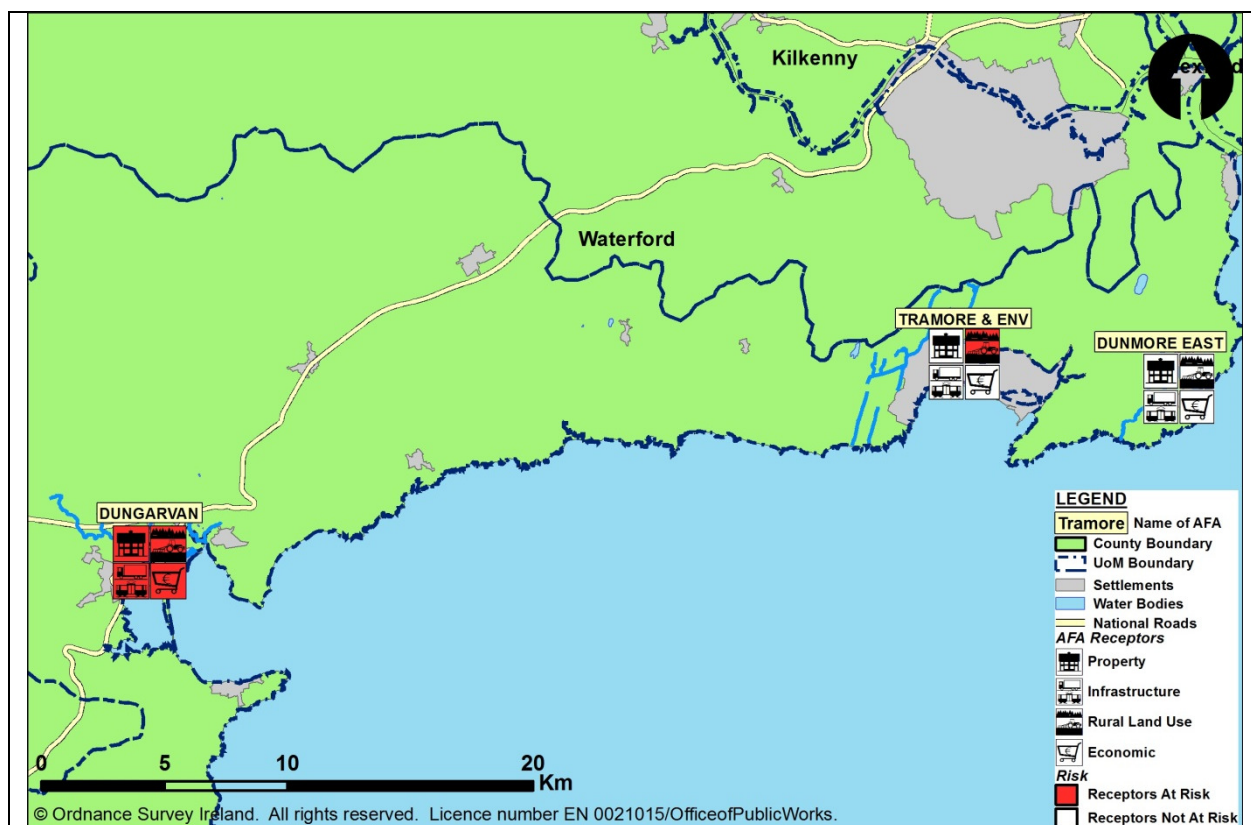


Figure 8.1.2 UoM17 Flood Risk during a 0.5% AEP Coastal Mechanism 1 (and Coastal Mechanism 2 where relevant) Flood Event

Figures 8.1.1 and 8.1.2 summarise the flood risk on the main economic activities within UoM17. During a 1% AEP fluvial flood event, Figure 8.1.1, residential properties are affected within all AFAs included in UoM17, infrastructure is affected within the Dungarvan AFA only, rural land use is affected in all AFAs and economic (commercial) properties are affected within the Dungarvan and Tramore and Environs AFAs.

During a 0.5% AEP coastal flood event (mechanism 1) there is no flood risk in the Dumore East AFA. Residential properties are affected within the Dungarvan and Tramore and Environs AFAs, infrastructure is affected within the Dungarvan AFA, rural land use is affected within both the Dungarvan and Tramore and Environs AFAs as are economic (commercial) properties.

Coastal mechanism 2 flooding affects residential and commercial properties and infrastructure in the Dungarvan AFA.

In Dungarvan AFAs the onset of property damage occurs in the 10% AEP event, in Dunmore East AFA damage commences in the 5% AEP event and in Tramore AFA damage first occurs in the 2% AEP event.

8.1.3 Monetary Benefit Within the AFAs in UoM17

	Dungarvan AFA	Dunmore East AFA*	Tramore AFA*
	€165,992		
	€344,868		
	€787,519		
	€3,565,844		
	€7,408,464		
	€16,917,477		
	1% AEP		
	0.5% AEP		
	0.5% AEP		
	25		
	59		
	43		
	€3,109,064		
	€6,891,195		
	€16,778,969		
	€3,094,630		
	€4,172,344		
	€10,102,448		

* There are no receptors at risk due to coastal flooding in this AFA



Fluvial risk



Coastal Mechanism 1



Coastal Mechanism 2

8.1.4 Monetary Damage for Present Day and Future Scenarios Within the AFAs in UoM17

	Dungarvan AFA	Dunmore East AFA	Tramore AFA
AAD (present day scenario)	€1,298,379	€ 23,878	€8,016
AAD (MRFS)	€14,292,992	€227,922	€34,321
AAD (HEFS)	€91,175,214	€271,972	€98,689

8.1.5 Short Listing FRM Methods

Method	Review Comment	Continue Screening
Do Nothing	Consider at AFA SSA - Reject	✗
Maintain Existing Regime	Consider at AFA SSA - Reject	✗
Do Minimum	Consider at AFA SSA - Reject	✗
Planning and Development Control	Consider Further	✓
Building Regulations	Consider Further	✓
Sub-catchment Wide SuDs	Consider Further	✓
Land Use Management	Consider Further	✓
Strategic Development Management	Consider Further	✓
Storage	Consider at Sub-Sub-catchment and AFA SSA – Reject	✗
Improvement of Channel Conveyance	Consider at Sub-Sub-catchment and AFA SSA – Reject	✗
Hard Defences	Consider at Sub-catchment and AFA SSA – Reject	✗
Relocation of Properties	Consider at AFA SSA - Reject	✗
Diversion of Flow	Consider at AFA SSA - Reject	✗
Flood Warning/Forecasting	Consider Further	✓
Public Awareness Campaign	Consider Further	✓
Individual Property Protection	Consider at AFA SSA - Reject	✗
Other Works	Consider at AFA SSA - Reject	✗

8.1.5.1 Feasibility Review Summary				
Method	Technical Screening	Economic Screening	Environmental and Cultural Heritage Screening	Social Screening
Planning and Development Control	✓	✓	✓	✓
Building Regulations	✓	✓	✓	✓
Sub-catchment Wide SuDs	✓	✓	✓	✓
Land Use Management	✓	✓	✓	✓
Strategic Development Management	✓	✓	✓	✓
Hard Defences	✗			
Flood Warning/Forecasting	✗			
Public Awareness Campaign	✓	✓	✓	✓
✗ - Reject ✓ - Progress ? - Progress, potential for impacts identified ! - Progress, potential for significant impacts identified				
8.1.5.2 Justification for Rejection/Retention				
Method	Tech	Econ	Env	Soc
Planning and Development Control	✓	✓	✓	✓
This method manages future flood risk for new development and is applicable throughout UoM17.				
Method	Tech	Econ	Env	Soc
Building Regulations	✓	✓	✓	✓
This method manages future flood risk for new development and is applicable throughout UoM17.				
Method	Tech	Econ	Env	Soc
Sub-catchment Wide SuDs	✓	✓	✓	✓
This method manages future flood risk for new development and is applicable throughout UoM17.				
Method	Tech	Econ	Env	Soc
Land Use Management	✓	✓	✓	✓
This method focuses on retaining water and slowing run-off in the catchment thereby lowering water levels and reducing the associated flood risk within the watercourses. This can be achieved by a number of				

techniques for example planting, restoring meanders and attenuation ponds. Land use management (LUM) methods can be applied to any catchment with characteristics that provide favourable conditions to make land use management an effective method in managing the flood risk.

This measure potentially supports flood risk management in combination with other methods and may be applicable throughout UoM17. Figure 8.1.3 shows the output of Land Use Management screening for UoM17. The output largely shows the UoM is generally moderate or highly suitable for Land Use Management methods. 2.8% of the 618km² catchment was classed as Very Low sensitivity to reducing runoff, 17.6% was classed as Low sensitivity, 49.0% was classed as Moderate sensitivity and 30.6% was classed as High sensitivity.

A classification of 1 identifies areas where NFM measures would have little impact in reducing the runoff and a classification of 4 identifies areas where NFM measures would have a significant impact in reducing the runoff (Section 7.1.7).

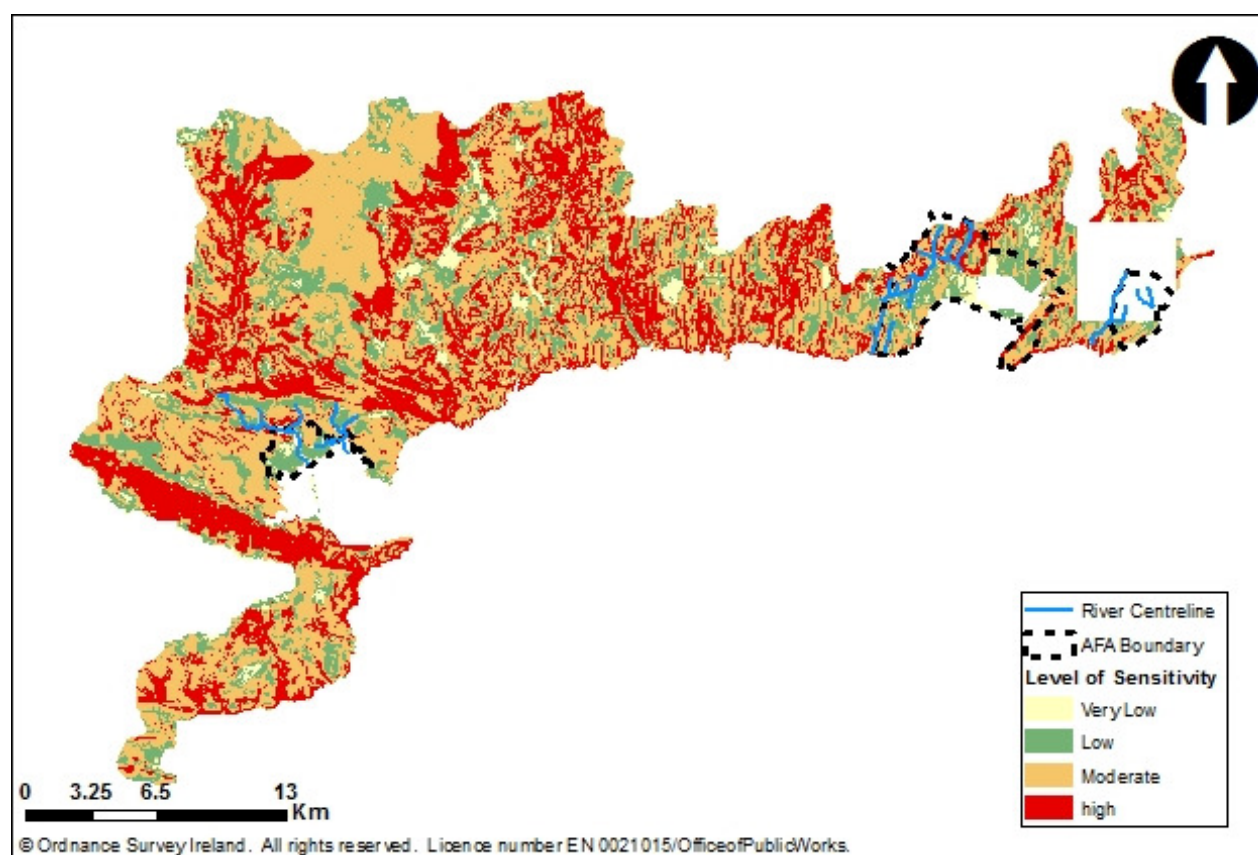


Figure 8.1.3 UoM17 Land Use Management Screening Results

This method is not feasible at UoM SSA due to the discrete coastal locations of the three AFAs, however its technical feasibility within each AFA has been assessed in further detail as part of this analysis. The method's applicability at AFA scale is subject to the measures it is taken in combination with, therefore the AFA SSA progresses this feasibility analysis to determine the overall suitability of the method at AFA level.

Dungarvan AFA

Dungarvan AFA spans across 6 catchments which fall from the Monavullagh Mountains to the Celtic Sea as shown in Figure 8.1.3. All the at risk properties during a 1% AEP flood event are located in the unnamed watercourse catchment labelled 3 in the Figure 8.1.4. In assessing the suitability of this catchment for land use management the following criteria was considered; the catchment area is 2.9km², the land use is predominantly agricultural throughout the catchment and the upper catchment, south of the Monvullagh Mountains, is steep but the steepness of the gradient decreases where the at risk properties

are located.

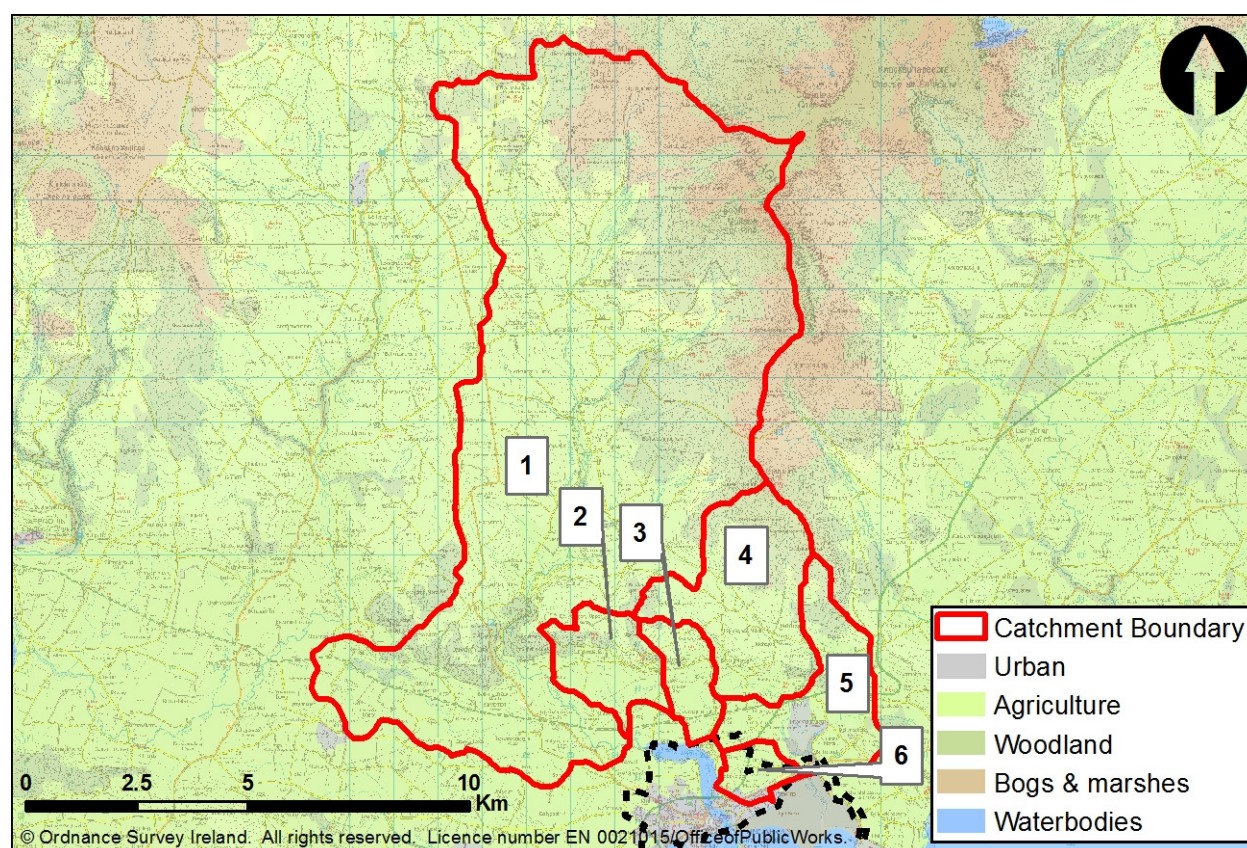


Figure 8.1.4 Land use of Dungarvan catchments

Dungarvan Harbour SPA encompasses the Colligan River within Dungarvan town which is downstream of catchment 3. Dungarvan WFD Drinking Water Area is within catchment 3. These issues need to be taken into consideration further during the detailed design and construction phases. There are no UNESCO World Heritage Sites in the vicinity of, or downstream of the AFA, and any AFA specific FRM methods to be employed.

Changing or disrupting land use practices either temporarily or permanently also has the potential to give rise to social impacts. With due consideration of the environmental and social factors, land use management is deemed a suitable FRM method for catchment 3.

Dunmore East AFA

Dunmore East AFA spans across 4 catchments which fall from high ground in the local topography to the Celtic Sea as shown in Figure 8.1.4. All the at risk properties during a 1% AEP flood event are located in the catchment labelled 2 in the figure. In assessing the suitability of this catchment for land use management the following criteria was considered; the catchment area is 1.4km², the land use is predominantly agricultural upstream of the flood risk and the catchment is relatively steep.

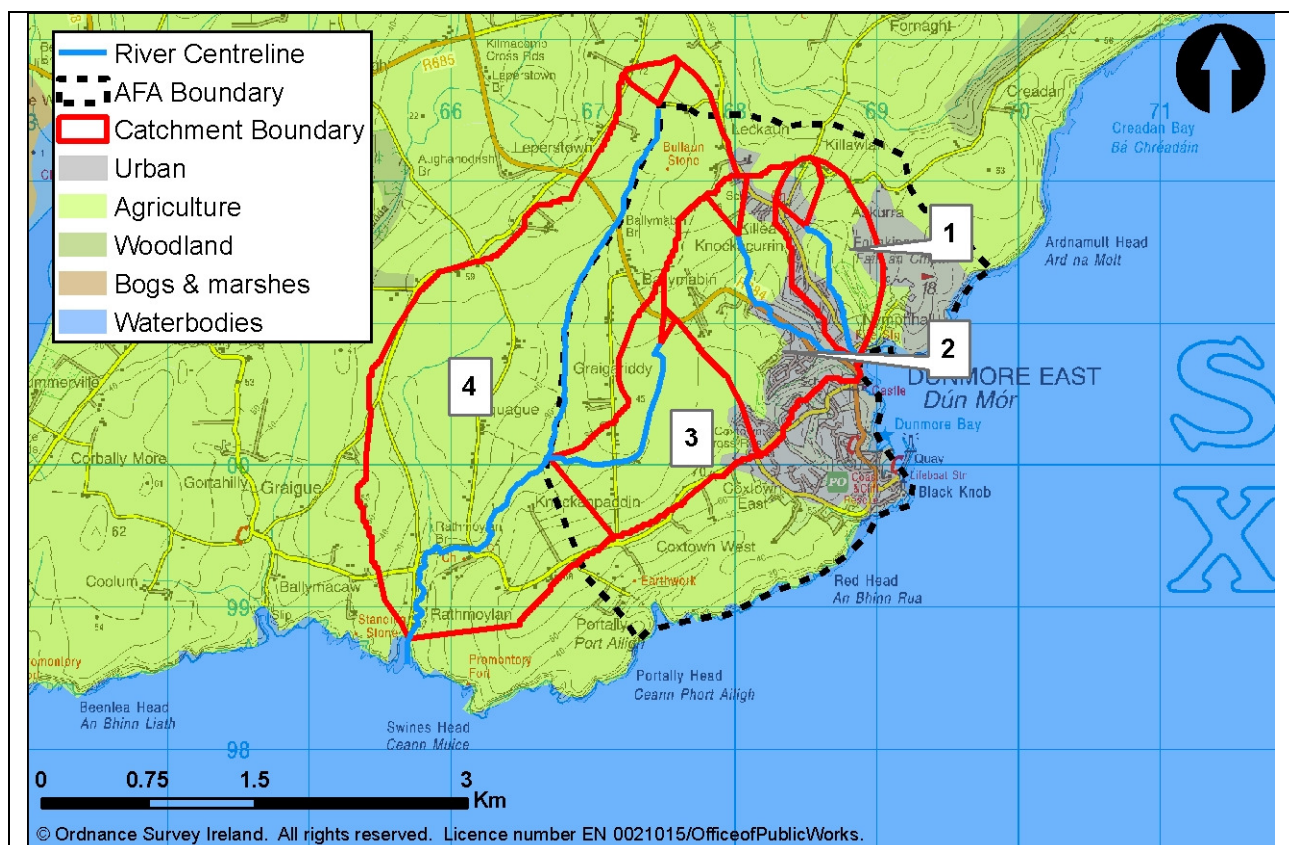


Figure 8.1.5 Land use of Dunmore East catchments

There are no SACs, SPAs or UNESCO World Heritage Sites in close proximity to the AFA, and any AFA specific FRM methods to be employed.

Changing or disrupting land use practices either temporarily or permanently also has the potential to give rise to social impacts. With due consideration of the environmental and social factors, land use management is deemed a suitable FRM method for catchment 2.

Tramore and Environs AFA

The Tramore & Environs AFA spans across 3 catchments which fall to the Backstrand and the Celtic Sea as shown in Figure 8.1.6. The properties that are at risk due to fluvial flooding during a 1% AEP flood event are distributed between catchments 1 and 2 in the figure. In assessing the suitability of these two catchments for land use management the following criteria was considered; the areas of catchments 1 and 2 are 12.8km² and 2.1km² respectively, the land use for both is predominantly agricultural with forested areas in the upper catchment of catchment 1.

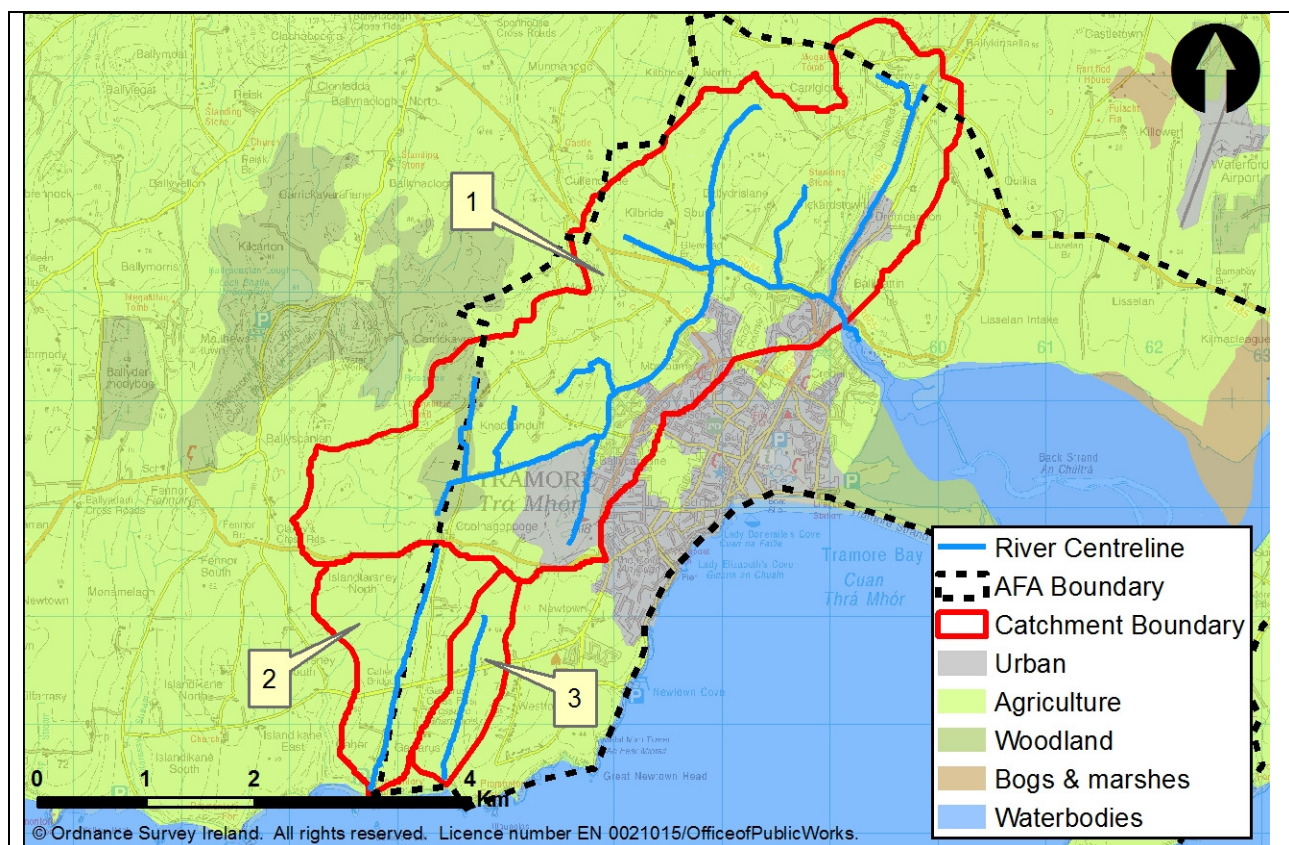


Figure 8.1.6 Land Use of Tramore & Environs catchments

While land use management methods can be applied to any catchment the characteristics of the two in question provide favourable conditions to make land use management an effective method in managing the flood risk.

The potential works associated with land use management could potentially impact on the Tramore Dunes and backstrand SAC, Tramore Dunes and backstrand SPA and Mid-Waterford Coast SPA environmental designations. Changing or disrupting land use practices either temporarily or permanently also has the potential to give rise to social impacts. With due consideration of the environmental and social factors, land use management can progress through the screening.

A summary table of the potential effectiveness of land use management for each AFA is provided in Section 8.1.6.

Method	Tech	Econ	Env	Soc
Strategic Development Management	✓	✓	✓	✓
This method manages future flood risk for new development and is applicable throughout UoM17.				
Method	Tech	Econ	Env	Soc
Hard Defences	✗			
This method involves the construction of a tidal barrier across a coastal lough or bay that would shut its flood gates when triggered by water levels predicted by a tidal surge forecast. Adoption of this method could cause significant changes to the hydrodynamics experienced in the proposed coastal cell. This could also negatively affect the local coastal environment. These structures are also generally very expensive to				

construct and operate therefore the cost/benefit ratio is an important factor in its assessment.

Due to the formation of the coast line and the location of the AFAs within UoM17 there was no area identified where the construction of a tidal barrier was technically feasible for more than one AFA. Therefore this method should be rejected from the screening process.

Method	Tech	Econ	Env	Soc
Flood Warning/Forecasting	x			

This method provides a warning to property owners that a flood event is imminent. This allows a period of time to defend the property from flooding or move contents out of flood risk areas. The warning time depends on whether a warning or forecasting system is operational. As this method's effectiveness relies on human intervention there is an element of uncertainty associated with it. In addition to this it is recognised that this method does not prevent flooding but rather allows the properties at risk to be prepared for flooding. As such a limited amount of damage can be expected to be prevented and is dependent on the warning time available. Where the warning period is greater than 12 hrs it is assumed that 10% of the flood damage would be avoided. Between 12-6hrs 6% of flood damage would be avoided. Between 6-2hrs 4% of the flood damage would be avoided. And where the warning period is less than 2hrs no flood damage would be avoided.

This assessment assumes that decisions on meteorological and tidal forecasting will be taken at national level and focuses on the assessment of river gauges (which may be augmented by rainfall gauges).

This measure potentially supports flood risk management in combination with other methods and may be applicable throughout UoM17. It is assessed in further detail at the AFA scale subject to the measures it is taken in combination with; the operational elements cost at UoM scale can be spread across AFAs and the infrastructure may be mutually beneficial.

River gauge locations have been identified for each AFA within UoM17 where feasible. Increased forecasting accuracy may also be achieved by locating a series of rainfall gauges within each catchment at a density of approximately 1 per 100km².

Dungarvan AFA

Properties in Dungarvan are at risk due to coastal mechanism 1, coastal mechanism 2 and fluvial flooding. Flood forecasting at UoM scale is not applicable for properties at risk from coastal mechanism 1 and mechanism 2 flooding and a decision on a tidal surge and overtopping flood forecasting will be taken at national level.

A review was carried out as to where a river gauge could be placed on the unnamed watercourse in catchment 3 in order to provide flood warning to the properties at risk of fluvial flooding. While locating the gauge close to the properties at risk would increase the accuracy of the gauge, as it represents a larger proportion of the catchment, locating it as far upstream of the at risk properties as possible would provide the maximum warning time. The unnamed watercourse in catchment 3 is approximately 2.8km in length. Figure 8.1.7 shows the proposed location of two new river gauging stations; one around 2.3km upstream of the first at risk properties (as far up the catchment as possible) and another at the first at risk properties which would allow for calibration, fine tuning and validation. An estimate of the travel time for a 1% AEP flood event to travel from the gauges to the properties at risk was calculated. Due to the steepness of the upper reaches of the catchment the Dungarvan hydraulic model showed that there was no significant difference in the time to peak of each gauge location.

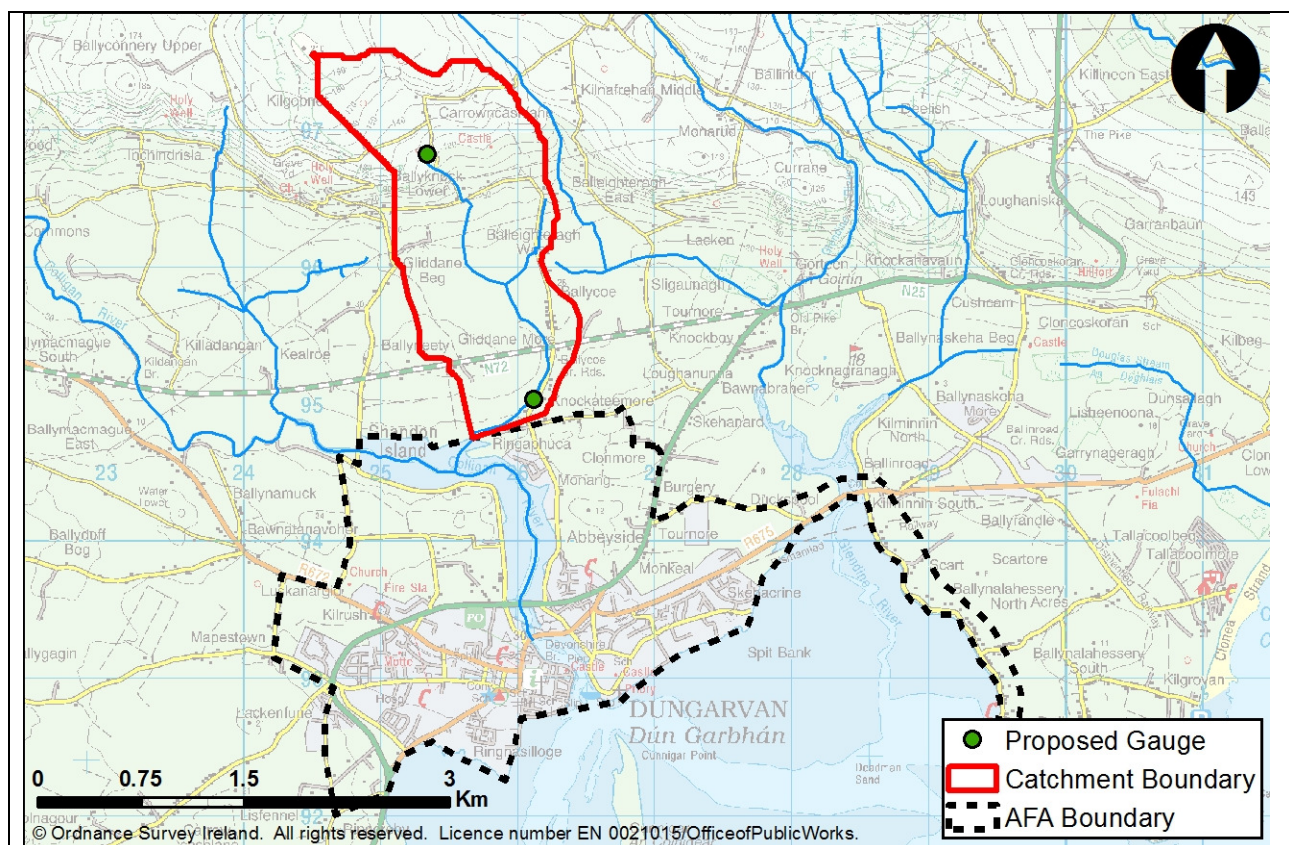


Figure 8.1.7 Location of proposed gauging stations in Dungarvan AFA

The minimum assumed warning time to allow flood warning/forecasting to be technically feasible is 2hrs. Given that the warning time on the unnamed watercourse in catchment 3 is estimated to be less than 5mins this method is considered technically unfeasible for the Dungarvan AFA. It was found that the catchment is too short and flashy for this method to be feasible.

Dunmore East AFA

A review was carried out as to where a river gauge could be placed on the unnamed watercourse in catchment 2 in order to provide flood warning to the properties at risk of fluvial flooding. Figure 8.1.7 shows the proposed location of two new river gauging stations; one around 500m upstream of the first at risk properties (as far up the catchment as possible) and another at the first at risk properties which would allow for calibration, fine tuning and validation. An estimate of the travel time for a 1% AEP flood event to travel from the gauge to the properties at risk was calculated. The Dunmore East hydraulic model showed that the average speed of water travel along the unnamed watercourse would be 0.55m/s and therefore the travel time between gauge 1a and 1b would be approximately 15mins.

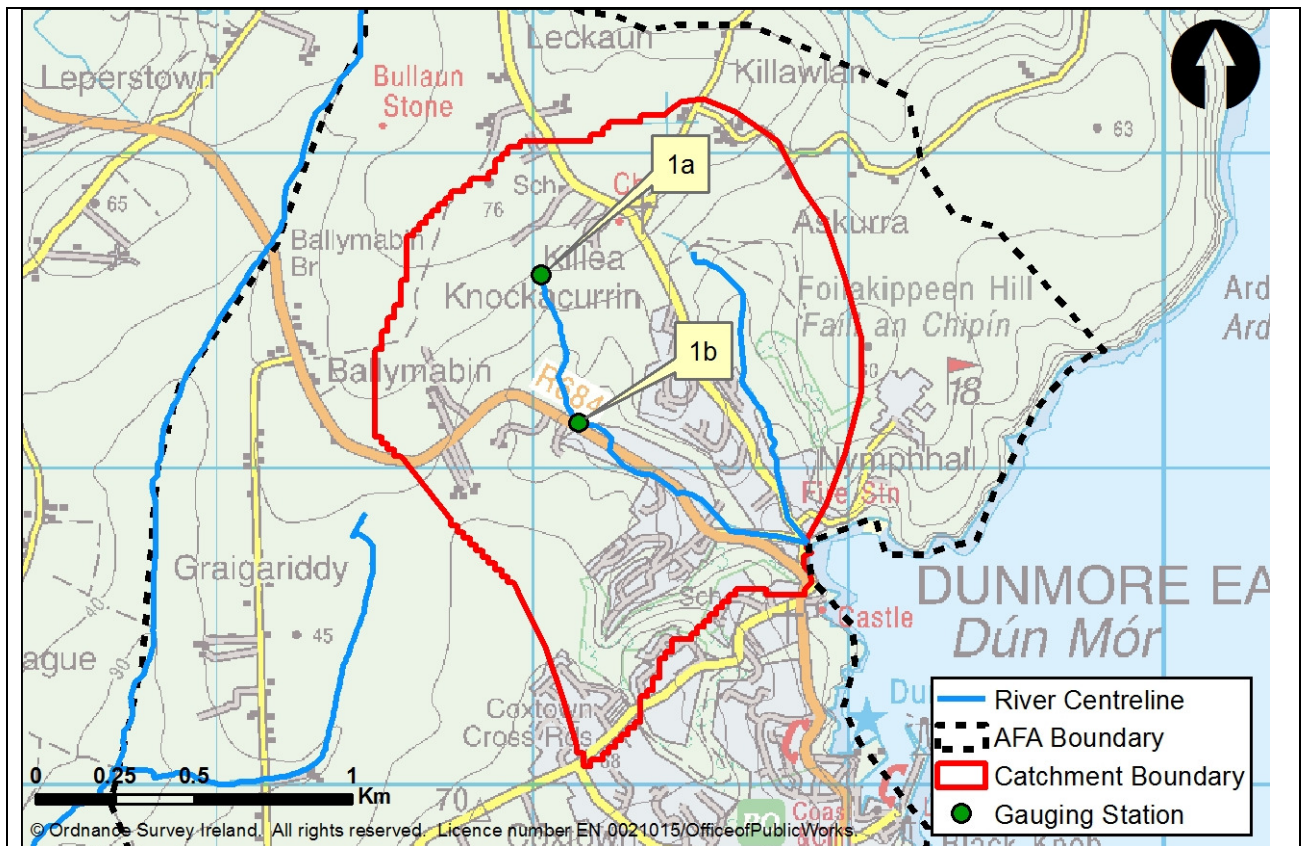


Figure 8.1.8 Location of proposed gauging stations in Dunmore East AFA

Given that the warning time on the unnamed watercourse is estimated to be approximately 15mins this method is considered technically unfeasible for the Dunmore East AFA.

Tramore & Environs AFA

A review was carried out as to where river gauges could be placed in the Tramore & Environs AFA in order to provide flood warning to the properties at risk. Figure 8.1.9 shows the location of the 6 proposed new river gauges. Proposed gauging stations are located on the Tramore Monvoy River, Tramore 11 tributary and Tramore 6 tributary. This includes a river gauge at the location of the first property at risk on each watercourse as well as gauges upstream of the properties at risk. This will allow for calibration, validation and fine tuning of the forecasting system.

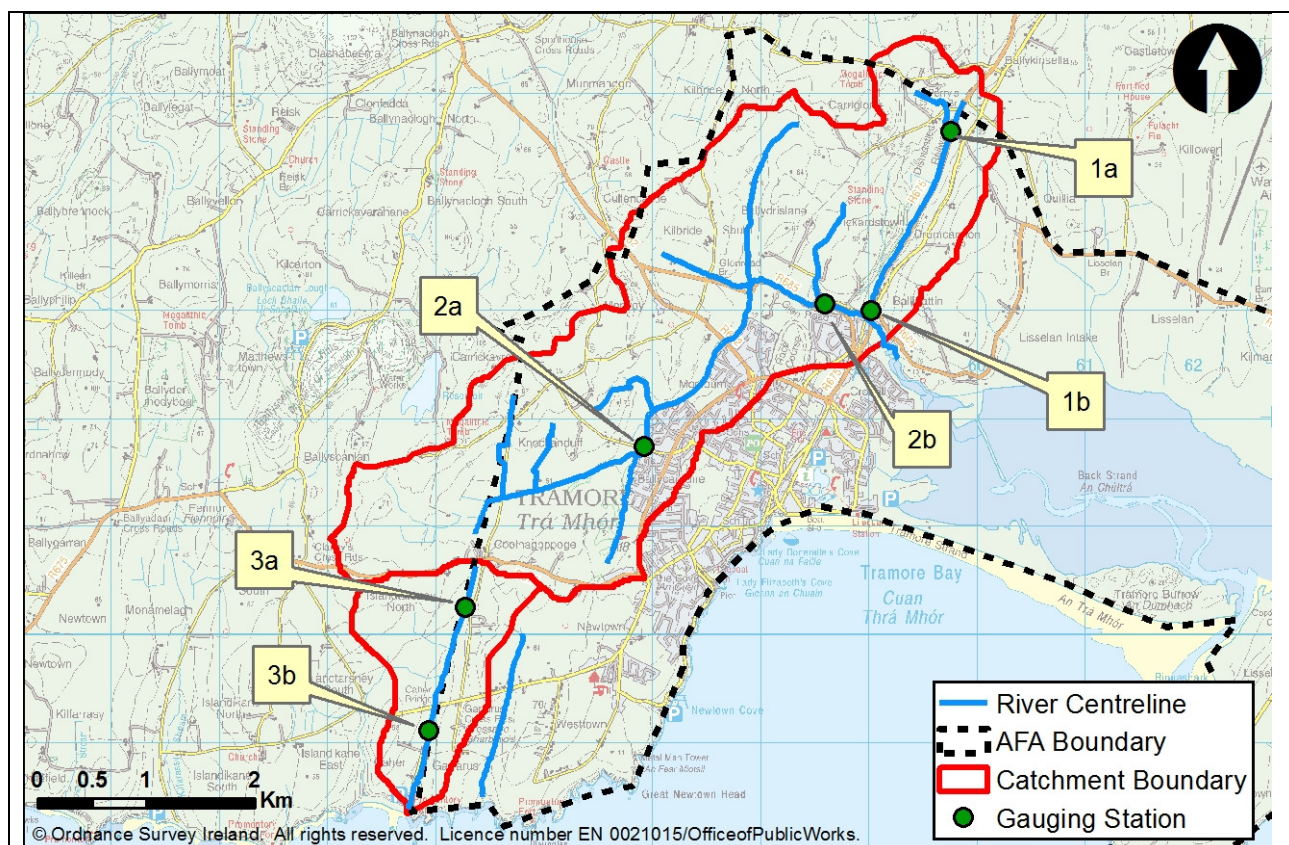


Figure 8.1.9 Location of proposed gauging stations in Tramore & Environs AFA

An estimate of the travel time for a 1% AEP flood event to travel from the gauge to the properties at risk was calculated for each gauge location. The Tramore & Environs hydraulic model showed that the average speed of water travel along the Tramore 11 tributary would be 0.5m/s and therefore the travel time between gauge 1a and 1b which are located 1.8km from each other would be approximately 60mins. The minimum assumed warning time to allow flood warning/forecasting to be technically feasible is 2hrs so this is insufficient warning time to benefit flooding on the Tramore 11 tributary.

The Tramore & Environs hydraulic model also showed that there is no significant difference between the time the peak water level occurs at the proposed gauging station 2a compared to station 2b located 2.8km downstream at the property at risk. This is due to the nature of the contributing catchment, with a substantial proportion of flow attributed to tributaries downstream of the proposed gauge. Given that there is no significant difference between the time the peak water level occurs at the proposed gauging station compared to the at risk property this method is considered technically unfeasible.

The Tramore & Environs hydraulic model showed that the average speed of water travel along the Tramore 6 tributary would be 2.2m/s and therefore the travel time between gauge 3a and 3b which are located 1.2km from each other would be approximately 10mins. This is insufficient warning time to benefit flooding on the Tramore 6 tributary.

None of the proposed gauging stations in the Tramore & Environs AFA were found to provide sufficient warning time, so flood warning/forecasting is considered to be technically unfeasible for this AFA.

Summary of Potential Warning Times

The following table summarises the potential warning times available to the AFAs where flood forecasting and warning was found applicable.

AFA		Warning times			
Dungarvan		<2hrs (5mins)			
Dunmore East		<2hrs (15mins)			
Tramore and Environs		<2hrs(10-60mins)			
Method	Tech	Econ	Env	Soc	
Public Awareness Campaign	✓	✓	✓	✓	
This measure supports flood risk management by informing resilient behaviour, in combination with other methods and is applicable throughout UoM17.					
Summary					
<p>The following measures are appropriate throughout the UoM:</p> <ul style="list-style-type: none">• Planning and Development Control• Building Regulations• Sub-catchment Wide SuDs• Strategic Development Management• Public Awareness Campaign <p>Hard defences in the form of a tidal barrier to protect coastal flood risk across multiple AFAs were assessed and found not to be technically feasible for more than one AFA.</p> <p>Land use management was found to be a potential measure for all of the AFAs assessed however the implementation of Land Use Management is dependent on the measures with which it might be combined at AFA level and therefore further assessment will be undertaken in the subsequent AFA SSA sections.</p> <p>A flood warning and forecasting system was found to be technically unfeasible for all AFAs.</p> <p>A summary of the potential effectiveness of these measures is as follows:</p>					
	Land Use Management	Flood Warning/Forecasting			
Dungarvan	✓	✗			
Dunmore East	✓	✗			
Tramore and Environs	✓	✗			

8. OPTIONEERING OF SSA'S

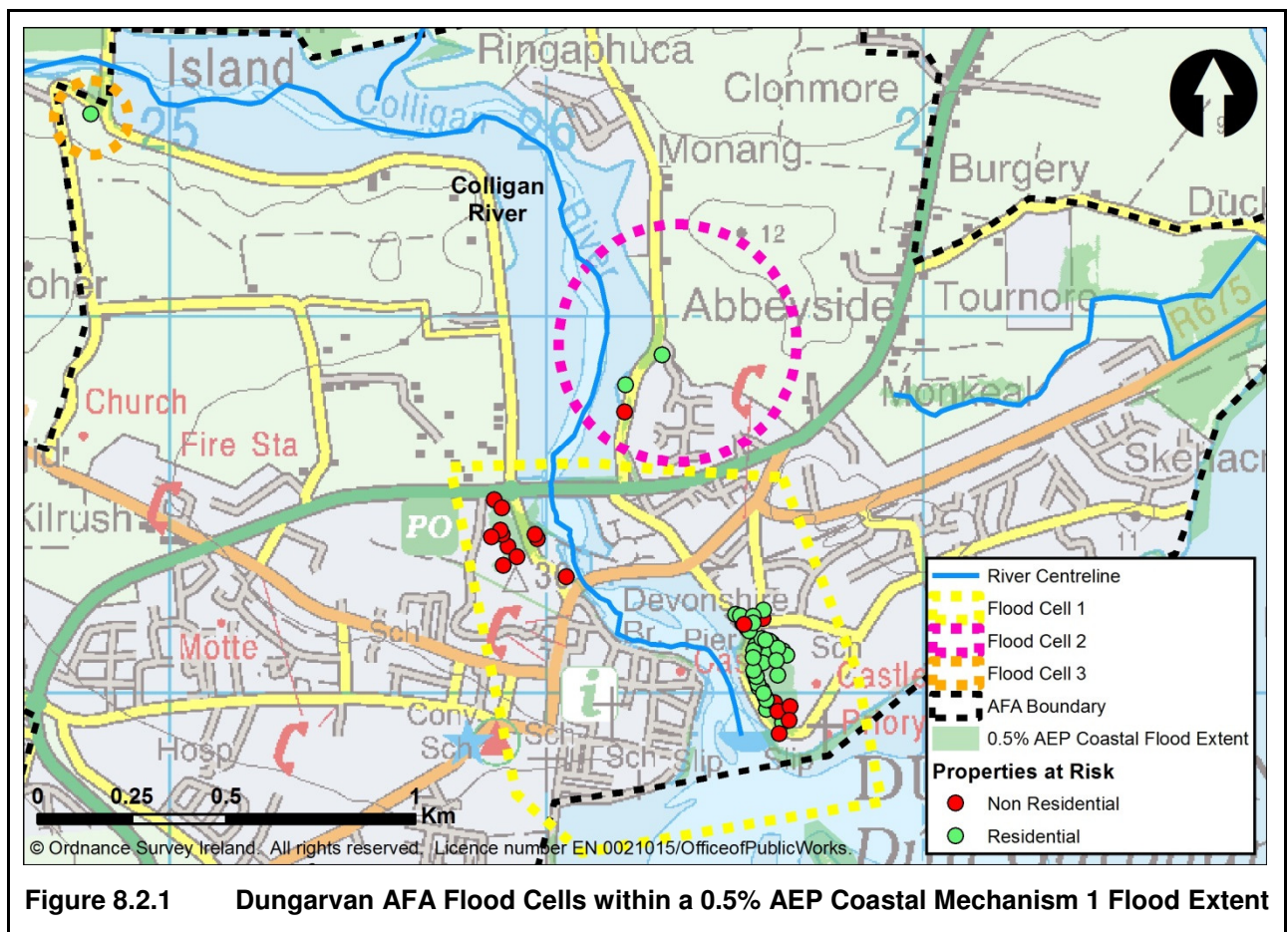
8.2 Dungarvan Optioneering of FRM Options

Name	Local Authority	Unique ID	SSA	Status	Date
Dungarvan	Waterford	170244	AFA	Final	08/06/2016

8.2.1 Source of flooding

Fluvial	Coastal Mechanism 1	Coastal Mechanism 2
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8.2.2 Flood Cells



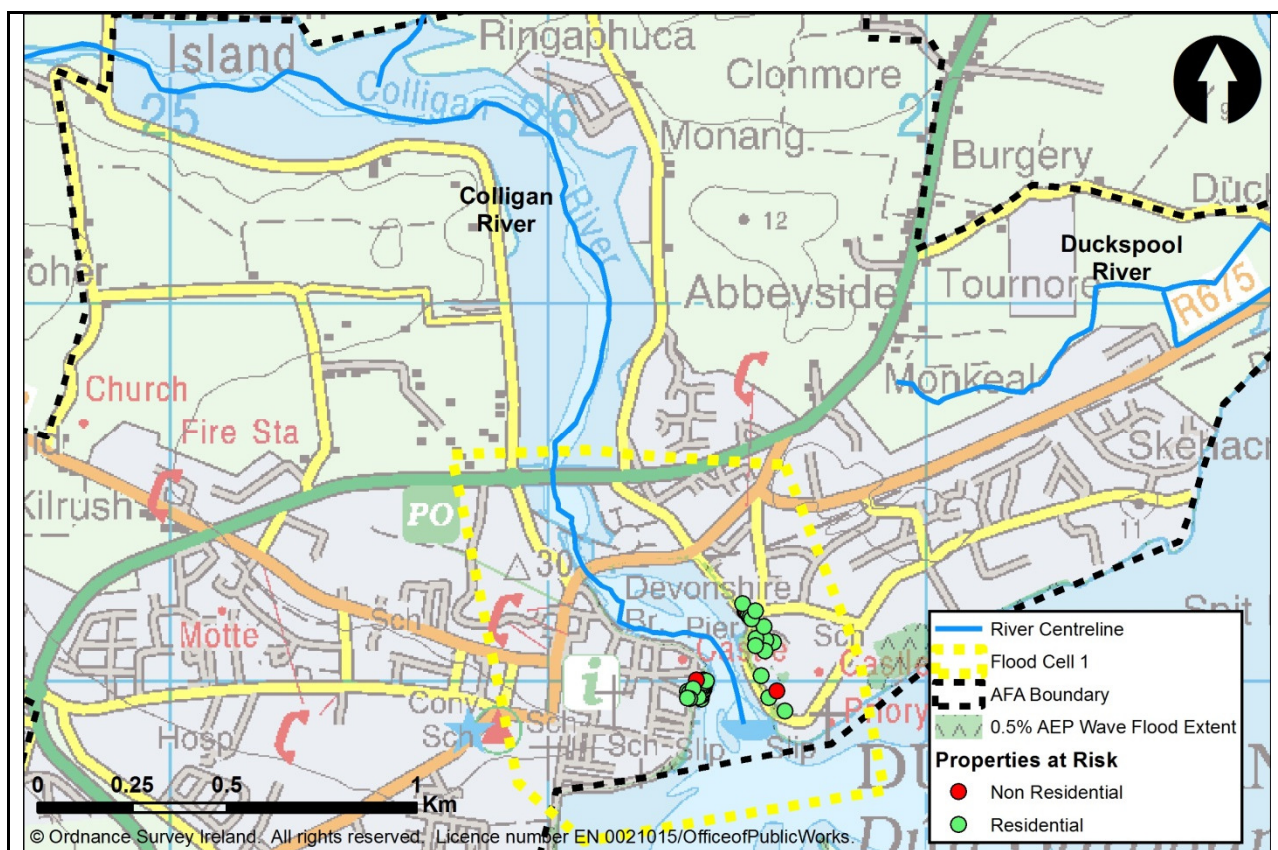


Figure 8.2.2 Dungarvan AFA Flood Cells within a 0.5% AEP Coastal Mechanism 2 Flood Extent

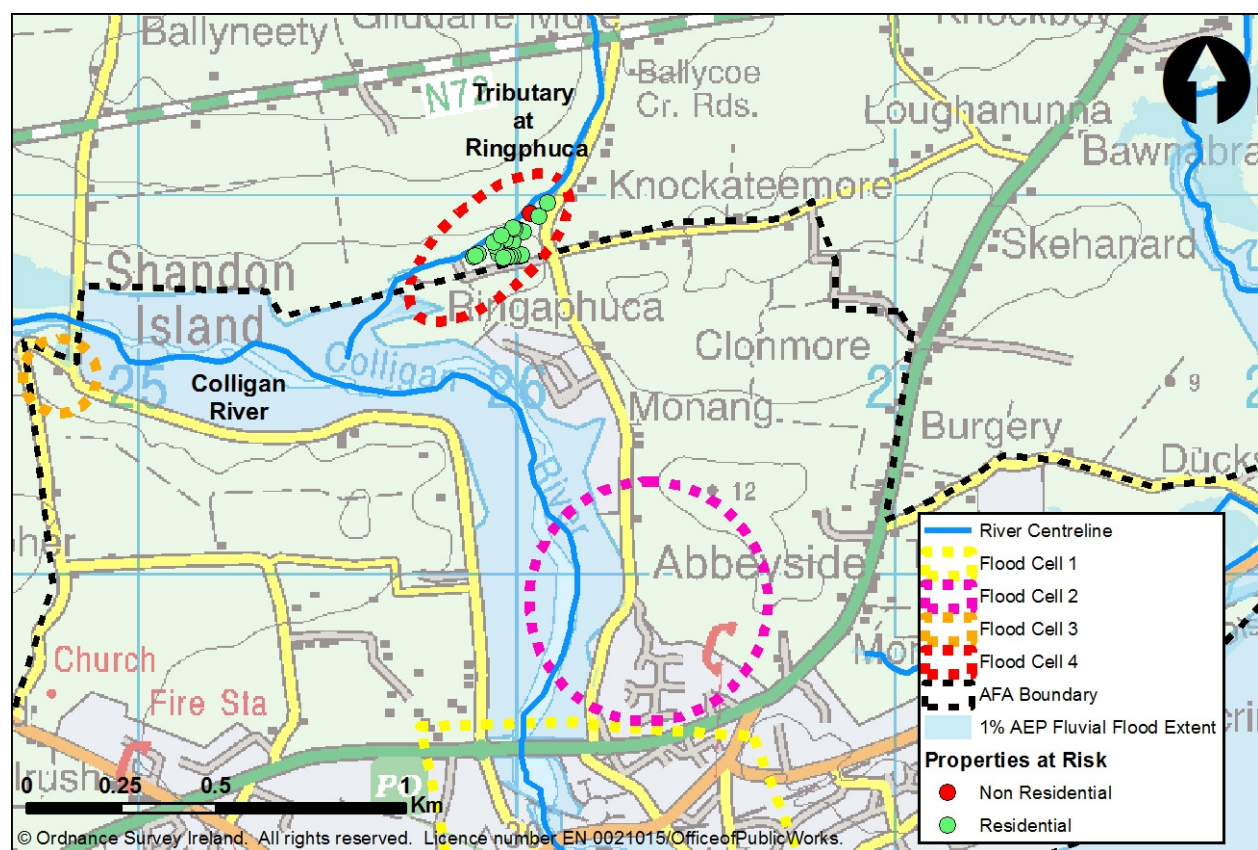


Figure 8.2.3 Dungarvan AFA Flood Cells within a 1% AEP Fluvial Flood Extent

Flood Cell 1:

Flooding would occur in Dungarvan Harbour during a 0.5% AEP coastal flood event due to tidal inundation of low lying ground and an unimpeded flow path through a slipway on the eastern side of Dungarvan Harbour. 55 properties are affected by coastal mechanism 1 flooding during a 0.5% AEP flood event and they are in close proximity to each other on both sides of the harbour, see Figure 8.2.1.

Flooding would also occur in Dungarvan Harbour during a 0.5% AEP event due to wave overtopping of the existing harbour walls. 43 properties are affected by coastal mechanism 2 flooding during a 0.5% AEP event and they are in close proximity to each other on both sides of the harbour, see Figure 8.2.2.

Flood cells 2 and 3 are located not far upstream of flood cell 1 and the properties in these cells are also affected by the tidal inundation. Given that flood cell 1 is subject to both mechanism 1 and mechanism 2 flooding and the proximity of flood cells 2 and 3, flood cell 1 is considered complex.

Flood Cell 2:

Flooding would occur along the Old Hospital Road during a 0.5% AEP tidally dominated flood event due to low lying ground. Four properties are affected by flooding during a 0.5% AEP flood event and these properties are clustered together, see Figure 8.2.1. The dominant flood mechanism affecting flood cell 2 is tidal flooding. Flood cells 1 and 3 are located not far downstream and upstream of flood cell 2 respectively and the properties in these cells are also affected by the same mechanism. Subsequently flood cell 2 is considered complex.

Flood Cell 3:

During a 0.5% AEP flood event tidal inundation would occur just upstream of the 1721DG00044D bridge on the Colligan Estuary flooding one property, see Figure 8.2.1. Given that flood cell 3 is located in close proximity to flood cells 1 and 2 and it is affected by the same flood mechanism as these cells, flood cell 3 is therefore considered complex.

Flood Cell 4:

Out of bank fluvial flooding would occur on a tributary of the Colligan River watercourse during a 1% AEP flood event, due to both insufficient channel and culvert capacity, inundating the floodplain, see Figure 8.2.3. 25 properties are located on the banks of the watercourse where this flooding would occur and would be affected by flooding during a 1% AEP flood event. Given this is the only fluvial flood risk area within Dungarvan and Environs, and this area is upstream of the tidal limit flood cell 4 is considered local.

Summary of Flood Cells:

As shown in Figure 8.2.1 - Figure 8.2.3 the main flood risk in the Dungarvan Harbour area originates from tidal inundation (flood cells 1, 2 and 3) and wave overtopping (flood cell 1 only). Due to the complexity and interaction of the flood risk within these flood cells it is considered appropriate that they are screened together in the optioneering process. (Section 8.2.6).

Flood cell 4 (Ringphuca) is a discrete area with closely clustered properties at risk and a single fluvial flood mechanism to consider. It is therefore appropriate to screen this flood cell as a standalone area assessing options applicable to localised works. (Section 8.2.7)

On completion of the optioneering screening assessment all flood cells will be combined to form complete options for the Dungarvan and Environs AFA as detailed in Section 8.2.8.

8.2.3 Existing Regime

This existing regime considers all activities currently carried out which impact on the management of flood risk. The level and frequency of maintenance is considered, along with inspection, and any other specific activity (for example the operation of locks, barrages, sluice gates and valves).

There are no Arterial Drainage Schemes located within the Dungarvan AFA. The Shandon DD which drains into the Colligan River is located within the Dungarvan AFA. Further details of this scheme are presented in Section 6.3.

The Colligan River and its tributaries, including the tributary at Ringphuca, are not located within a Drainage District or an Arterial Drainage scheme and for the most part are in private lands and are not the responsibility of Waterford County Council. Nevertheless inspections and maintenance are carried out as and when resources are available.

8.2.4 Summary of Flood Risk within SSA boundary

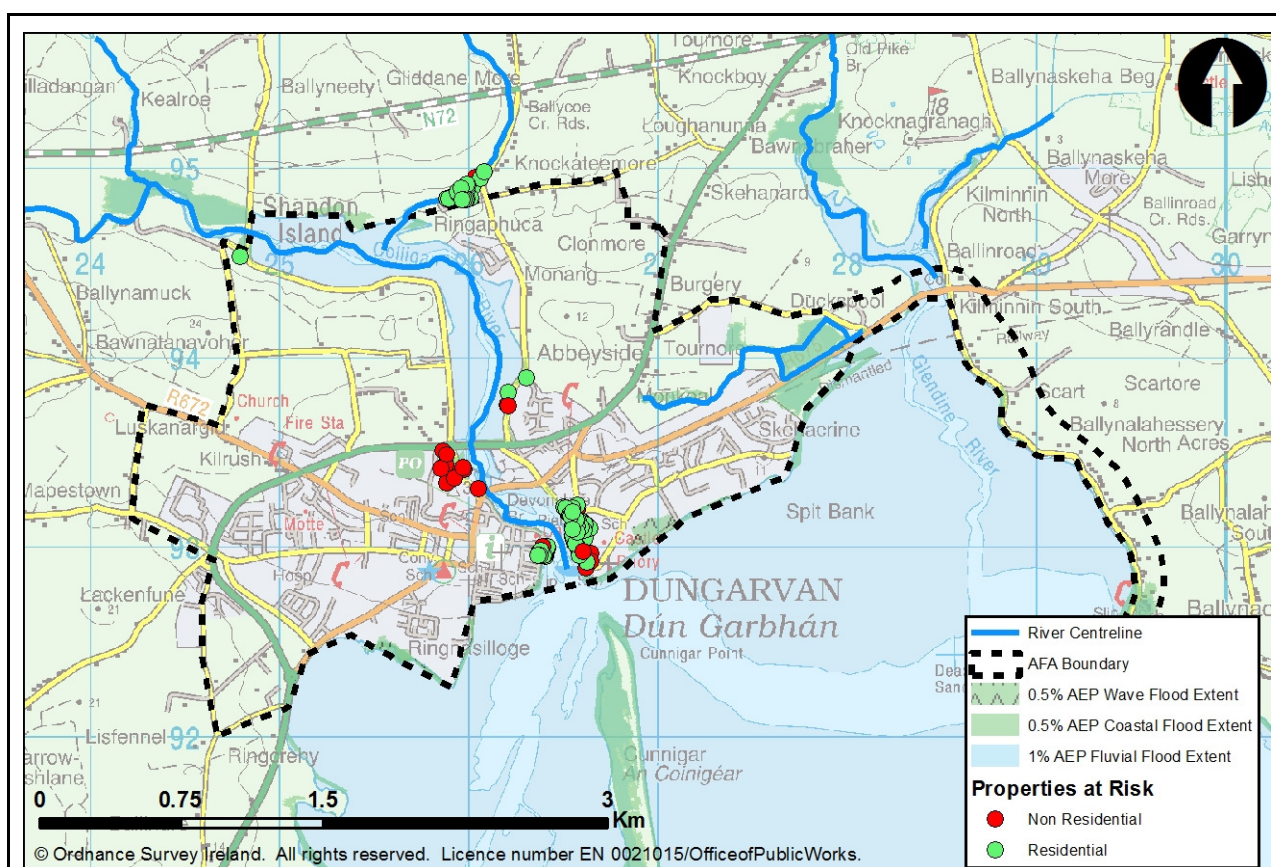


Figure 8.2.4 Flood risk in Dungarvan AFA within a 1% Fluvial Flood extent and within a 0.5% Coastal Mechanism 1 and Coastal Mechanism 2 Flood Extent

In Dungarvan AFA the onset of residential property damage occurs in the 20% AEP event in flood cells 1-3 and the 10% AEP event in flood cell 4, flooding commences at a non-residential properties within flood cells 1-3 in the 50% AEP event and flood cell 4 in the 2% AEP event.

8.2.5 Monetary Damage and Benefit

	Flood Cells 1, 2 & 3	Flood Cell 4	Total in AFA
Annual Average Damage (AAD)*	€ 1,131,425	€ 165,992	€1,298,379
Present Value Damage (pvD)*	€ 24,305,264	€ 3,565,844	€27,891,785
Standard of Protection (SoP)	0.5% AEP	1% AEP	0.5% AEP
Number of Properties Benefiting from Design SoP	85	25	110
Minimum Present Value Benefit	€ 23,670,164	€ 3,109,064	€ 26,779,228
Capped Minimum Present Value Benefit	€ 14,274,792	€ 3,094,630	€ 17,369,422

*The sum of the flood cell AAD or pvD values may not equate to the values presented for the Total in SSA due to flooding greater than the 1% AEP occurring outside the flood cell extents.

8.2.6 Short Listing FRM Methods – Complex Cells (flood cells 1, 2 & 3)

Method	Review Comment	Continue Screening
		Flood Cells 1, 2 & 3
Do Nothing	Consider Further	✓
Do Minimum	Consider Further	✓
Additional maintenance	Consider Further	✓
Planning and Development Control	Consider at UoM SSA - Reject	✗
Building Regulations	Consider at UoM SSA - Reject	✗
Catchment Wide SuDs	Consider at UoM SSA - Reject	✗
Land Use Management	This method would not be effective in this Flood Cell - Reject	✗
Strategic Development Management	Consider at UoM SSA - Reject	✗
Storage	This method would not be effective in this Flood Cell - Reject	✗
Improvement of Channel Conveyance	This method would not be effective in this Flood Cell - Reject	✗
Hard Defences	Consider Further	✓
Relocation of Properties	Consider Further	✓
Diversion of Flow	This method would not be effective in this Flood Cell - Reject	✗
Flood Warning/Forecasting	Consider at UoM SSA - Reject	✗
Public Awareness Campaign	Consider at UoM SSA - Reject	✗
Individual Property Protection	Consider Further	✓
Other Works	Consider Further	✓

8.2.6.1 Feasibility Review Summary for Complex Cells (flood cells 1, 2 & 3)

Method	Technical Screening	Economic Screening	Environmental and Cultural Heritage Screening	Social Screening
Do nothing	✗			
Additional maintenance	✗			
Do Minimum	✗			
Hard Defences	✓	✓	!	✓
Relocation of properties	✓	✗		
Individual Property Protection	✗			
Other Works	✗			
✗ - Reject ✓ - Progress ? - Progress, potential for ! - Progress, potential for significant impacts identified				

8.2.6.2 Justification for Rejection/Retention

Method	Tech	Econ	Env	Soc
Do nothing	✗			
<p>The do nothing FRM method would involve stopping the current maintenance regime. The expected outcomes in the Dungarvan and Environs AFA would be continued coastal erosion of natural barriers such as beach berms or dunes and deterioration of existing coastal defence particularly the harbour walls adjacent to Strandside South. Strong tidal surge currents would carry away the eroded material which would ultimately result in a breach in the barrier or defence. Given that there are properties at risk during the high frequency flood events it is expected that the level of flood risk would be increased. This is an unacceptable outcome in terms of contributing to design SoP and should therefore be rejected from the screening process.</p>				
Additional maintenance	✗			
<p>This method considers the provision of additional maintenance and seeks to determine if any improvements can be made which will provide a beneficial impact on the flood risk in the AFA.</p> <p>A review of the flood risk within flood cells 1, 2 and 3 has identified that coastal mechanism 1 and 2 flooding occurs in the Dungarvan and Environs AFA due to low lying ground, unimpeded flow paths and wave overtopping of existing defence assets. Therefore it is expected that implementing any additional maintenance in the Dungarvan coastal areas would have minimal impact on the overall flood risk as it would not address the flood mechanisms attributed to the flood risk.</p> <p>Increasing maintenance activities will not significantly contribute to achieving the preferred SoP and</p>				

therefore will not be pursued under the CFRAM Study.

Method	Tech	Econ	Env	Soc
Do Minimum	✗			
<p>In coastal areas this method can include raising ground levels in low lying areas where narrow gaps in an existing natural or manmade barrier allow tidal inundation to occur. This method could also include the introduction of flood gates at points of access to the beach and is also appropriate where an isolated/single issue exists which can be easily addressed in order to reduce the flood risk. These activities would be considered relatively straightforward, discrete and low cost. Do Minimum is a standalone method, as it cannot be combined with others without contradicting its definition, therefore the design SoP must be achieved for this method to progress.</p> <p>There is one slipway on the eastern side of Dungarvan Harbour allowing boat access from Strandside South, Castlekeep which contributes to the flood extents of both the 0.5% AEP tidal inundation and wave overtopping events. This slipway could be sealed by tidal flood gates. Addressing this issue with this method however would have minimal impact on the overall flood risk as it does not address all of the flooding attributed to tidal inundation and wave overtopping in flood cell 1. This is an unacceptable outcome in terms of achieving a 0.5%AEP standard of flood protection and should therefore be rejected from the screening process.</p>				
Method	Tech	Econ	Env	Soc
Hard Defences	✓	✓	!	✓
<p>The term Hard Defences refers to physical barriers which prevent water from entering an area such as flood walls, embankments and barrages. As a general rule Hard Defences are kept as far back from the river channel or coast line as possible allowing the floodplain function to remain active. Where this is not possible, due to flood risk receptors being located within the floodplain, Hard Defences are placed around the property boundary to afford it protection. Where space allows flood embankments are used but where space is restricted flood walls are utilised.</p> <p>A review was carried out to ascertain where Hard Defences would be required to protect existing property within flood cells 1, 2 and 3. Figure 8.2.5 shows the location of the Hard Defences required to protect properties during the 0.5% AEP tidal event and 0.5% AEP wave overtopping event. These Hard Defences are a series of urban walls with and without sheet piling, quay walls, seawalls and a flood gate as appropriate.</p>				



Figure 8.2.5 Location of Hard Defences in flood cells 1, 2 and 3

In order to ascertain the effectiveness of Hard Defences a hydraulic model was constructed to simulate the method. The model showed that hard defences with an average height of 1.2m and a total length of 1.3km would protect to the 0.5% AEP tidal event and the 0.5% AEP wave event. An economic review estimated the cost of the hard defences to be approximately €7.1m making this method economically viable.

Dungarvan Harbour SPA includes the Colligan River within Dungarvan town and Dungarvan Harbour downstream of the AFA. Helvick Head to Ballyquin SPA and Helvick Head SAC are 6km across Whitehouse Bank and Dungarvan harbour from the Dungarvan AFA, on Helvick Head. The Glendine SAC is 2km upstream of the AFA on the Glendine River. The Comeragh Mountains SAC is 13km upstream of the AFA on the Colligan River. These issues need to be taken into consideration during the detailed design by ensuring that FRM Methods in Dungarvan AFA do not cause hydrological or coastal process alterations that might impact any of the nearby designations.

There are no UNESCO World Heritage Sites in the vicinity of, or downstream of the AFA, or any AFA specific FRM methods to be employed. No other socially detrimental impacts were identified. Therefore this method will be put forward for consideration in the optioneering process.

Method	Tech	Econ	Env	Soc
Relocation of properties	✓	✗		

To relocate a property is to abandon the existing at risk property and provide an alternative in a location not at risk. While this method is, in theory, possible, it is not practical for a whole town of many at risk properties. Its use is more applicable for discrete areas where single properties or small clusters of properties are located.

An assessment of the distribution of properties within flood cells 1, 2 and 3 was carried out. There are 86 properties at risk from a 0.5%AEP tidal event and a 0.5% AEP wave overtopping event in flood cell 1. This method is technically feasible although it would include the relocation of two waste water treatment plants on the Old Hospital Road and electrical infrastructure at Strandside. An economic review estimated the cost of relocating the 81 properties at €37.4m. This method was therefore considered economically unviable and should therefore be rejected from the screening process.

Method	Tech	Econ	Env	Soc
Individual Property Protection	✓	✓	✓	✓

This method is aimed at individual properties that are remote from the main flood risk areas. Where the AFA being considered consists of a small number of remote properties this method is a feasible solution. But for AFAs with multiple properties at risk this method would only be considered an add on to a primary method. Individual property protection could consist of flood gates and vent seals on the building structure itself. Where flood depths are over 0.6m this method becomes unfeasible and flood resilience techniques would be recommended over flood gates. As this method is temporary and relies of human intervention there is an element of uncertainty as to whether the full SoP will be met for every flood event. As such it is assumed that 20% of the flood damage will be avoided.

The flood depths modelled for the majority of the properties at risk during a 0.5%AEP tidal event and a 0.5% AEP wave overtopping event are below 0.6m therefore this method is technically feasible for flood cells 1, 2 and 3. An economic review estimated the cost at €2.4m which is less than the benefit of protecting those properties at risk within Dungarvan AFA. No environmental or socially detrimental impacts were identified. However this method would not provide the preferred SoP and therefore should only be considered as a secondary method to providing flood protection.

Method	Tech	Econ	Env	Soc
Other Works	✗			

No other works were identified for these flood cells

8.2.6.3 Summary of Feasibility Review – Flood Cells 1, 2 and 3

The following FRM method has been carried forward to address the flood risk arising in flood cells 1, 2 and 3;

- Hard Defences

Hard Defences can provide the full protection to all properties at risk during the 0.5% AEP tidal event and 0.5% AEP wave overtopping event in flood cells 1, 2 and 3

Individual Property Protection can only provide partial protection. Individual Property Protection should therefore only be used should all other methods be deemed unsuitable later in the optioneering process.

8.2.7 Short Listing FRM Methods – Local Cell (flood cell 4)

Method	Review Comment	Continue Screening
		Flood Cell 4
Do Nothing	Consider Further	✓
Additional maintenance	Consider Further	✓
Do Minimum	Consider Further	✓
Planning and Development Control	Consider at UoM SSA - Reject	✗
Building Regulations	Consider at UoM SSA - Reject	✗
Catchment Wide SuDs	Consider at UoM SSA - Reject	✗
Land Use Management	Consider Further	✓
Strategic Development Management	Consider at UoM SSA - Reject	✗
Storage	Consider Further	✓
Improvement of Channel Conveyance	Consider Further	✓
Hard Defences	Consider Further	✓
Relocation of Properties	Consider Further	✓
Diversion of Flow	Consider Further	✓
Flood Warning/Forecasting	Consider Further	✓
Public Awareness Campaign	Consider at UoM SSA - Reject	✗
Individual Property Protection	Consider Further	✓
Other Works	Consider Further	✓

8.2.7.1 Feasibility Review Summary for Local Cell (flood cell 4)

Method	Technical Screening	Economic Screening	Environmental and Cultural Heritage Screening	Social Screening
Do nothing	✗			
Additional maintenance	✗			
Do Minimum	✗			
Land Use Management	✓	?	?	?
Storage	✓	✓	!	✓
Improvement of Channel Conveyance	✓	✓	!	✓
Hard Defences	✓	✓	!	✓
Relocation of properties	✓	✓	✓	?
Diversion of Flow	✓	✓	!	✓
Flood Warning/Forecasting	✗			
Individual Property Protection	✓	✓	✓	✓
Other Works	✗			
✗ - Reject ✓ - Progress ? - Progress, potential impacts identified ! - Progress, potential for significant impacts identified				

8.2.7.2 Justification for Rejection/Retention

Method	Tech	Econ	Env	Soc
Do nothing	✗			
The do nothing FRM method would involve stopping the current maintenance regime. This would not provide the preferred SoP and should therefore be rejected from the screening process.				
Method	Tech	Econ	Env	Soc
Additional maintenance	✗			
<p>A review of the flood risk within flood cell 4, has identified that out of bank flooding occurs on a tributary of the Colligan River due to insufficient channel and culvert capacity. Therefore it is expected that implementing additional maintenance on this watercourse would have minimal impact on the overall flood risk as it would not provide the additional conveyance needed within the channel.</p> <p>Increasing maintenance activities on the relevant watercourses will not significantly contribute to achieving the preferred SoP and therefore will not be pursued under the CFRAM Study.</p>				

Method	Tech	Econ	Env	Soc
Do Minimum	✗			
<p>This method is appropriate where an isolated/single issue exists which can be easily addressed in order to reduce the flood risk, for example the removal of a pinch point/obstruction, or the upgrade of a blockage prone culvert screen, etc. These activities would be considered relatively straightforward, discrete and low cost. Do Minimum is a standalone method, as it cannot be combined with others without contradicting its definition, therefore the design SoP must be achieved for this method to progress.</p> <p>Within flood cell 4 the Do Minimum method would involve clearing the channel of the tributary of the Colligan River flowing through this flood cell. Addressing the issue however would have minimal impact on the overall flood risk as it would not provide the additional conveyance needed within the channel. This is an unacceptable outcome in terms of achieving a 1%AEP standard of flood protection and should therefore be rejected from the screening process.</p>				
Method	Tech	Econ	Env	Soc
Land Use Management	✓	?	?	?
<p>The application of land use management measures was tested at UoM scale. Flood cell 4 is located within a catchment which is considered suitable as a pilot area and should progress in the optioneering process should no other method providing the full SoP be found suitable.</p>				
Method	Tech	Econ	Env	Soc
Storage	✓	✓	!	✓
<p>This method considers areas where flood water can be stored and then released at a controlled rate therefore reducing the flow rate through the AFA and hence the level of flood risk. This can be achieved by using existing depressions to create online or offline storage areas or by identifying pinch points which could be dammed such as a restricted point along a valley. Storage areas can be effective either upstream of the risk areas or within the risk area where parks or open areas are located.</p>				

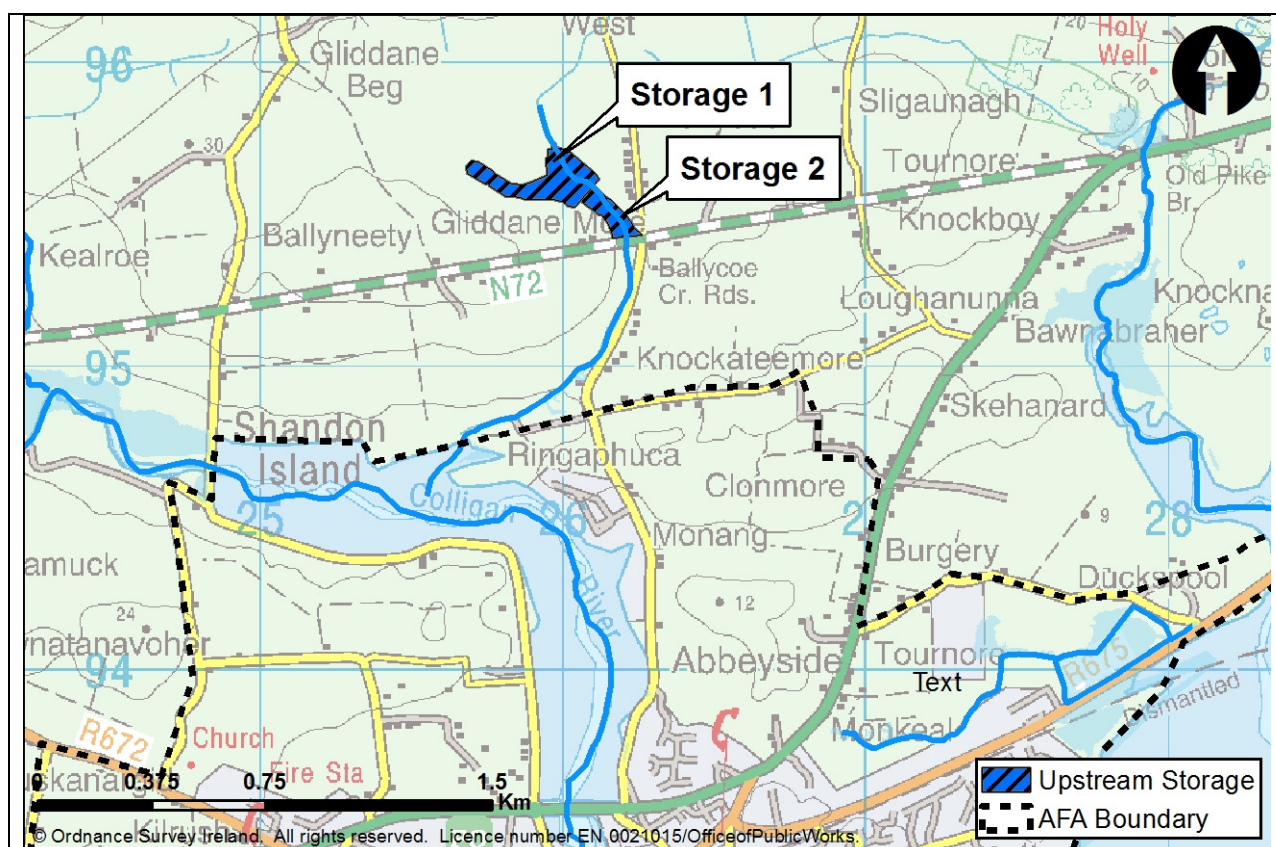


Figure 8.2.6 Location of Storage 1 and Storage 2

The volume of water required to be stored on the tributary of the Colligan River before reaching flood cell 4 has been estimated to be 42,250m³. A review of the surrounding land was carried out and two separate areas near the source of the watercourse were identified that would accommodate up to 44,949m³ (see Figure 8.2.6). The available storage is greater than the volume required therefore this method is technically feasible.

An economic review was carried out and estimated that the total cost of storage of this amount of water, including an embankment, culvert and overtopping weir, is approximately €1.75m. Therefore this method is economically viable.

Dungarvan Harbour SPA is within Dungarvan town in the Colligan River which is downstream of this tributary. Dungarvan WFD Drinking Water Area is also within flood cell 4. These issues need to be taken into consideration further during the detailed design and construction phases. There are no UNESCO World Heritage Sites in the vicinity of, or downstream of the AFA, or any AFA specific FRM methods to be employed. No other socially detrimental impacts were identified. Therefore storage is deemed a suitable FRM method for flood cell 4.

Method	Tech	Econ	Env	Soc
Improvement of Channel Conveyance	✓	✓	!	✓

This method focuses on increasing watercourse conveyance thereby lowering water levels and reducing the associated flood risk. This can be achieved by lowering bed level, widening/reshaping channels, removing channel/structure constrictions, culverting reaches of watercourse and reducing roughness of the channel.

In flood cell 4 there is a stretch of the watercourse that has a low lying left bank, see Figure 8.2.7. During a 1% AEP fluvial flood event the water levels increase beyond the level of the left bank and inundate the

floodplain. Therefore in order to reduce out of bank flooding along this stretch of the watercourse the channel conveyance would need to be improved. A review of the of the various FRM method techniques was carried out and widening of the channel along this stretch of the watercourse was found to be the most appropriate.

Figure 8.2.7 shows that approximately 150m downstream of the low lying left bank there is a twin culvert. During flood events the water levels at the culvert increase resulting in out of bank flooding at that location. A review of the of the various FRM method techniques was carried out and upgrading the culvert at this location was found to be the most appropriate.

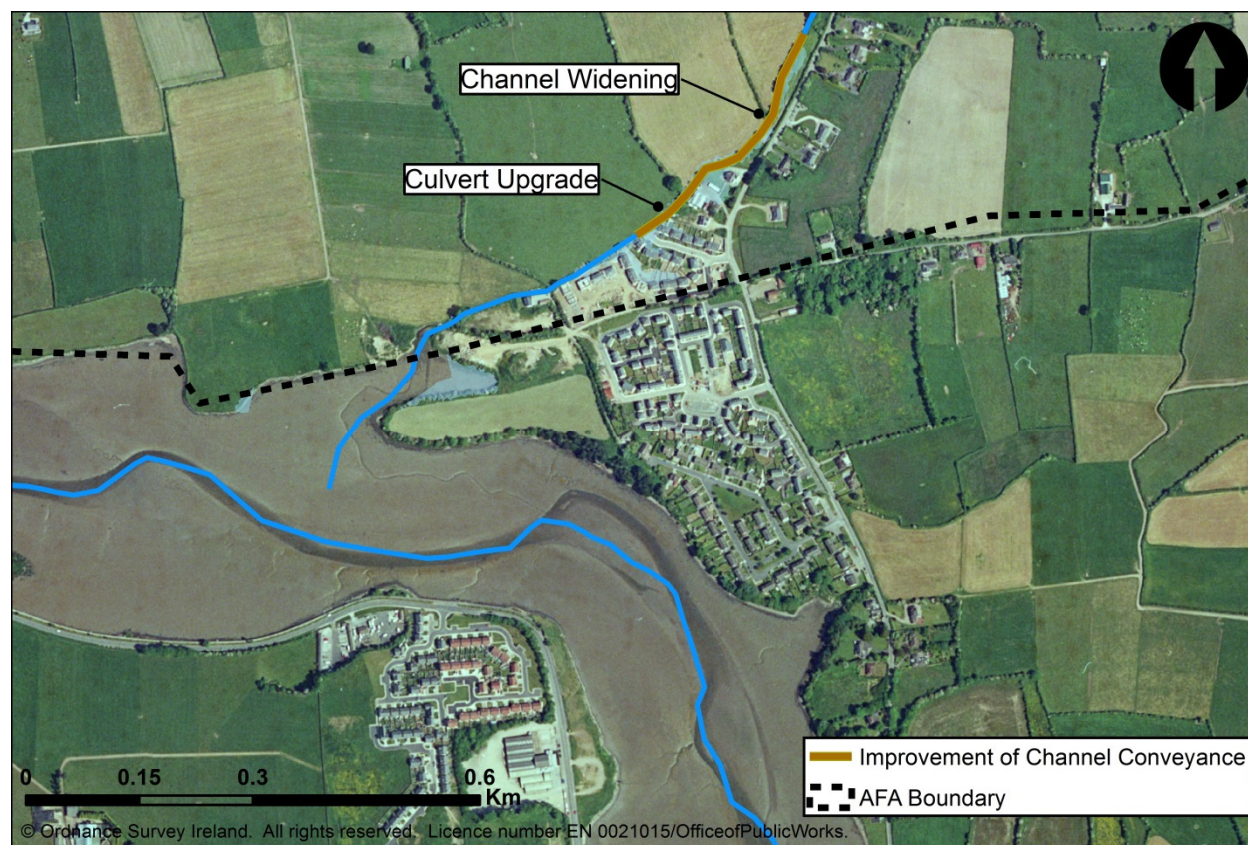


Figure 8.2.7 Location of Channel Improvement

To provide the preferred SoP for flood cell 4. the twin culvert, ID: 1722DG000231, adjacent to the River Lane estate would need to be upgraded and the watercourse channel would need to be widened upstream. An economic review estimated the cost of these works together, the channel widening and the culvert upgrade, to be approximately €737k making this method economically viable.

Dungarvan Harbour SPA is within Dungarvan town in the Colligan River which is downstream of the Colligan River tributary affecting flood cell 4. Dungarvan WFD Drinking Water Area is within flood cell 4. These issues need to be taken into consideration further during the detailed design and construction phases. There are no UNESCO World Heritage Sites in the vicinity of, or downstream of the AFA, and any AFA specific FRM methods to be employed. No other socially detrimental impacts were identified. Therefore improvement of channel conveyance is deemed a suitable FRM method for flood cell 4.

Method	Tech	Econ	Env	Soc
Hard Defences	✓	✓	!	✓

A review was carried out to ascertain where Hard Defences would be required to protect existing property within flood cell 4. Figure 8.2.8 shows the location of the Hard Defences required to protect properties during the 1% AEP event.

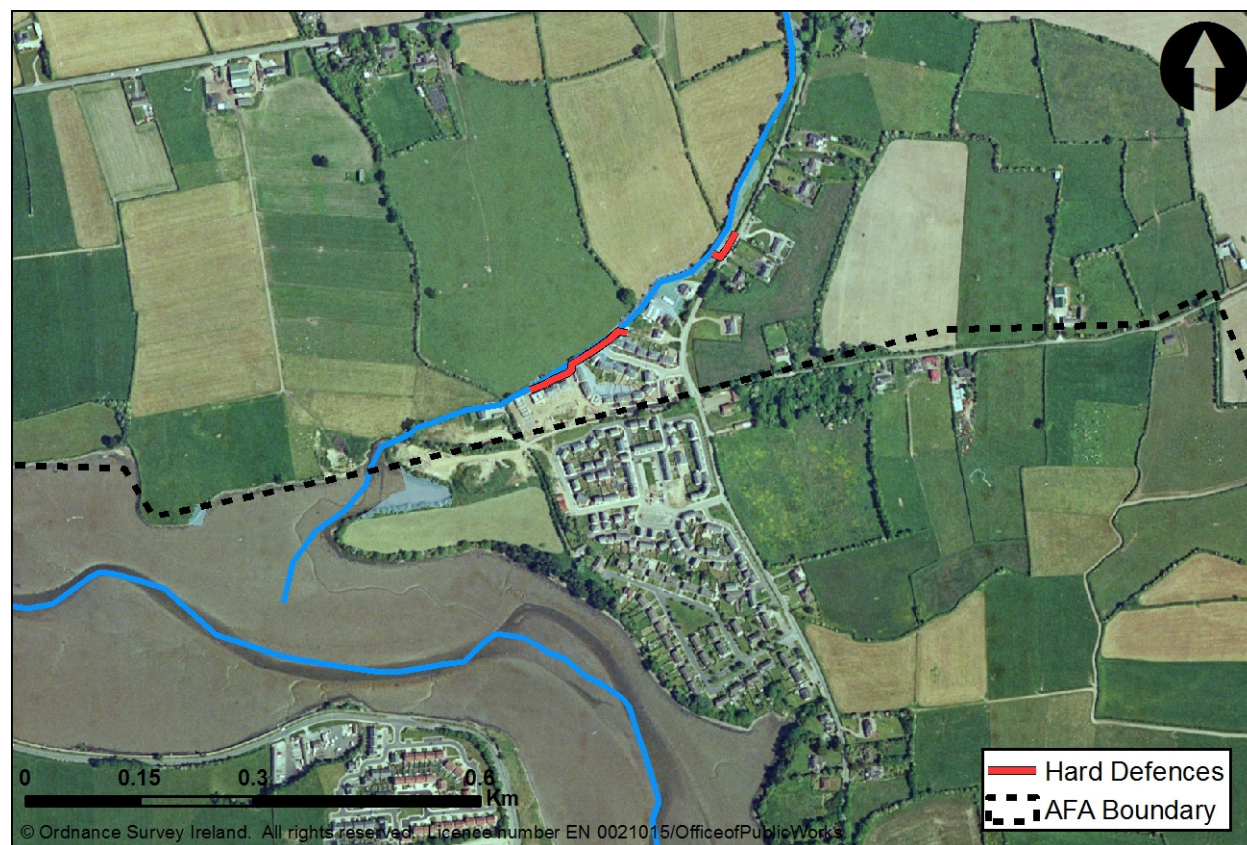


Figure 8.2.8 Location of Hard Defences in flood cell 4

In order to ascertain the effectiveness of Hard Defences a hydraulic model was constructed to simulate the method. The model showed these hard defences would protect to the 1% AEP flood event with an average height of 0.5m and a total length of 206m. An economic review estimated the cost of the hard defences to be approximately €175k making this method economically viable.

Dungarvan Harbour SPA is within Dungarvan town in the Colligan River which is downstream of the 1722DG watercourse. Dungarvan WFD Drinking Water Area is within flood cell 4. These issues need to be taken into consideration further during the detailed design and construction phases. There are no UNESCO World Heritage Sites in the vicinity of, or downstream of the AFA, and any AFA specific FRM methods to be employed. No other socially detrimental impacts were identified. Therefore hard defences is deemed a suitable FRM method for flood cell 4.

Method	Tech	Econ	Env	Soc
Relocation of properties	✓	✓	✓	?
<p>This method is technically feasible for flood cell 4. An economic review estimated the cost of relocating the 25 properties as €12.5m. This method was therefore considered economically viable. There are unlikely to be any significant impacts on the environment from the relocation of properties/infrastructure away from flood risk areas, provided the properties are removed sensitively from flood cell 4.</p> <p>Relocation of Properties could have direct, significant, long term social impacts to those required to relocate. These impacts could be positive or negative depending on the occupants attitude to relocating. There is the potential for indirect, significant social impacts to residents through fragmentation of neighbourhoods. There is the potential for indirect, significant social impacts to relocated commercial properties if old customers do not frequent the new premises. Relocation of properties / infrastructure may de-value the remaining properties / infrastructure in the area.</p> <p>Relocation of properties is deemed a suitable FRM method for flood cell 4. Considering the level of uncertainty associated with the social implications of Relocation of Properties it should only be considered should no other method be found suitable.</p>				
Method	Tech	Econ	Env	Soc
Diversion of Flow	✓	✓	!	✓
<p>This method involves directing some of the floodwater via a new route thereby reducing flow and associated flood risk along the original route. This would be carried out upstream of where floodwaters reach the area of at risk properties. The new flow route would normally consist of a constructed open channel and/or culvert system or an existing linear feature able to convey the flow to a designated discharge point.</p> <p>A review was carried to identify locations where a Flow Diversion route could be constructed in the vicinity of flood cell 4.</p>				

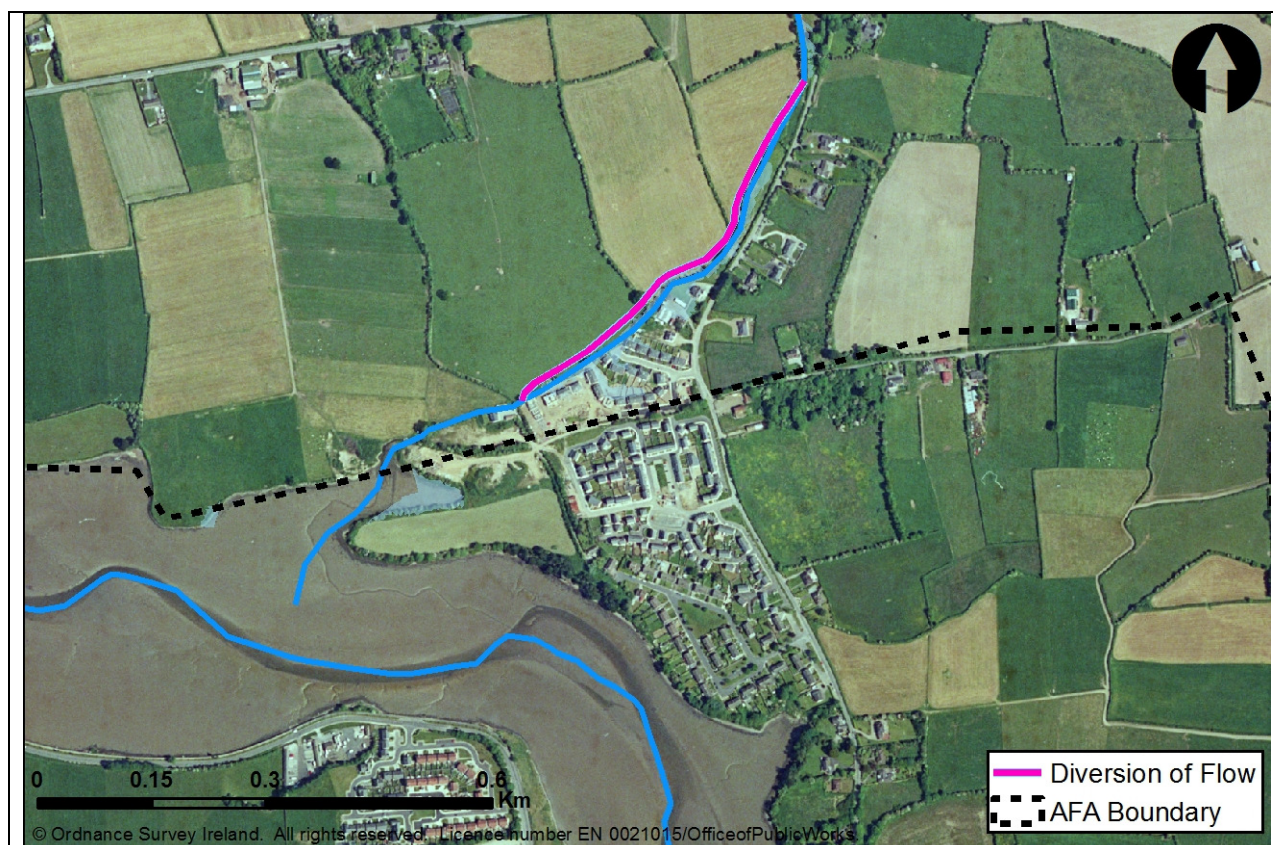


Figure 8.2.9 Location of Diversion of Flow in flood cell 2

One flow route was identified where the flow could be diverted from a point upstream of the flood risk area discharging to another point downstream of the flood risk area, see Figure 8.2.9.

The target flow for the diversion channel was set at $1.7\text{m}^3/\text{s}$ as this would provide protection to all properties affected in flood cell 4 by the 1% AEP flood event. This was found to be feasible and would require a 585m long channel 6.95m wide and 0.65m deep. The resulting flood extent showed minimal difference to the current scenario outside the at risk area and no additional receptors were affected by it. An economic review estimated the flow diversion to be approximately €248k making this method economically viable.

Dungarvan Harbour SPA is within Dungarvan town in the Colligan River which is downstream of the 1722DG watercourse. Dungarvan WFD Drinking Water Area is within flood cell 4. These issues need to be taken into consideration further during the detailed design and construction phases. There are no UNESCO World Heritage Sites in the vicinity of, or downstream of the AFA, and any AFA specific FRM methods to be employed. No other socially detrimental impacts were identified. Therefore Diversion of Flow is deemed a suitable FRM method for flood cell 4.

Method	Tech	Econ	Env	Soc
Flood Warning / Forecasting	x			

The application of flood warning / forecasting was tested at UoM scale. There are no suitable locations far enough upstream to place a gauge which would provide sufficient warning for flood cell 4. This method is technically unfeasible.

Method	Tech	Econ	Env	Soc
Individual Property Protection	✓	✓	✓	✓
<p>There are 25 properties at risk from a 1% AEP fluvial flood event in flood cell 4. The flood depths modelled for the majority of the properties at risk during a 1% AEP fluvial flood event are below 0.6m therefore this method is technically feasible for flood cell 4. An economic review estimated the cost at €472k which is less than the benefit of protecting the properties at risk within Dungarvan AFA.</p> <p>Property level protection will provide positive social impacts to those provided with protective equipment by giving them more peace of mind. There will be positive benefits to the public that can protect themselves from small flood events, reducing or even eliminating damages that would otherwise cause disturbance and inconvenience. There are unlikely to be significant impacts at the strategic level with this FRM method, provided that IPP is not implemented on protected architectural or archaeological heritage so that it permanently physically alters the feature or the setting of the feature.</p> <p>Therefore IPP is deemed a suitable FRM method for flood cell 4. However this method would not provide the preferred SoP and therefore should only be considered as a secondary method of providing flood protection.</p>				
Method	Tech	Econ	Env	Soc
Other Works	✗			
No other works were identified for this flood cell				
8.2.7.3 Conclusion and Summary of Feasibility Review – Flood Cell 4				
<p>The following FRM methods which provide the full design SoP have been carried forward to address the flood risk arising from flood cell 4;</p> <ul style="list-style-type: none"> • Storage • Improvement of Channel Conveyance • Hard Defences • Relocation of Properties and • Diversion of Flow. <p>The FRM methods deemed suitable for flood cell 4 were compared against each other in order to progress one method to the optioneering process which addresses the localised flood risk.</p> <p>Storage is significantly more complex technically and more expensive than the other FRM methods proposed. It could also have significant negative environmental and social impacts compared with the other proposed methods. Therefore it can be deemed an alternative method rather than the preferred method for this localised cell.</p> <p>Relocation of Properties is significantly more expensive than the other FRM methods proposed. This is evident as the combined cost of the Relocation of Properties and Hard Defences for flood cells 1, 2 and 3 would render that option economically unviable for the Dungarvan AFA. Relocation of Properties could also have direct, significant, long term social impacts to those required to relocate. Therefore it can be deemed an alternative method rather than the preferred method for this localised cell.</p> <p>Improvement of Channel Conveyance, Hard Defences and Diversion of Flow are comparatively close when compared technically, economically and environmentally. There is the potential for positively impacting upon the local environment during the detailed design using Hard Defences or Improvement of Channel Conveyance through mitigation measures that could include habitat creation. Therefore</p>				

Diversion of Flow can be deemed a reserve method rather than the preferred method for this localised cell.

Improvement of Channel Conveyance would involve less social interruption than hard defences since it would require the least amount of land acquisition. Hard Defences can be deemed a reserve method and Improvement of Channel Conveyance the preferred method for this localised cell. Subsequently Improvement of Channel Conveyance has been put forward to the optioneering process.

Improvement of Channel Conveyance can provide the full protection to all properties during the 1% AEP flood event. Flood Cell 4 is considered a suitable area to consider Land Use Management as an FRM method and it is recommended that it is considered as a pilot should the other feasible methods listed above be found unsuitable.

Land Use Management and Individual Property Protection can only provide partial protection. These FRM methods should therefore only be used should all other methods be deemed unsuitable later in the optioneering process.

8.2.8 Selection of Options

Method	Option 1	Option 2	Option 3	Option 4	Option 5
Hard Defences and Improvement of Channel Conveyance	✓				
The Improvement of Channel Conveyance method identified for local flood cell 4 has been combined with the Hard Defences FRM method identified for flood cells 1, 2 and 3, to provide the full design SoP for the Dungarvan and Environs AFA.					

8.2.8.1 Option 1 details - Hard Defences

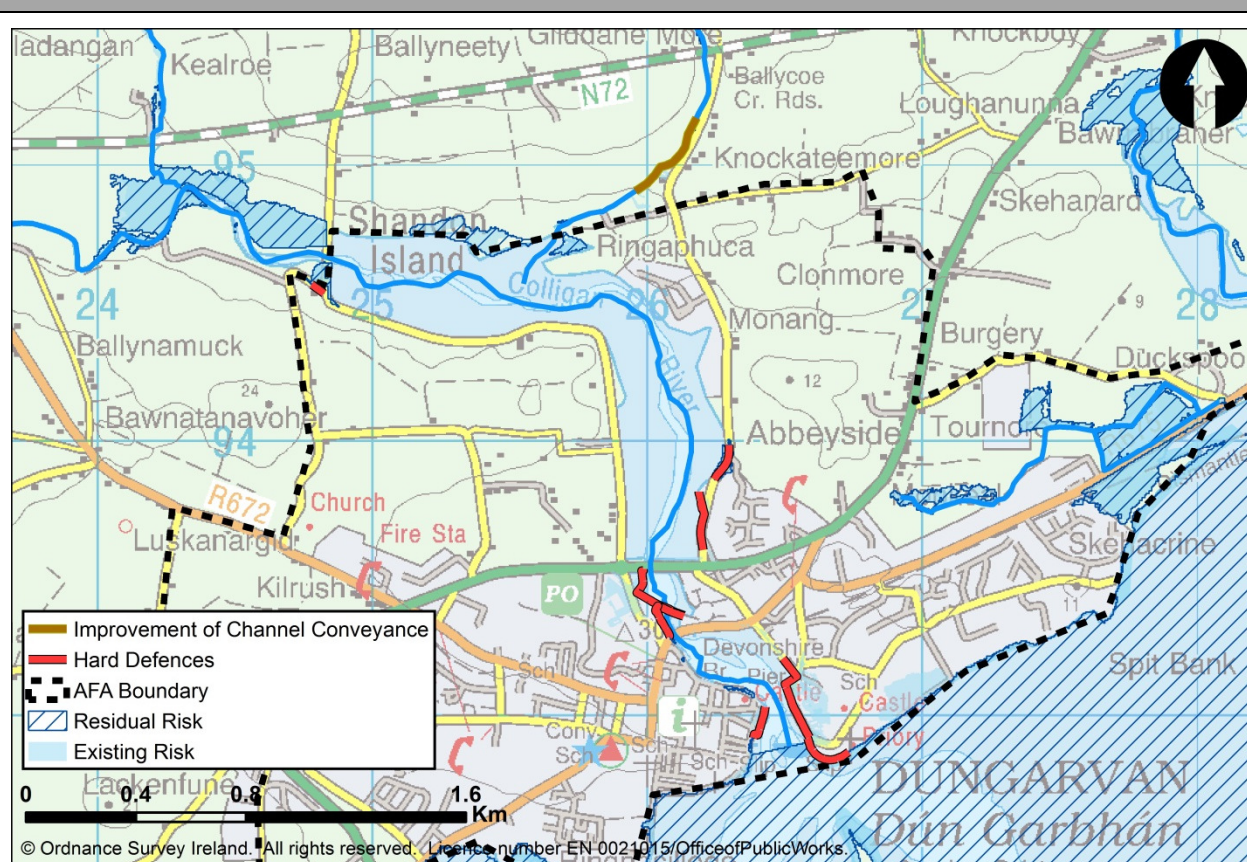


Figure 8.2.10 Dungarvan AFA Option 1

At risk properties would be protected by a series of walls within flood cells 1, 2 and 3. At risk properties within flood cell 4 would be protected by widening the channel and upgrading the culvert, ID: 1722DG00023I, adjacent to the River Lane estate, see Figure 8.2.10. This combination of hard defences and improvement of channel conveyance would protect to the 0.5% AEP tidal event, 0.5% AEP wave overtopping event and 1% AEP fluvial event and would provide the preferred SoP for the whole AFA.

Figure 8.2.10 presents the effect of the potential option on the design flood event by overlaying the present day flood extent (labelled existing risk) with the flood extent that would occur after the option is put in place (labelled residual risk).

In addition to these methods the following methods were also identified at UoM level (see section 8.1) to

be included in any potential option identified:

- Planning and Development Control
- Building Regulations
- Sub-catchment Wide SuDs
- Strategic Development Management
- Public Awareness Campaign

Option Item	Quantity	Construction Cost	
Walls	1.3km length, 1.2m high (average)	€3,434,888	
Flood gate	Double 2x3m at the Strandside South slipway	€221,200	
In channel excavation	388m³, chanel widened 1.6m approx	€13,313	
Culvert upgrade	1722DG00023l adjacent to the River Lane estate	€268,116	
Total MCA-Benefit Score	Option Cost (€millions)	MCA-Benefit Score / Cost Ratio	
1055	8.92	118.24	
Economic Appraisal (Cost-Benefit Analysis) Outcomes			
Area NPVd (uncapped)	Option Cost	Option NPVb (capped)	Benefit - Cost Ratio
€27,891,785	€8,923,163	€ 17,369,422	1.95

8.2.8.2 AFA Sensitivity to Future Change

During a MRFS 0.5% AEP mechanism 1 flood event the increase in flood extent is significant as flood waters occupy any unprotected area in Dungarvan that lies below an elevation of approximately 3.2m OD Malin. This would result in an additional 387 properties being at risk bringing the property count from 59 in the present day 0.5% AEP mechanism 1 event to 446. During a MRFS 0.5% AEP mechanism 2 flood event the increase in flood extent is also significant as areas previously protected by defences would either experience increased wave overtopping discharge or would experience tidal inundation. This would result in an additional 280 properties being at risk bringing the property count from 43 in the present day 0.5% AEP mechanism 2 event to 323.

The flood risk identified for the area around Dungarvan Harbour, the Corrigan Estuary and the Duckspool area would be increased. There would also be other areas within the Dungarvan AFA that present an additional flood risk, when considering flood extents for MRFS and HEFS 0.5% AEP mechanism 1 and 2 flood extents. These areas include the Gold Coast Golf Resort, Scart, Seapark, Friars Walk, Loughmore and Springduke as shown in Figure 8.2.11 and Figure 8.2.12.

During a MRFS 1% AEP flood event the increase in flood extent is minimal due to the topography of the valley that the Colligan River tributary giving rise to the flooding flows through. This would result in an additional 7 properties being at risk bringing the property count from 25 in the present day 1% AEP fluvial event to 32. The main area of additional flood risk is confined to the estates around River Lane, Ringphuca as shown in Figure 8.2.13.

The AAD would increase from €1,298,379 to €14,292,992. As a result the Dungarvan AFA would be considered to be at high vulnerability from the MRFS.

During a HEFS 0.5% AEP mechanism 1 flood event the increase in flood extent is significant as flood waters occupy any unprotected area in Dungarvan that lies below an elevation of approximately 3.7m OD Malin. This would result in an additional 648 properties being at risk bringing the property count from 59 in the present day 0.5% AEP mechanism 1 event to 707. During a HEFS 0.5% AEP mechanism 2 flood event the increase in flood extent is again significant as areas previously protected by defences would either experience increased wave overtopping discharge or would allow tidal inundation. This would result in an additional 461 properties being at risk bringing the property count from 43 in the present day 0.5% AEP mechanism 2 event to 504.

The flood risk identified for the area around Dungarvan Harbour, the Corrigan Estuary and the Duckspool area would be further increased. There would also be other areas within the Dungarvan AFA that present an additional flood risk, when considering flood extents for MRFS and HEFS 0.5% AEP mechanism 1 and 2 flood extents. These areas include the Gold Coast Golf Resort, Scart, Seapark, Friars Walk, Loughmore and Springduke.

During a HEFS 1% AEP flood event the increase in flood extent is minimal due to the topography of the valley Colligan River tributary giving rise to the flooding flows through. This would result in an additional 16 properties being at risk bringing the property count from 25 in the present day 1% AEP fluvial event to 41. The main area of additional flood risk is confined to the estates around River Lane, Ringaphuca.

The AAD would increase from €1,298,379 to €91,175,214. As a result the Dungarvan AFA would be considered to be at high vulnerability from the HEFS.

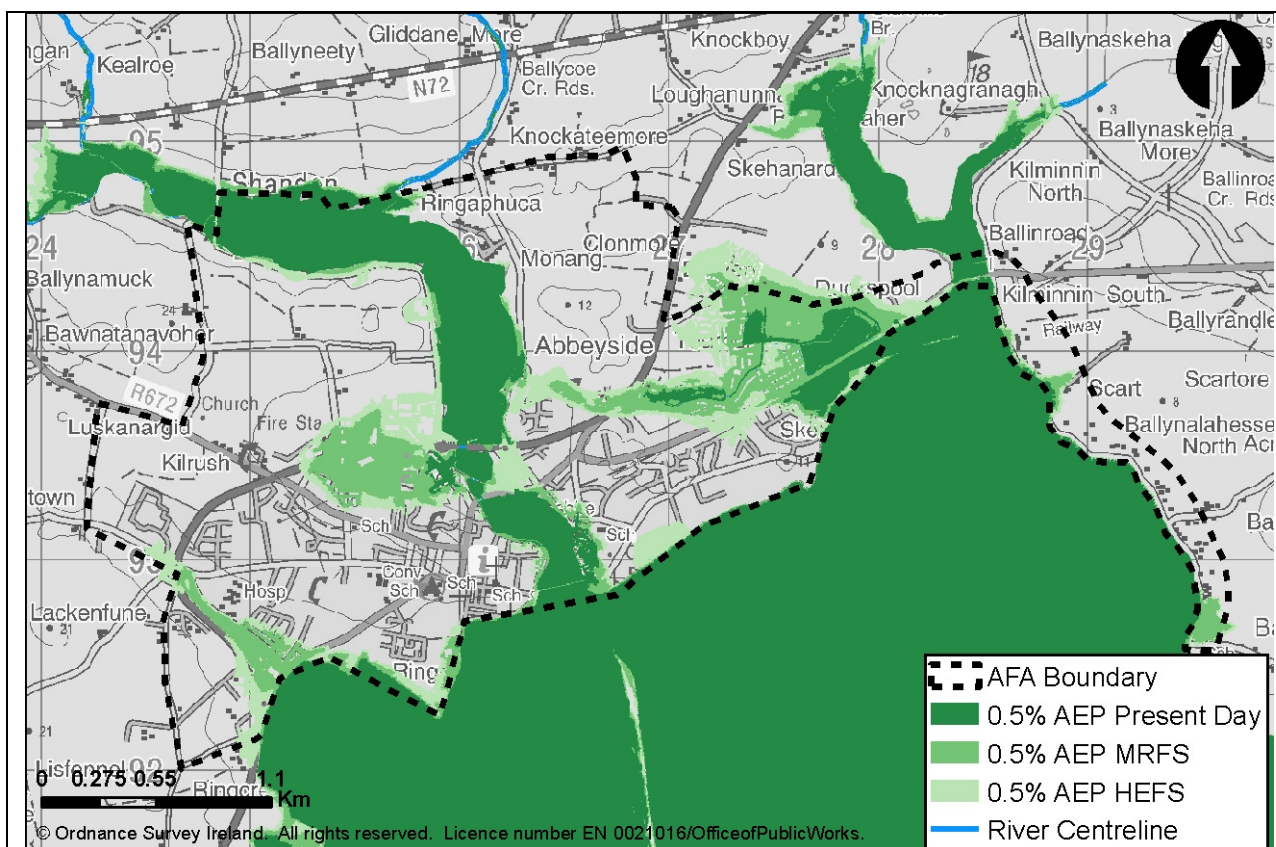


Figure 8.2.11 Future Change - Coastal Flood Extents (Mechanism1)

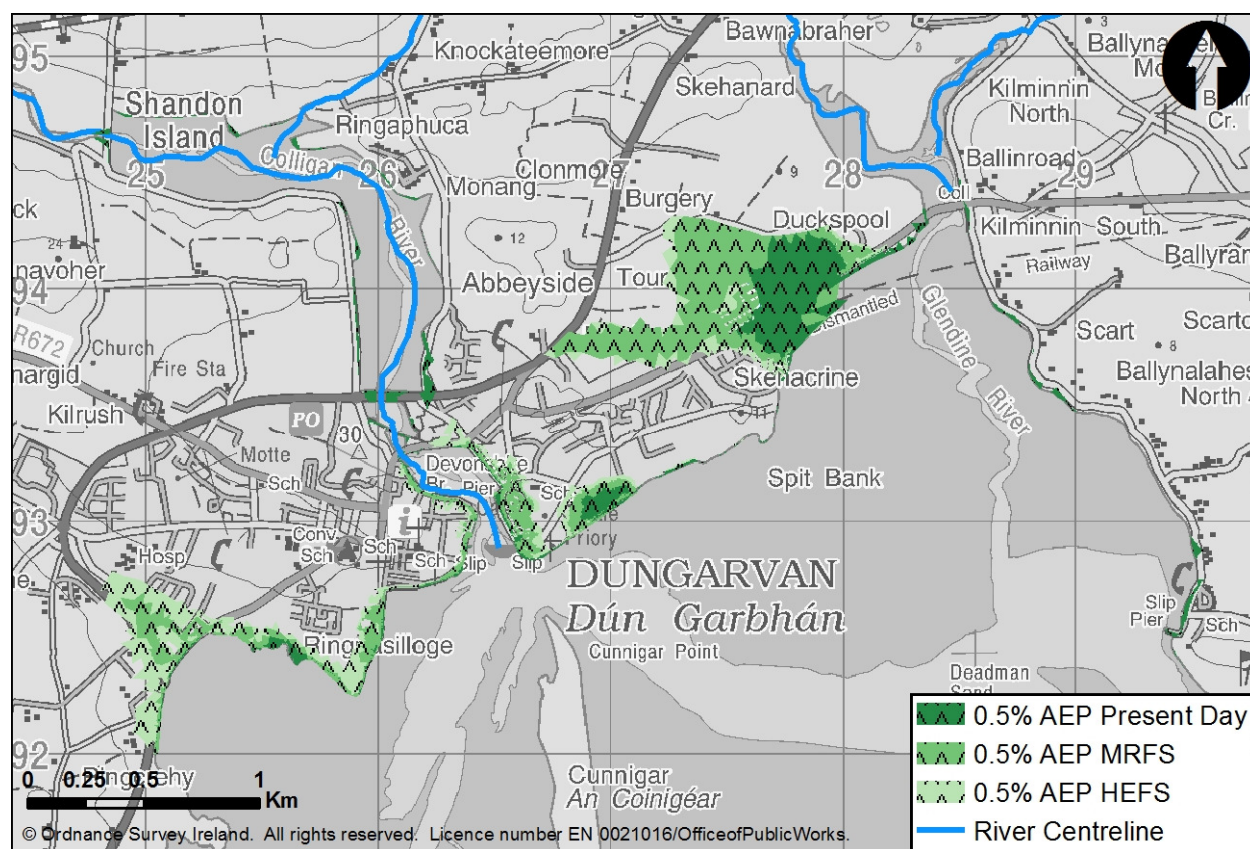
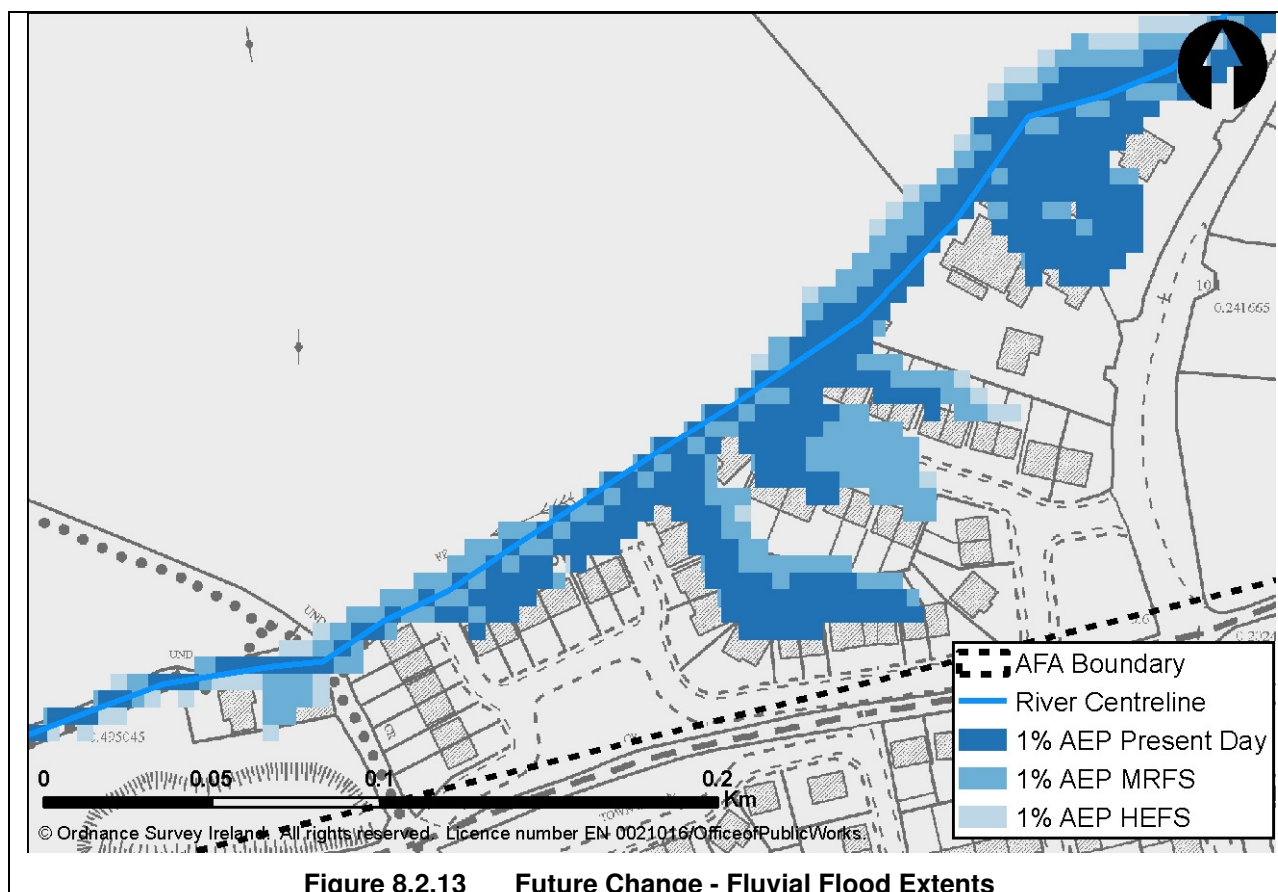


Figure 8.2.12 Future Change - Coastal Flood Extents (Mechanism2)



8.2.8.3 Future Change Adaptability

The following discusses the adaptability of the potential FRM methods proposed in the Dungarvan AFA to deal with projected future flood risk:

Hard Defences Flood Cells 1, 2 and 3 - This method could be adapted by increasing the height of the retaining structure and extending its length to tie into high ground. As the retaining structure is a wall it would need to be designed to accommodate additional height in the future. The height of the wall would need to be increased to 1.7m or 2.2m on average in the MRFS or HEFS respectively and lengthed by 2.2km or 3.4km for the MRFS or HEFS respectively, in some sections, this would raise concerns over the residual risk and social impact. The design of the walls that are constructed along the open coast, with properties immediately on their leeward side, would also have to account for wave overtopping. Hard Defences in flood cells 1, 2 and 3 would therefore be considered to have poor adaptability due to the significant increase in the length of wall required to retain the preferred SoP.

Improvement of Channel Conveyance Flood Cell 4 - This method could be adapted by increasing channel capacity and culvert size. There would be potential to widen or lower the bed level further to accommodate the additional flows as well as upgrade the proposed culvert. There is enough scope to widen the channel where the flood waters exceed bank levels however additional dredging may be required to accommodate a larger culvert. Given the additional work required to upgrade the culvert this method is considered to have moderate adaptability.

A review of the potential options show that option 1, Hard Defences and Improvement of Channel Conveyance, is adaptable to the MRFS and HEFS.

The potential **options** identified have been further assessed using 5 criteria in an attempt to identify low – or no regret combinations of measures.

1. **Does the option reduce vulnerability?** In addition to the methods above other methods aimed at reducing future flood risk at UoM scale have been discussed in section 8.1 and are detailed in each potential option. These methods, such as building regulations and planning & development control will reduce the impact to potential future receptors. Given that Dungarvan is currently largely urbanised there would be limited scope for some of these methods to impact on the area being assessed. There are areas such as Monkeal and north of Shandon where these methods including a strategic development plan would be effective. Since there is a relatively large increase in the number of properties affected in the MRFS and HEFS there is a need to ensure that future at risk receptors are prepared through methods such as a public awareness campaign.
2. **Does the option make space for water?** The FRM method that would address the flood risk in flood cells 1, 2 and 3 would not make space for water as the Hard Defences proposed are protecting at risk properties from tidal inundation along the coastline in an urban area. The FRM method that would address the flood risk in flood cell 4 would make space for water as the Improvement of Channel Conveyance involves widening of the channel and upgrading of the existing culvert, to increase the capacity of the watercourse.
3. **Does the option deliver co-benefits?** No co-benefits were identified.
4. **Does the option provide flexibility?** A review of the potential option shows that the Hard Defences in flood cells 1, 2, and 3, have poor adaptability as a significant length of Hard Defences would need to be added in newly identified areas of risk. Improvement of Channel Conveyance in flood cell 4 has moderate adaptability.
5. **Does the option allow for deferring/removing or abandoning?** Given the present day risk there is no allowance for options to be deferred or any that could be removed later. However should opportunity ever arise, options with channel modification are most easily reverted, which is a FRM method proposed to address the flood risk in flood cell 4.

An objective for each potential option is to ensure that flood risk can be managed effectively and sustainably into the future accounting for the potential impacts of climate change. Based on this future change adaptability assessment table below summarises how well each option achieves this objective.

Summary of Option Adaptability

Option	Description	Score
Option 1 – Hard Defence (FC 1, 2, 3) and Improvement of Channel Conveyance (FC 4)	Option is adaptable at significant cost, difficulty and impact	1

8.2.8.4 Local Authority Comments

LA representatives reviewed preliminary options in November 2015.

8.2.8.5 Summary

There is good confidence in both the hydrology and hydraulics of the Dungarvan AFA. While there are no flow or water level gauges within model reaches for the purposes of flow calibration the Dungarvan flood model does agree with flood extent verification events.

The following potential options, with a BCR ≥ 0.5 have been identified:

- Option 1 –Hard Defences (FC 1, 2, 3), Improvement of Channel Conveyance (FC 4) and FRM measures identified for UoM17

Alongside any potential option the existing regime should continue with maintenance being carried out ad hoc when resources allow. Maintenance of the option structures should will also form part of the ongoing regime once in place.

Methods also were identified at UoM level (see section 8.1) that are applicable to Dungarvan AFA, that if implemented, will serve to avoid increasing flood risk in the future :

- Planning and Development Control
- Building Regulations
- Sub-catchment Wide SuDs
- Strategic Development Management
- Public Awareness Campaign

No communities are located upstream that would be affected by any of the potential options identified. However any interactions with the drainage system in this urbanised area may need to be addressed during the development of the preferred option.

The Dungarvan AFA is located with the Dungarvan SPA therefore this specially designated area would also need to be addressed during the development of the preferred option.

It should be noted that this area is significantly sensitive to climate change and is suitable for an adaptive approach be incorporated into detailed design.

These recommendations should be taken forward with a view to identification of a preferred option for the flood risk management plan.

8. OPTIONEERING OF SSA'S

8.3 Dunmore East Optioneering of FRM Options

Name	Local Authority	Unique ID	SSA	Status	Date
Dunmore East	Waterford	170245	AFA	Final	08/06/2016

8.3.1 Source of flooding

Fluvial	Coastal Mechanism 1	Coastal Mechanism 2
There are no receptors at risk due to coastal flooding in this AFA.		

8.3.2 Flood Cells

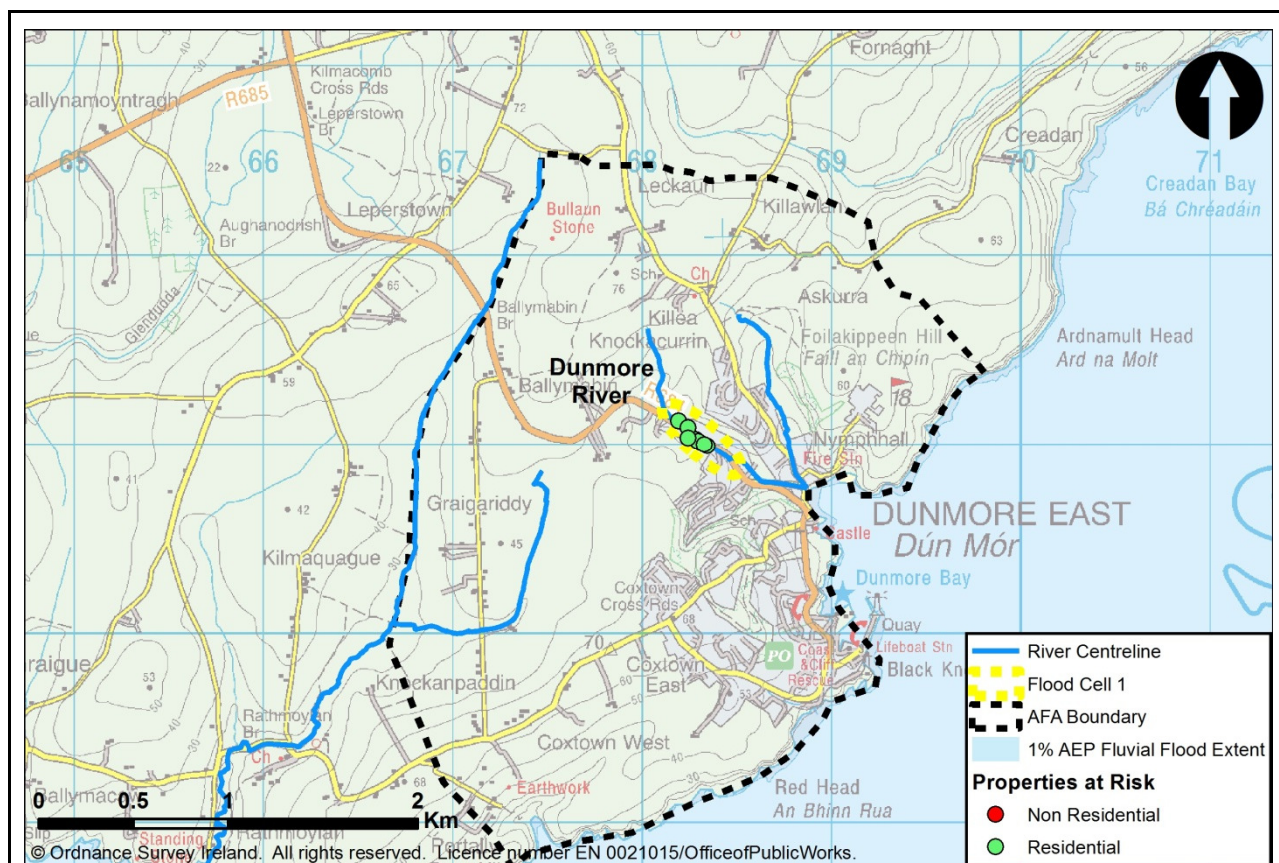


Figure 8.3.1 Dunmore East AFA Flood Cells within a 1% AEP Fluvial Flood Extent

Flood Cell 1:

Out of bank flooding would occur on the Dunmore River watercourse during a 1% AEP flood event due to both insufficient channel and culvert capacity inundating the floodplain affecting 8 properties. Given this is the only area within the Dunmore East AFA where there is a flood risk and the properties at risk are in close proximity to each other flood cell 1 is considered local.

Summary of Flood Cells:

As shown in Figure 8.3.1 the fluvial flood risk originates from the Dunmore River watercourse. As this is only flood cell it will be screened as a standalone area assessing options applicable to localised works (Section 8.3.5).

8.3.3 Existing Regime

This existing regime considers all activities currently carried out which impact on the management of flood risk. The level and frequency of maintenance is considered, along with inspection, and any other specific activity (for example the operation of locks, barrages, sluice gates and valves).

The watercourses in Dunmore East are not located within a Drainage District or an Arterial Drainage scheme. These watercourses are, for the most part, in private lands and are not the responsibility of Waterford County Council. Nevertheless, inspections and maintenance are carried out as and when resources are available.

8.3.4 Summary of Flood Risk within SSA boundary

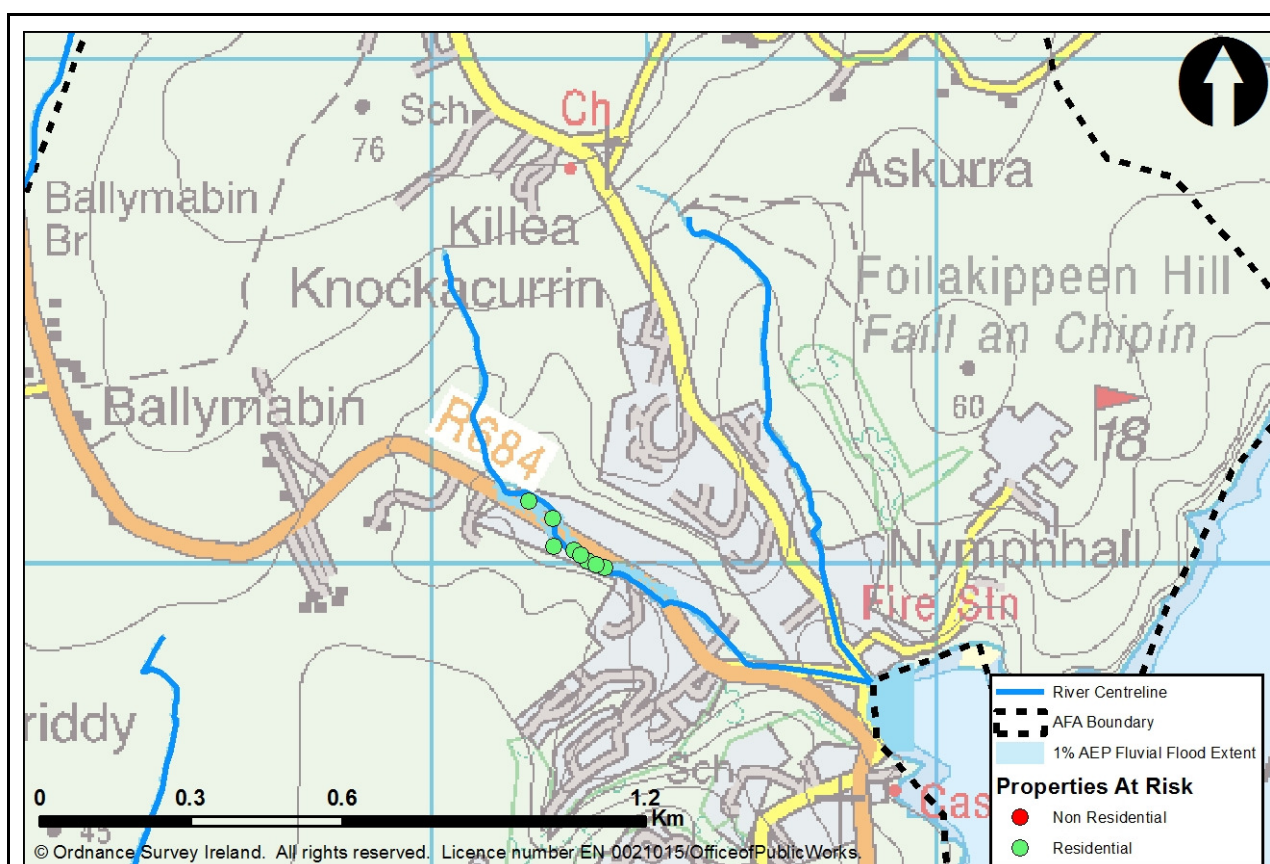


Figure 8.3.2 Flood risk in Dunmore East AFA within a 1% AEP Fluvial Flood Extent

In Dunmore East AFA the onset of residential property damage occurs in the 5% AEP event.

Monetary Damage and Benefit

	Flood Cell 1	Total in AFA
Annual Average Damage (AAD)	€ 23,878	€ 23,878
Present Value Damage (pvD)	€ 512,948	€ 512,948
Standard of Protection (SoP)	1% AEP Fluvial	1% AEP Fluvial
Number of Properties Benefiting from Design SoP	8	8
Minimum Present Value Benefit	€ 255,180	€ 255,180
Capped Minimum Present Value Benefit	€ 255,180	€ 255,180

*The sum of the flood cell AAD or pvD values may not equate to the values presented for the Total in SSA due to flooding greater than the 1% AEP occurring outside the flood cell extents.

8.3.5 Short Listing FRM Methods – Local Cell

Method	Review Comment	Continue Screening
		Flood Cell 1
Do Nothing	Consider Further	✓
Do Minimum	Consider Further	✓
Additional Maintenance	Consider Further	✓
Planning and Development Control	Consider at UoM SSA - Reject	✗
Building Regulations	Consider at UoM SSA - Reject	✗
Catchment Wide SuDs	Consider at UoM SSA - Reject	✗
Land Use Management	Consider Further	✓
Strategic Development Management	Consider at UoM SSA - Reject	✗
Storage	Consider Further	✓
Improvement of Channel Conveyance	Consider Further	✓
Hard Defences	Consider Further	✓
Relocation of Properties	Consider Further	✓
Diversion of Flow	Consider Further	✓

Flood Warning/Forecasting	Consider Further	✓
Public Awareness Campaign	Consider at UoM SSA - Reject	✗
Individual Property Protection	Consider Further	✓
Other Works	Consider Further	✓

8.3.5.1 Feasibility Review Summary for Local Cell (flood cell 1)

Method	Technical Screening	Economic Screening	Environmental and Cultural Heritage Screening	Social Screening
Do nothing	✗			
Do Minimum	✗			
Additional Maintenance	✗			
Land Use Management	✓	✓	✓	✓
Storage	✓	✗		
Improvement of Channel Conveyance	✓	✗		
Hard Defences	✓	✓	✓	✓
Relocation of properties	✓	✗		
Diversion of Flow	✗			
Flood Warning/Forecasting	✗			
Individual Property Protection	✓	✓	✓	✓
Other Works	✗			
✗ - Reject ✓ - Progress ? - Progress, potential for significant impacts identified ! - Progress, potential for significant impacts identified				

8.3.5.2 Justification for Rejection/Retention

Method	Tech	Econ	Env	Soc
Do Nothing	✗			
The do nothing FRM method would involve stopping the current maintenance regime. This would not provide the preferred SoP and should therefore be rejected from the screening process.				
Method				
Do Minimum	✗			
This method is appropriate where an isolated/single issue exists which can be easily addressed in order to reduce the flood risk, for example the removal of a pinch point/obstruction, or the upgrade of a blockage prone culvert screen, etc. These activities would be considered relatively straightforward, discrete and low cost. Do Minimum is a standalone method, as it cannot be combined with others without contradicting its definition, therefore the design SoP must be achieved for this method to progress.				

There were no FRM methods identified that would be considered relatively straightforward or discrete as out of bank flooding would occur in flood cell 1 due to both insufficient channel and culvert capacity inundating the floodplain. Therefore this method was rejected from the screening process.

Method	Tech	Econ	Env	Soc
Additional Maintenance	x			

This method considers the provision of additional maintenance and seeks to determine if any improvements can be made which will provide a beneficial impact on the flood risk in the AFA.

A review of the flood risk within flood cell 1, Section 8.3.2, has identified that out of bank flooding occurs on the Dunmore River watercourse due to insufficient channel and culvert capacity inundating the floodplain. Therefore it is expected that implementing any additional maintenance on this watercourse would have minimal impact on the overall flood risk as it would not provide the additional conveyance needed within the channel.

Increasing maintenance activities will not significantly contribute to achieving the preferred SoP and therefore will not be pursued under the CFRAM Study.

Method	Tech	Econ	Env	Soc
Land Use Management	✓	✓	✓	✓

The application of land use management measures was tested at UoM scale. Flood cell 1 is located within a catchment which is considered suitable as a pilot area and should progress in the optioneering process should no other method providing the full SoP be found suitable.

Method	Tech	Econ	Env	Soc
Storage	✓	x		

This method considers areas where flood water can be stored and then released at a controlled rate therefore reducing the flow rate through the AFA and hence the level of flood risk. This can be achieved by using existing depressions to create online or offline storage areas or by identifying pinch points which could be dammed such as a restricted point along a valley. Storage areas can be effective either upstream of the risk areas or within the risk area where parks or open areas are located.

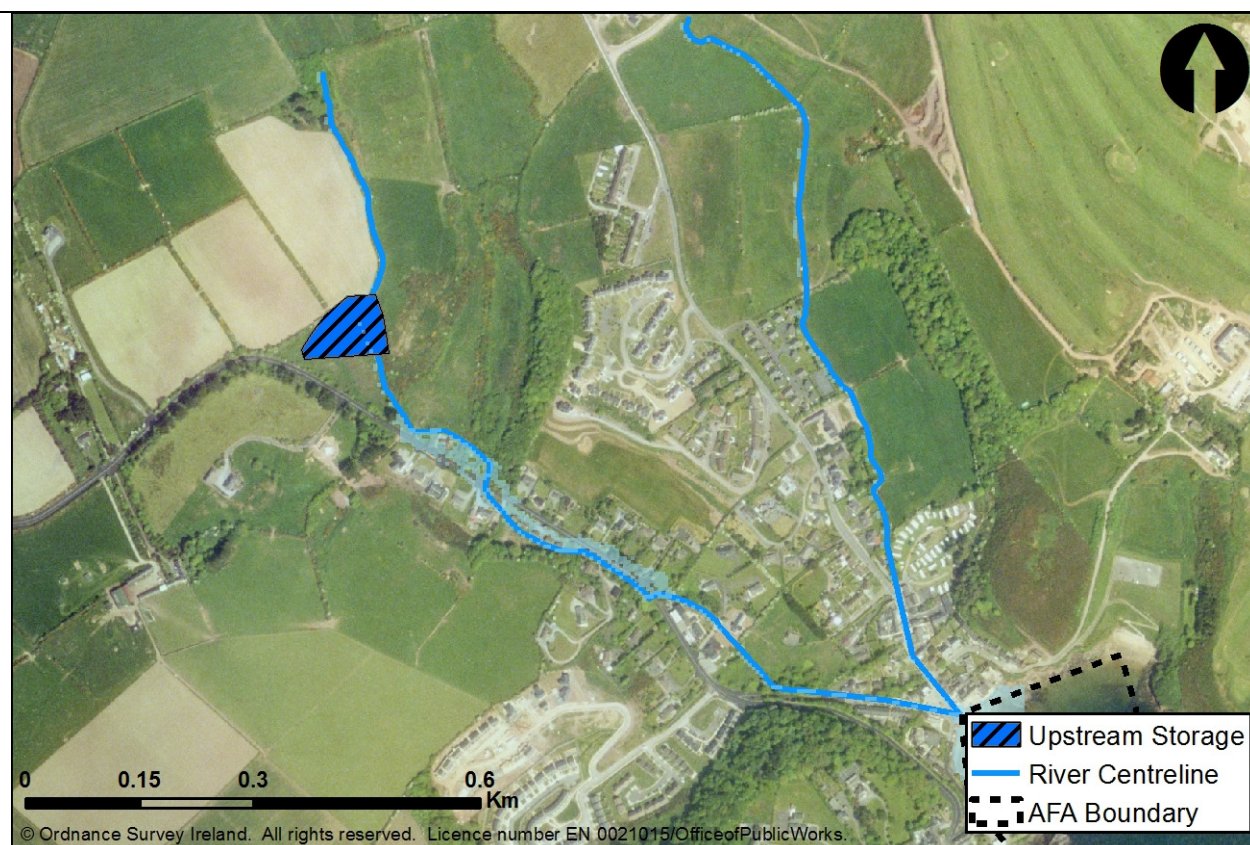


Figure 8.3.3 Location of Storage

The volume of water required to be stored on the Dunmore River watercourse before reaching flood cell 1 has been estimated to be $3,636\text{m}^3$. A review of the surrounding land was carried out and an area near the source of the watercourse was identified that would accommodate up to $3,850\text{m}^3$ (see Figure 8.3.3). The available storage is greater than the volume required therefore this method is technically feasible.

An economic review was carried out and estimated that the total cost of storage for this amount of water, including an embankment, culvert and overtopping weir, is approximately €477k. This renders this method economically unviable for flood cell 1 and should therefore be rejected from the screening process.

Method	Tech	Econ	Env	Soc
Improvement of Channel Conveyance	✓	✗		

This method focuses on increasing watercourse conveyance thereby lowering water levels and reducing the associated flood risk. This can be achieved by lowering bed level, widening/reshaping channels, removing channel/structure constrictions, culverting reaches of watercourse and reducing roughness of the channel. While some of these activities can also form part of the 'Do Minimum' method, Improvement of Channel Conveyance differs in that it holistically addresses all risk areas while the other two methods consider one or more discrete activities. A review of the various FRM method techniques was carried out and modifying the channel and upgrading an existing culvert was found to be the most appropriate way to implement this method.

In flood cell 1 there is a stretch of the watercourse that has a low lying right bank. During a 1% AEP fluvial flood event the water levels increase beyond the level of the right bank inundating the floodplain. Therefore in order to improve the channel conveyance along this stretch of the watercourse the in bank capacity of the channel would need to be improved. This method would involve widening of the channel.

Figure 8.3.4 shows that approximately 200m downstream of the low lying section of right bank is a series of 2 culverts, 15m apart. During flood events the water levels at the downstream culvert increase and while this does not result in out of bank flooding at that location it contributes to the water levels increasing at the upstream culvert where out of bank flooding occurs.

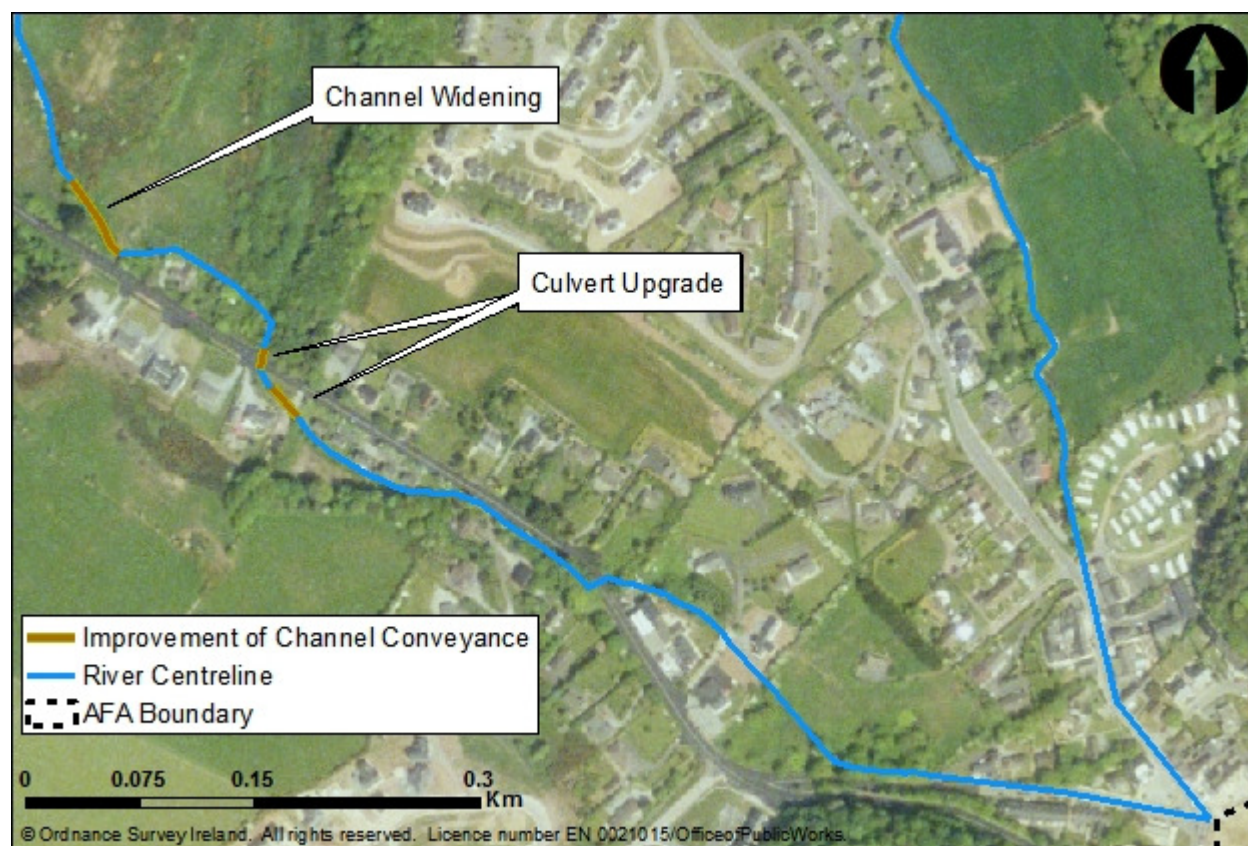


Figure 8.3.4 Locations of Channel Improvements in flood cell 1

To provide the preferred SoP both culverts would need to be upgraded in addition to the channel widening upstream. An economic review estimated the cost of these works together, i.e. the channel widening and the two culvert upgrades, to be approximately €309k making this method economically unviable therefore this method should be removed from the screening process.

Method	Tech	Econ	Env	Soc
Hard Defences	✓	✓	✓	✓

The term Hard Defences refers to physical barriers which prevent water from entering an area such as flood walls, embankments and barrages. As a general rule Hard Defences are kept as far back from the river channel or coast line as possible allowing the floodplain function to remain active. Where this is not possible, due to flood risk receptors being located within the floodplain, Hard Defences are placed around the property boundary to afford it protection. Where space allows flood embankments are used but where space is restricted flood walls are utilised.

A review was carried out to ascertain where Hard Defences could protect existing property within flood cell 1. Figure 8.3.5 shows the location of the Hard Defences required to protect properties during the 1% AEP event.

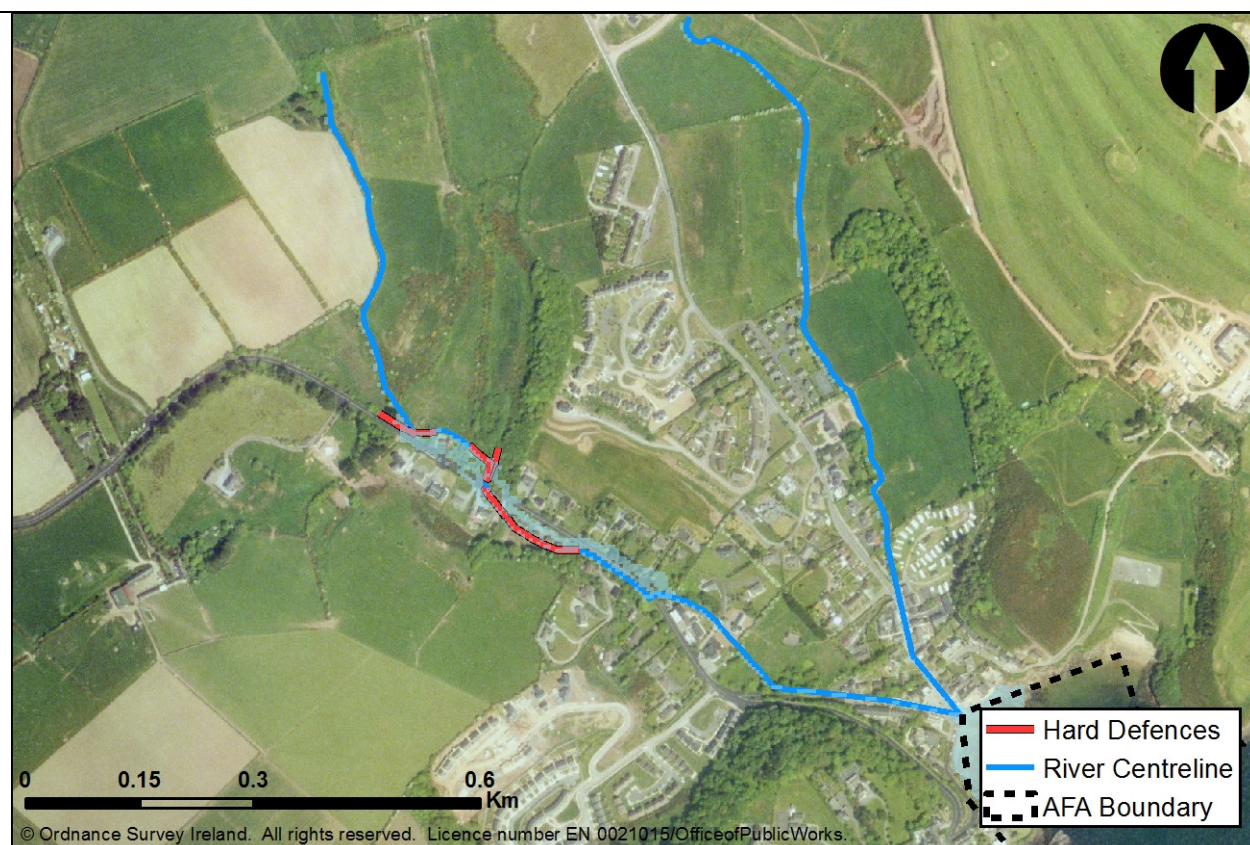


Figure 8.3.5 Location of Hard Defences in flood cell 1

In order to ascertain the effectiveness of Hard Defences a hydraulic model was constructed to simulate the method. The model showed these hard defences would protect to the 1% AEP flood event with an average height of 0.8 m and a total length of 345m. An economic review estimated the cost of the hard defences to be approximately €387k making this method economically viable.

There are no SACs, SPAs or UNESCO World Heritage Sites in the vicinity of, or downstream of the AFA, or of any AFA specific FRM methods to be employed. There were also no social impacts identified therefore this method can be brought forward to be considered further in the optioneering process.

Method	Tech	Econ	Env	Soc
Relocation of properties	✓	✗		

To relocate a property is to abandon the existing at risk property and provide an alternative in a location not at risk. While this method is, in theory, possible anywhere, it is not practical for a whole town of many at risk properties. Its use is more applicable for discrete areas where single properties or small clusters of properties are located.

An assessment of the distribution of properties within flood cell 1 was carried out. There are 8 residential properties at risk in flood cell 1. As this method is technically feasible an economic review estimated the cost of relocated the 8 properties as €4m. This method was therefore considered economically unviable and should therefore be rejected from the screening process.

Method	Tech	Econ	Env	Soc
Diversion of Flow	x			

This method involves directing some of the floodwater via a new route thereby reducing flow and associated flood risk along the original route. The diversion would be carried out upstream of where floodwaters reach the area of at risk properties. The new flow route would normally consist of a constructed open channel and/or culvert system or an existing linear feature able to convey the flow to a designated discharge point.

A review was carried out to identify locations where a Flow Diversion route could be constructed in the vicinity of flood cell 1. One location was identified where flow could be diverted from the Dunmore River watercourse as shown in Figure 8.3.6. This route would circumnavigate the flood risk area to a point downstream that would have enough cross-sectional area in the river channel to convey the flood water. This route however would flow through 3 residential properties along the downstream stretch of the proposed route which would make this FRM method technically unfeasible and therefore should be removed from the screening process.

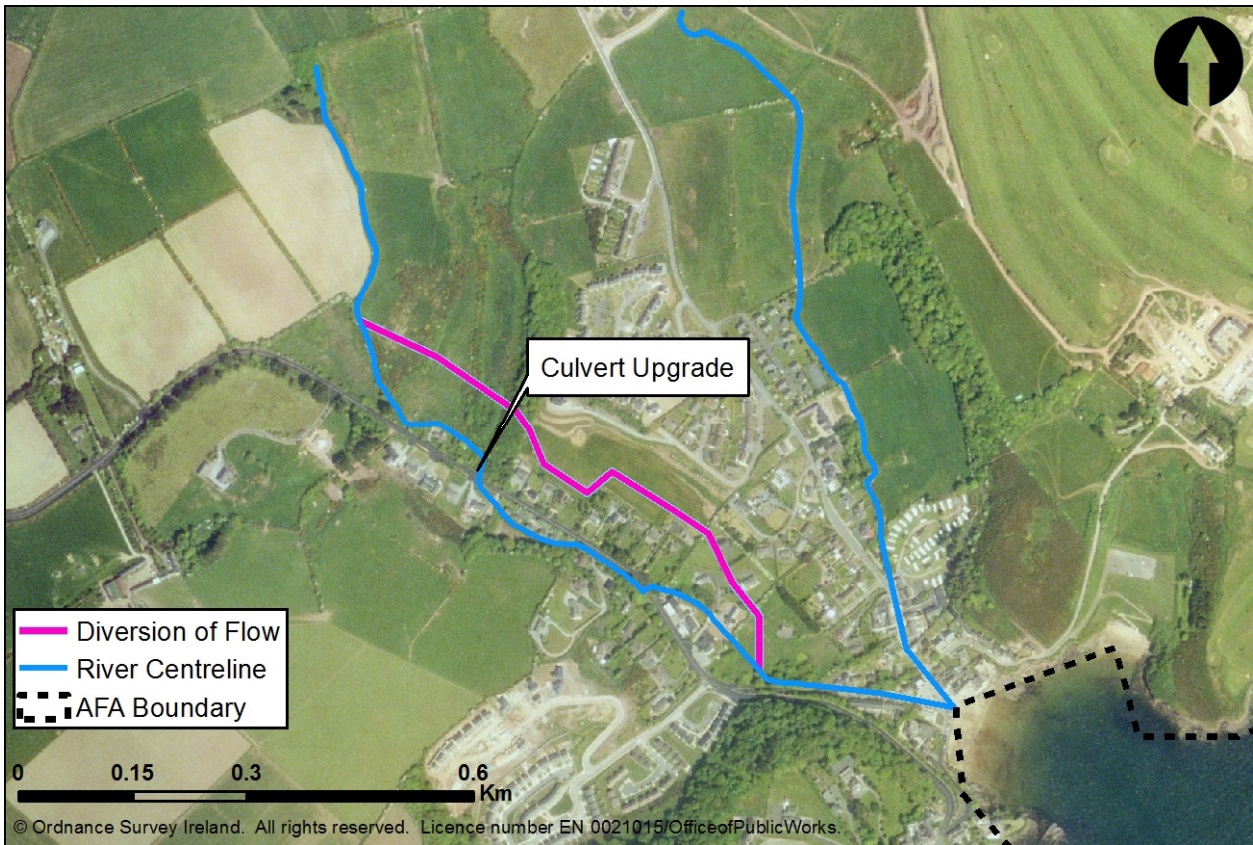


Figure 8.3.6 Location of Flow Diversion in flood cell 1

Method	Tech	Econ	Env	Soc
Flood Warning/Forecasting	✗			
The application of flood warning / forecasting was tested at UoM scale. There is no suitable location far enough upstream to place a gauge which would provide sufficient warning for flood cell 1. This method is technically unfeasible.				
Method	Tech	Econ	Env	Soc
Individual Property Protection	✓	✓	✓	✓
<p>This method is aimed at individual properties that are remote from the main flood risk areas. Where the AFA being considered consists of a small number of remote properties this method is a feasible solution, but for AFAs with multiple properties at risk this method would only be considered an add on to a primary method. Individual property protection could consist of flood gates and vent seals on the building structure itself. Where flood depths are over 0.6m this method becomes unfeasible and flood resilience techniques would be recommended over flood gates. As this method is temporary and relies of human intervention there is an element of uncertainty as to whether the full SoP will be met for every flood event. As such it is assumed that 20% of the flood damage will be avoided.</p> <p>The flood depths at the properties are below 0.6m therefore this method is feasible for flood cell 1. An economic review estimated the cost of €93k. Consequently this method was considered economically viable.</p> <p>There are no SACs, SPAs or UNESCO World Heritage Sites in the vicinity of, or downstream of the AFA, or of any AFA specific FRM methods to be employed. There were also no social impacts identified. Considering that this method will not provide the preferred SoP it should only be considered should no other method be found suitable.</p>				
Method	Tech	Econ	Env	Soc
Other Works	✗			
No other works were identified for this flood cell				
8.3.5.3 Summary of Feasibility Review – Flood Cell 1				
<p>The following FRM method has been carried forward to address the flood risk arising from flood cell 1;</p> <ul style="list-style-type: none"> • Hard Defences <p>Hard Defences can provide the full protection to all properties at risk during the 1% AEP flood event in flood cell 1. Therefore it can be considered in the optioneering process.</p> <p>Land Use Management and Individual Property Protection can only provide partial protection. These FRM methods should therefore only be used should all other methods be deemed unsuitable later in the optioneering process.</p>				

8.3.6 Selection of Options

Method	Option 1
Hard Defences*	✓

The most applicable local works measure selected for flood cell 1 and subsequently the Dunmore East AFA is Hard Defences as it provides the preferred SoP without being combined with another method.

8.3.6.1 Option 1 details - Hard Defences

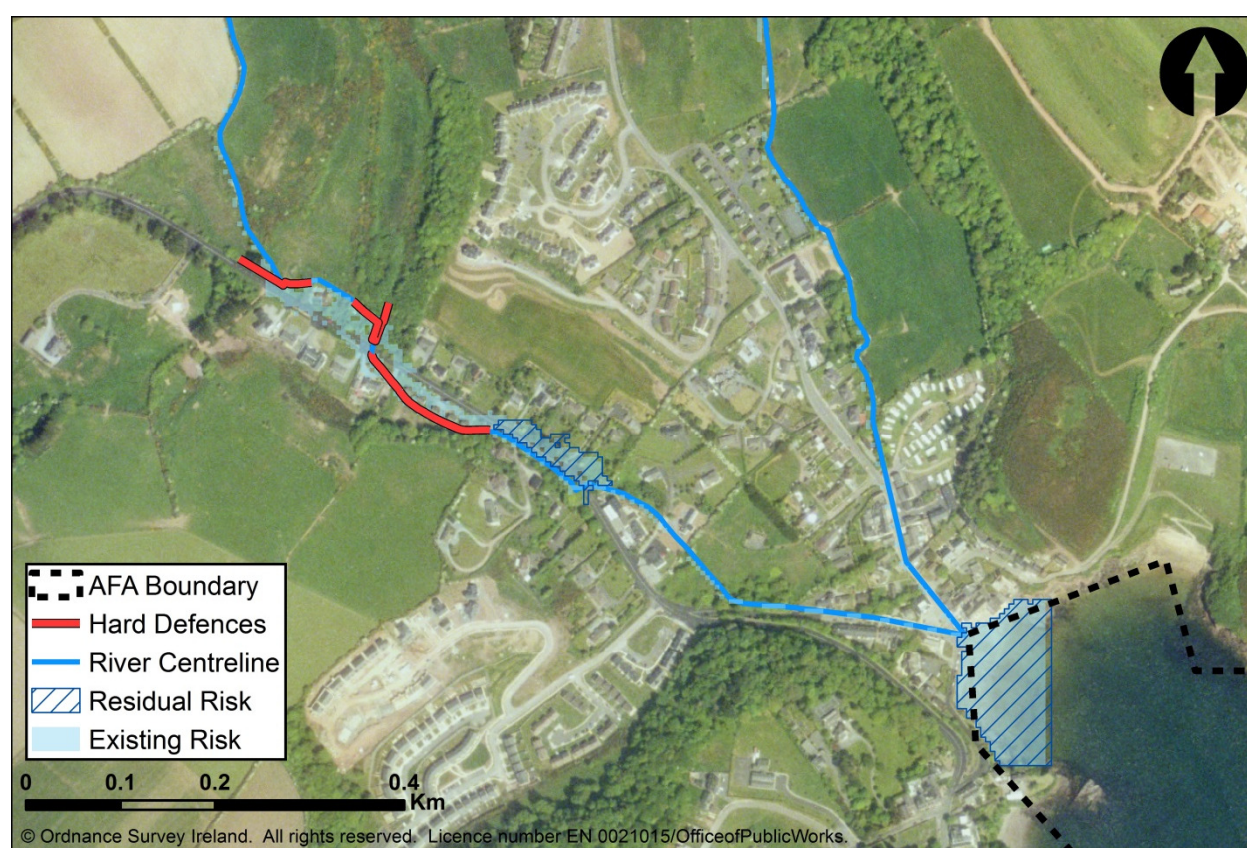


Figure 8.3.7 Dunmore East AFA Option 1

At risk properties would be protected by a series of flood embankments and walls. These hard defences would protect to the 1% AEP flood event with an average height of 0.8m and a total length of 345m.

Figure 8.3.7 presents the effect of the potential option on the design flood event by overlaying the present day flood extent (labelled existing risk) with the flood extent that would occur after the option is put in place (labelled residual risk).

In addition to these methods the following was also identified at UoM level (see section 8.1) to be included in any potential option identified:

- Planning and Development Control
- Building Regulations

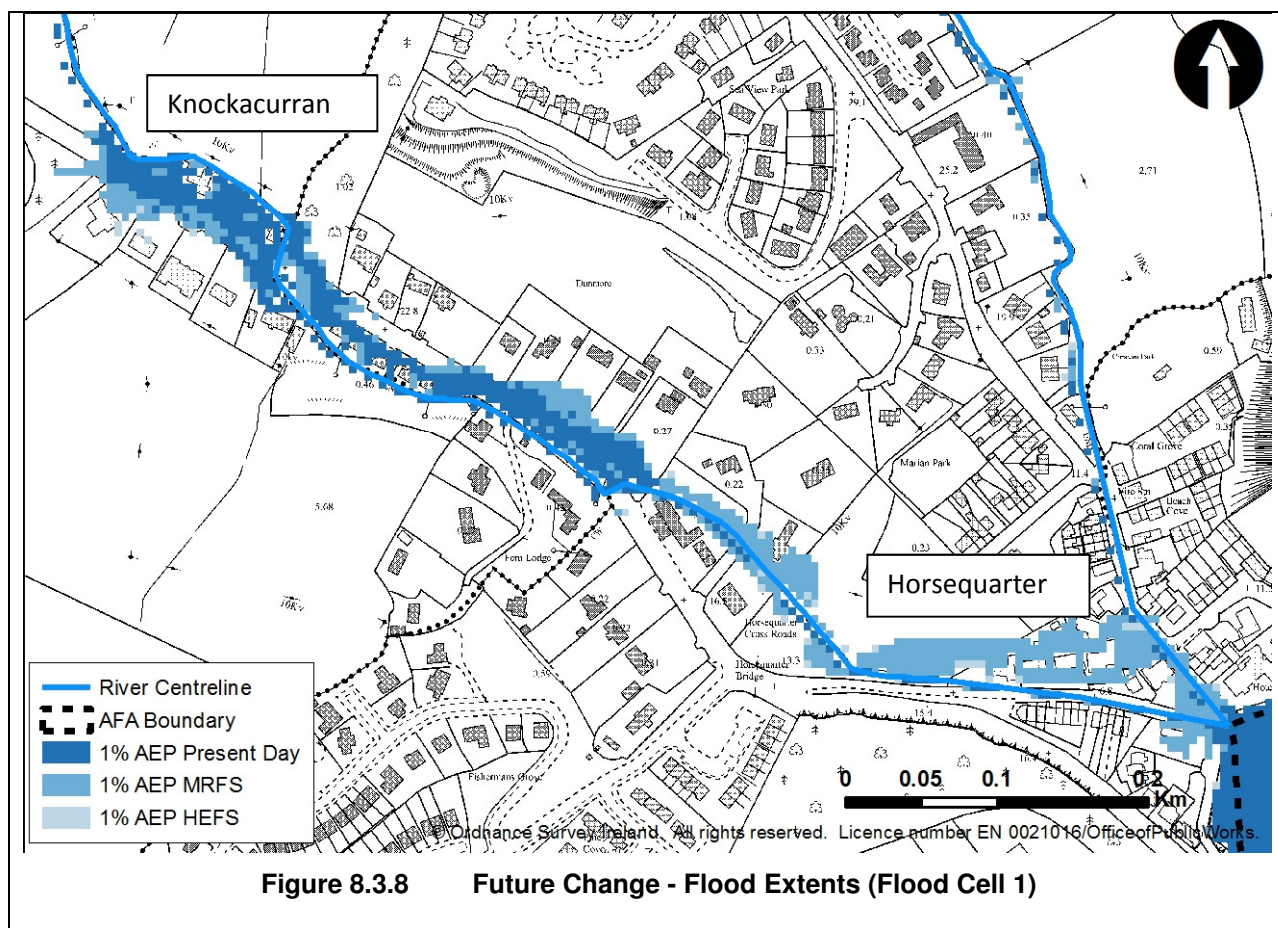
<ul style="list-style-type: none">• Sub-catchment Wide SuDs• Strategic Development Management• Public Awareness Campaign			
Option Item		Quantity	Construction Cost
Walls		295m length, 0.86m high (average)	€127,852
Embankments		50m length, 0.95m (average)	€6,400
Total MCA-Benefit Score	Option Cost (€millions)		MCA-Benefit Score / Cost Ratio
45	0.39		114.99
Economic Appraisal (Cost-Benefit Analysis) Outcomes			
Area NPVd (uncapped)	Option Cost	Option NPVb (capped)	Benefit - Cost Ratio
€ 512,948	€387,922	€ 255,180	0.66

8.3.6.2 AFA Sensitivity to Future Change

During a MRFS 1% AEP flood event the increase in flood extent is minimal due to the topography of the valley that the Dunmore River watercourse flows through. This would result in an additional 11 properties being at risk bringing the property count from 8 in the present day 1% AEP fluvial event to 19. No properties were found to be at risk during a MRFS 0.5% AEP coastal mechanism 1 flood event. The AAD would increase from €23,878 to €227,922. As a result the Dunmore East AFA would be considered to be at moderate vulnerability from the MRFS.

During a HEFS 1% AEP flood event the increase in flood extent is minimal due to the topography of the valley that the Dunmore River watercourse flows through. This would result in an additional 17 properties being at risk bringing the property count from 8 in the present day 1% AEP fluvial event to 25. No properties were found to be at risk during a HEFS 0.5% AEP coastal mechanism 1 flood event. The AAD would increase from €23,878 to €271,972. As a result the Dunmore East AFA would be considered to be at moderate vulnerability from the HEFS.

The main area of additional flood risk is in the Knockacurran and Horsequarter areas as shown in Figure 8.3.8



8.3.6.3 Future Change Adaptability

The following discusses the adaptability of the potential FRM methods proposed in the Dunmore East AFA to future flooding scenarios:

Hard Defences Flood Cell 1 - This method could be adapted by increasing the height of the walls. The length of embankment would not need to be adjusted. A review of the effect of the MRFS and the HEFS showed that the embankment height would need to be increased from 1.55m to 1.95m for both scenarios. This additional height could be accommodated. To ensure that this embankment would be adaptable the design would need to account for the potential increase in height. This method is considered to be **readily adaptable**.

Other

Additional defences would also be required on the Dunmore River watercourse to protect other properties against flooding under the MRFS and HEFS. These properties are not at risk under the present day and are downstream from the defined flood cell.

A review of the potential options show that option 1, Hard Defences, is adaptable to the MRFS and HEFS.

The potential **options** identified have been further assessed using 5 criteria in an attempt to identify low – or no regret combinations of measures.

1. **Does the option reduce vulnerability?** In addition to the methods above other methods aimed at reducing future flood risk have been discussed in section 8.1 at UoM scale and are detailed in each potential option. These methods, such as building regulations and planning & development control will reduce the impact to potential future receptors. Given that Dunmore East is largely rural some of these methods including a strategic development plan would be highly effective. Since there is a relatively large increase in the number of properties affected in the MRFS and HEFS there is a need to ensure that future receptors at risk are prepared through methods such as public awareness campaigns.
2. **Does the option make space for water?** The FRM method selected to address the flood risk in flood cell 1 would not make space for water. The Hard Defences proposed are protecting at risk properties from out of bank flooding on a steep slope with at risk properties adjacent to the watercourse. Therefore these Hard Defences are intended to contain flood waters within the channel.
3. **Does the option deliver co-benefits?** No co-benefits were identified.
4. **Does the option provide flexibility?** A review of the potential options show that option 1, Hard Defences, is readily adaptable to the MRFS and HEFS. Alternative FRM methods, such as Land Use Management, could also be added to option 1 to provide an increased SoP.
5. **Does the option allow for deferring/removing or abandoning?** Given the present day risk there is no allowance for options to be deferred or any that could be removed later

An objective for each potential option is to ensure that flood risk can be managed effectively and sustainably into the future accounting for the potential impacts of climate change and other factors affecting future flood risk. The table below summarises how well the preferred option achieves this objective.

Summary of Option Adaptability

Option	Description	Score
Option 1 – Hard Defence (FC 1)	Option is adaptable at limited cost, difficulty and impact	4

8.3.6.4 Local Authority Comments

LA representatives reviewed preliminary options in November 2015.

8.3.6.5 Summary

There is moderate confidence in both the hydrology and hydraulics of the Dunmore East AFA. Despite the lack of calibration and verification data, the model is shown to be a reasonable representation of the flood mechanisms described from the available flood event records and considered to be performing satisfactorily for design event simulation.

The following potential options, with a BCR ≥ 0.5 have been identified:

- Option 1 –Hard Defences (FC 1) and FRM measures identified for UoM17

Alongside any potential option the existing regime should continue with maintenance being carried out ad hoc when resources allow. Maintenance of the option structures should will also form part of the ongoing regime once in place.

Methods also were identified at UoM level (see section 8.1) that are applicable to Dunmore East AFA, that if implemented, will serve to avoid increasing flood risk in the future :

- Planning and Development Control
- Building Regulations
- Sub-catchment Wide SuDs
- Strategic Development Management
- Public Awareness Campaign

No communities are located upstream that would be affected by any of the potential options identified. There are no SACs or SPAs in close proximity to the Dunmore East AFA and no critical cultural heritage or social issues have been identified.

It should be noted that has a moderate sensitivity to climate change and is suitable for an assumptive approach be incorporated into detailed design.

Very low risk was identified in Dunmore East AFA and a suitable low cost option has been developed.

The Minor Works Scheme is available to the local authorities to address any local flood problems with local solutions.

8. OPTIONEERING OF SSA'S

8.4 Tramore & Environs optioneering of FRM Options

Name	Local Authority	Unique ID	SSA	Status	Date
Tramore & Environs	Waterford	172228	AFA	Final	08/06/2016

8.4.1 Source of flooding

Fluvial	Coastal Mechanism 1*	Coastal Mechanism 2
*No properties were found to be at risk due to the present day 0.5% AEP Coastal Mechanism 1 design event. This mechanism was therefore not considered for optioneering.		

8.4.2 Flood Cells

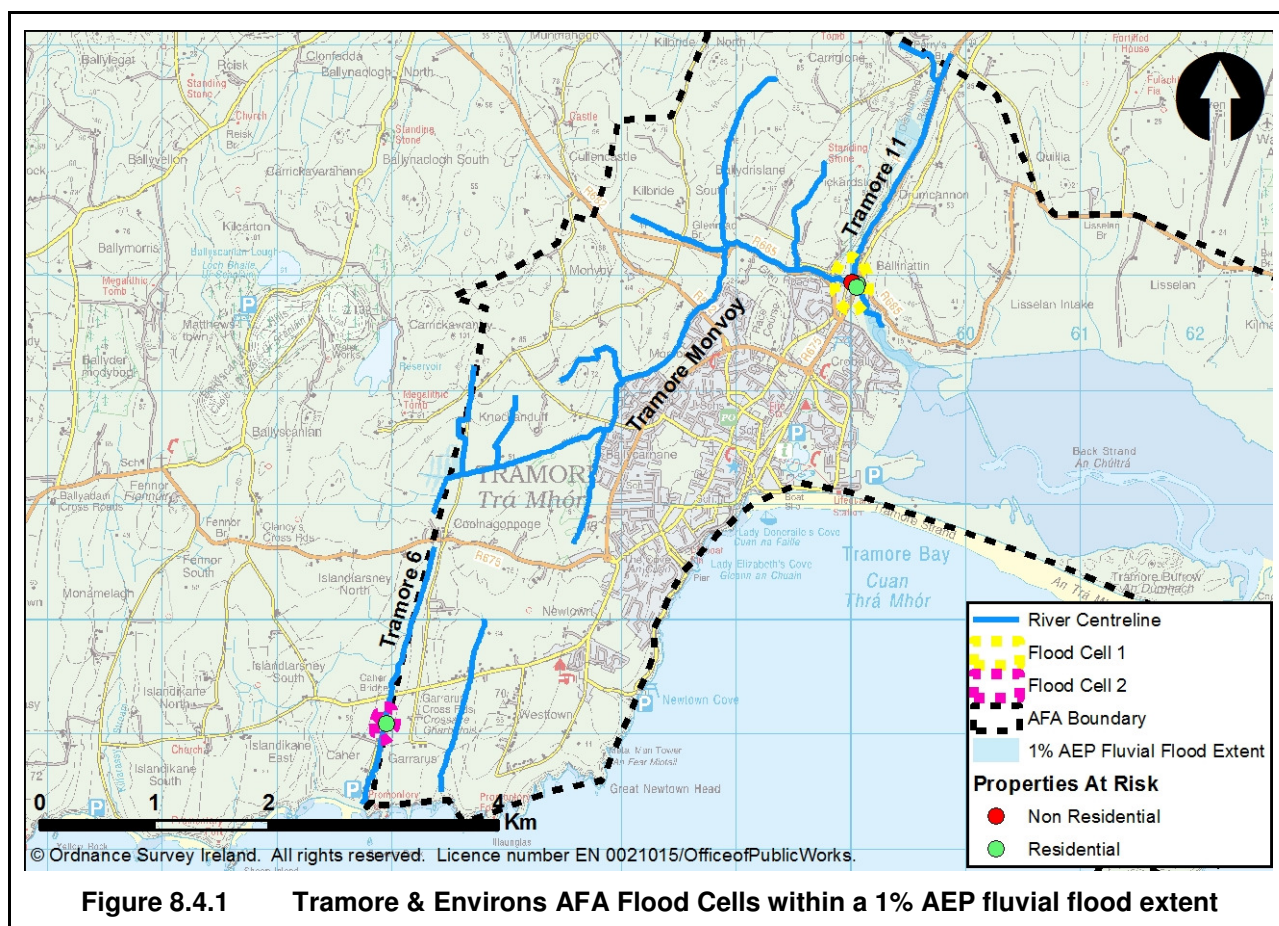


Figure 8.4.1 Tramore & Environs AFA Flood Cells within a 1% AEP fluvial flood extent

Flood Cell 1:

Out of bank flooding occurs on the Tramore 11 watercourse during a 1% AEP fluvial flood event due to insufficient capacity of culvert 1710TR00001I upstream of Pickardstown Service Station. Five properties are affected by this flooding. Flood cell 1 is affected by a single flood mechanism and is a discrete area affecting five properties. The flood risk in flood cell 1 is therefore considered local.

Flood Cell 2:

On the Tramore 6 watercourse, culvert 1706TR00029I restricts flow and causes out of bank flooding affecting one property during a 1% AEP flood event. Flood cell 2 is affected by a single flood mechanism and is a discrete area affecting one property. The flood risk in flood cell 2 is therefore considered local.

Summary of Flood Cells:

As shown in Figure 8.4.1 flood cells 1 and 2 are both discrete areas with few properties at risk and each with a single flood mechanism to consider. It is therefore appropriate to screen these flood cells as standalone areas assessing options applicable to localised works (section 8.4.6).

On completion of the optioneering screening assessment all flood cells will be combined to form complete options for the Tramore AFA as detailed in section 8.4.7.

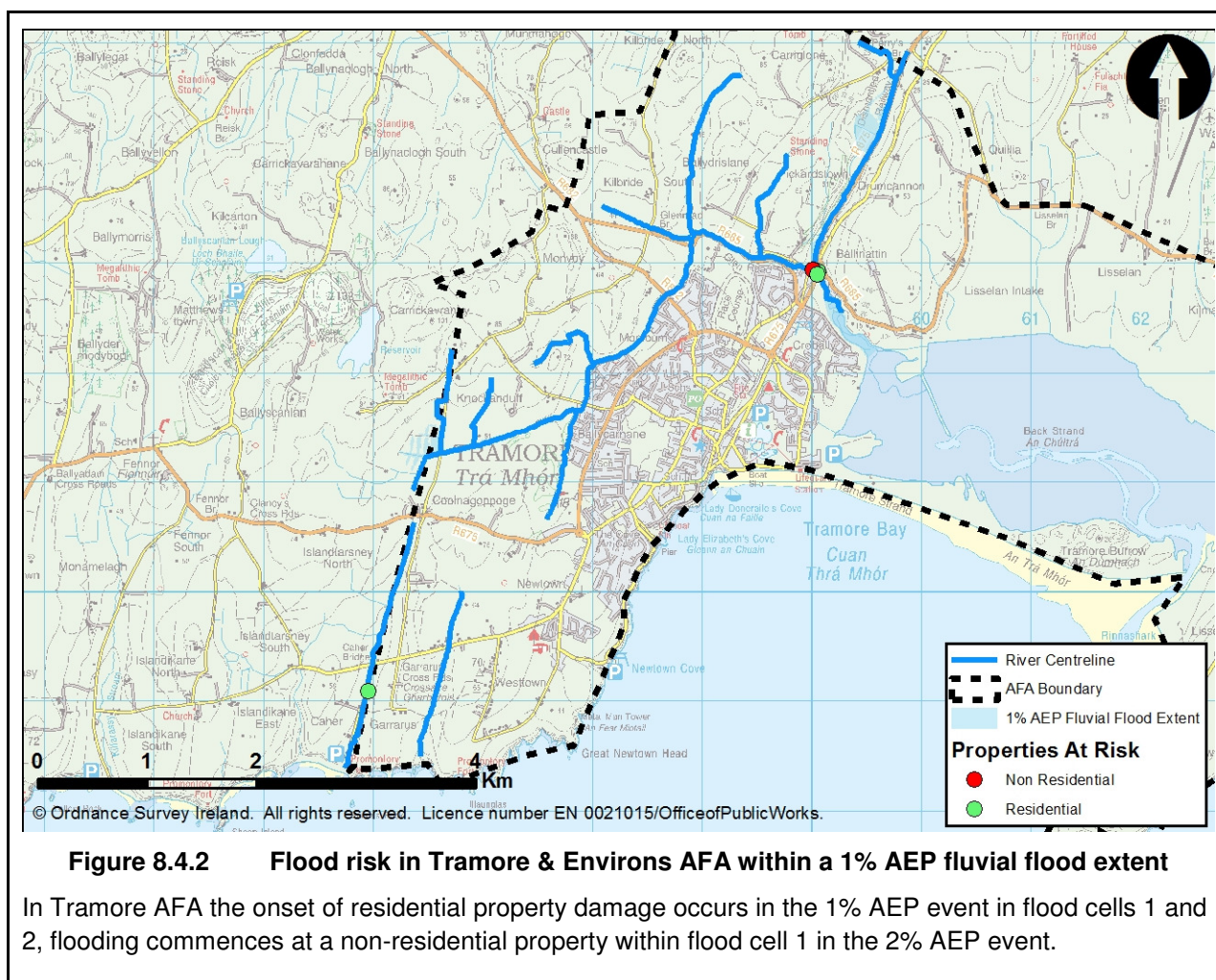
8.4.3 Existing Regime

This existing regime considers all activities currently carried out which impact on the management of flood risk. The level and frequency of maintenance is considered, along with inspection, and any other specific activity (for example the operation of locks, barrages, sluice gates and valves).

The watercourses in Tramore are not located within a Drainage District or an Arterial Drainage scheme.

The watercourses in the Tramore AFA are for the most part in private lands and are not the responsibility of Waterford County Council. Nevertheless, inspections and maintenance are carried out as and when resources are available.

8.4.4 Summary of Flood Risk within SSA boundary



8.4.5 Monetary Damage and Benefit

	Flood Cell 1	Flood Cell 2	Total in AFA
Annual Average Damage (AAD)	€7,710	€128	€8,016
Present Value Damage (pvD)	€165,635	€2,770	€172,199
Standard of Protection (SoP)	1%AEP	1%AEP	1%AEP
Number of Properties Benefiting from Design SoP	5	1	6
Minimum Present Value Benefit	€95,099	€1,357	€96,457
Capped Minimum Present Value Benefit	€95,099	€1,357	€96,457

*The sum of the flood cell AAD or pvD values may not equate to the values presented for the Total in SSA due to flooding greater than the 1% AEP occurring outside the flood cell extents.

8.4.6 Short Listing FRM Methods – Local Cells

Method	Review Comment	Continue Screening	
		Flood Cell 1	Flood Cell 2
Do Nothing	Consider Further	✓	✓
Additional Maintenance	Consider Further	✓	✓
Do Minimum	Consider Further	✓	✓
Planning and Development Control	Consider at UoM SSA - Reject	✗	✗
Building Regulations	Consider at UoM SSA - Reject	✗	✗
Catchment Wide SuDs	Consider at UoM SSA - Reject	✗	✗
Land Use Management	Consider Further	✓	✓
Strategic Development Management	Consider at UoM SSA - Reject	✗	✗
Storage	Consider Further	✓	✓
Improvement of Channel Conveyance	Consider Further	✓	✓
Hard Defences	Consider Further	✓	✓
Relocation of Properties	Consider Further	✓	✓
Diversion of Flow	Consider Further	✓	✓
Flood Warning/Forecasting	Consider Further	✓	✓
Public Awareness Campaign	Consider at UoM SSA - Reject	✗	✗
Individual Property Protection	Consider Further	✓	✓
Other Works	Consider Further	✓	✓

8.4.6.1 Feasibility Review Summary of FRAM Methods for flood cell 1

Method	Technical Screening	Economic Screening	Environmental and Cultural Heritage Screening	Social Screening
Do nothing	✗			
Additional Maintenance	✗			
Do Minimum	✗			
Land Use Management	✓	-	?	?
Storage	✗			
Improvement of Channel Conveyance	✓	✗		
Hard Defences	✓	✓	?	✓
Relocation of properties	✓	✗		
Diversion of Flow	✗			
Flood Warning/Forecasting	✗			
Individual Property Protection	✓	✓	✓	✓
Other Works	✗			
✗ - Reject ✓ - Progress ? - Progress, potential for impacts identified ! - Progress, potential for significant impacts identified				

8.4.6.2 Justification for Rejection/Retention

Method	Tech	Econ	Env	Soc
Do nothing	✗			
The do nothing FRM method would involve stopping the current maintenance regime. This would not provide the preferred SoP and therefore was rejected from the screening process.				
Method	Tech	Econ	Env	Soc
Additional Maintenance	✗			
This method considers whether improvements can be made to augment existing maintenance regime which will provide a significant beneficial impact on flood risk in the AFA. A review was carried out of the existing watercourse network. This included assessing the channel vegetation, the amount of debris present in the channels and the likelihood of structures blocking.				

Increasing maintenance activities on the relevant watercourses will not significantly contribute to achieving the preferred SoP and therefore will not be pursued under the CFRAM Study.

Method	Tech	Econ	Env	Soc
Do Minimum	✗			

This method is appropriate where an isolated/single issue exists which can be easily addressed in order to reduce the flood risk, for example the removal of a pinch point/obstruction, or the upgrade of a blockage prone culvert screen, etc. These activities would be considered relatively straightforward, discrete and low cost. Do Minimum is a standalone method, as it cannot be combined with others without contradicting its definition, therefore the design SoP must be achieved for this method to progress.

Within flood cell 1 there is little opportunity to improve the conditions in the Tramore 11 watercourse and therefore little scope to reduce the overall flood risk. This is an unacceptable outcome in terms of achieving a design SoP and should therefore be rejected from the screening process.

Method	Tech	Econ	Env	Soc
Land Use Management	✓	-	?	?

The application of land use management measures was tested at UoM scale. Flood cell 1 is located within a catchment which is considered suitable as a pilot area and should progress in the optioneering process should no other method providing the full SoP be found suitable.

Method	Tech	Econ	Env	Soc
Storage	✗			

This method considers areas where flood water can be stored and then released at a controlled rate therefore reducing the flow rate through the AFA and hence the level of flood risk. This can be achieved by using existing depressions to create online or offline storage areas or by identifying pinch points which could be dammed such as a restricted point along a valley. Storage areas can be effective either upstream of the risk areas or within the risk area where parks or open areas are located.

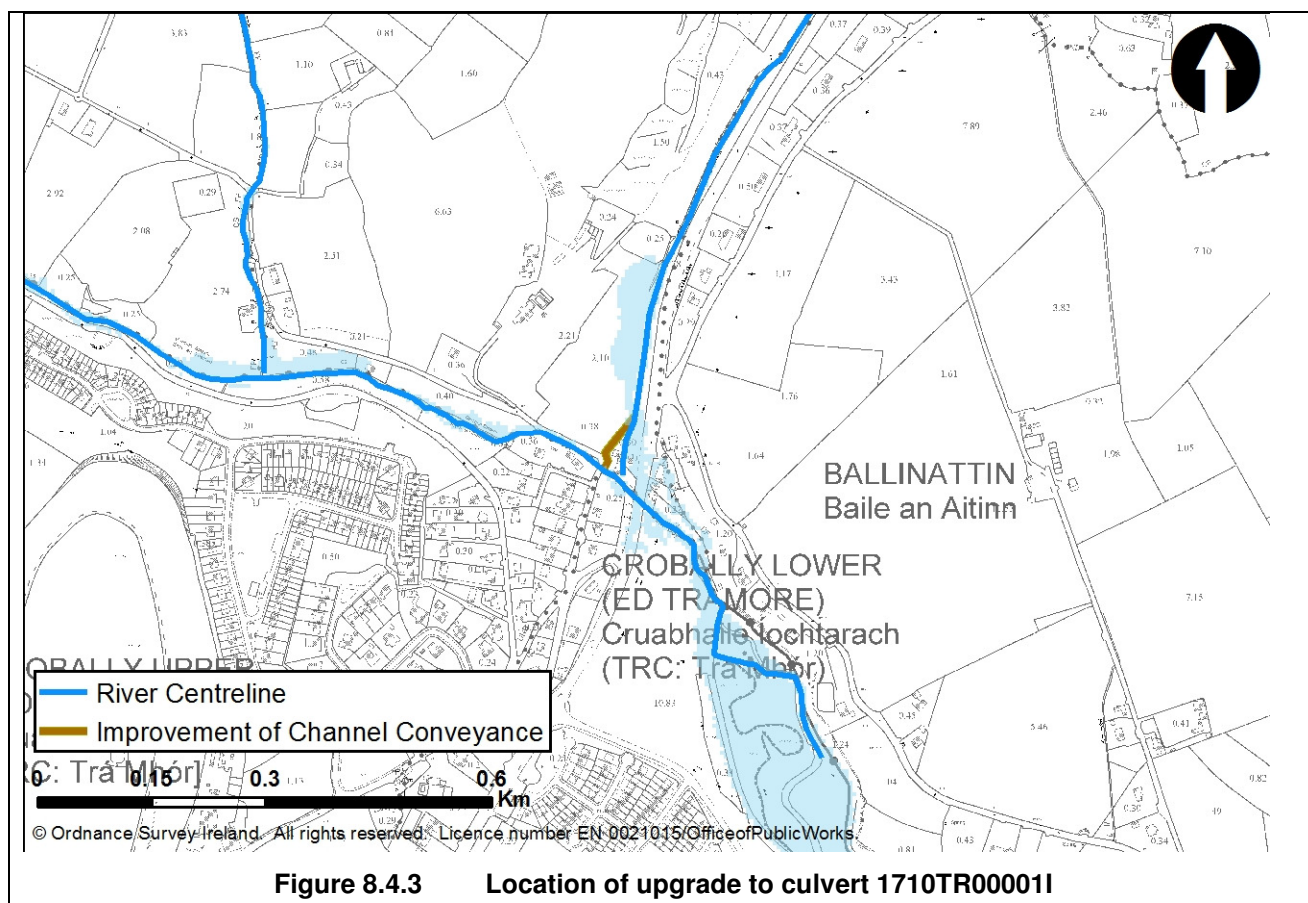
A review of the surrounding land was carried out but due to the nature of the upstream topography which includes steep channel banks, no suitable location was identified for storage. This method is therefore considered technically unfeasible.

Method	Tech	Econ	Env	Soc
Improvement of Channel Conveyance	✓	✗		

This method focuses on increasing watercourse conveyance thereby lowering water levels and reducing the associated flood risk. This can be achieved by lowering bed level, widening/reshaping channels, removing channel/structure constrictions, culverting reaches of watercourse and reducing roughness of the channel.

In flood cell 1 the main source of flooding is insufficient capacity in culvert 1710TR000011. Increasing capacity of this culvert may therefore reduce flood risk. Figure 8.4.3 shows the location of this culvert.

The maximum flow on this watercourse during a 1% AEP flood event is approximately 1.2m³/s, so it is estimated that a culvert diameter of 1.35m would be required in order to prevent flooding. Installation of a new culvert and headwall is estimated to cost around €430,000. This method is therefore not economically viable.



Method	Tech	Econ	Env	Soc
Hard Defences	✓	✓	?	✓

The term Hard Defences refers to physical barriers which prevent water from entering an area such as flood walls, embankments and barrages. As a general rule Hard Defences are kept as far back from the river channel or coast line as possible allowing the floodplain function to remain active. Where this is not possible, due to flood risk receptors being located within the floodplain, Hard Defences are placed around the property boundary to afford it protection. Where space allows flood embankments are used but where space is restricted flood walls are utilised.

A review was carried out to ascertain where Hard Defences would be required to protect existing property within flood cell 1. Figure 8.4.4 shows the location of the Hard Defences required to protect properties during the 1% AEP event.

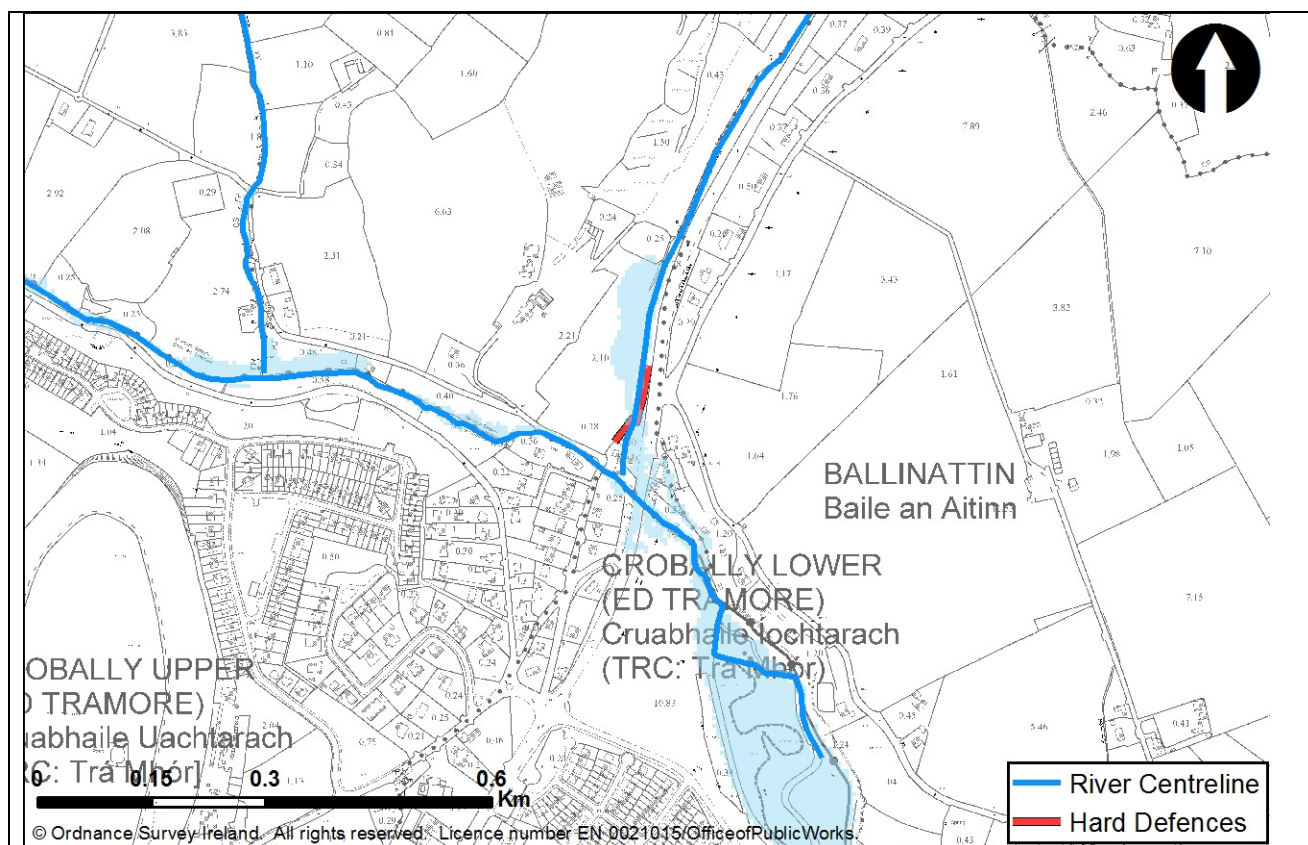


Figure 8.4.4 Location of Hard Defences in flood cell 1

In order to ascertain the effectiveness of Hard Defences a hydraulic model was constructed to simulate the method. The model showed these hard defences would protect to the 1% AEP flood event with an average height of 1.0m and a total length of 123m. An economic review estimated the cost of the hard defences to be approximately €72,000 making this method economically viable. Tramore Dunes and backstrand SAC are within the AFA boundary. Hook Head SAC is 10km to the east of the AFA. Tramore Dunes and backstrand SPA is within the AFA boundary. Mid-Waterford Coast SPA is within and to the south west of the AFA on the coastline. The proposed hard defences are not within any of these designations however there may be potential impacts to the Tramore Dunes and Backstrand SAC and Tramore Dunes and Backstrand SPA designated sites downstream of the flood cell. There are no UNESCO World Heritage Sites in the vicinity of, or downstream of the AFA.

Method	Tech	Econ	Env	Soc
Relocation of properties	✓	✗		

To relocate a property is to abandon the existing at risk property and provide an alternative in a location not at risk. While this method is, in theory, possible, it is not practical for a whole town of many at risk properties. Its use is more applicable for discrete areas where single properties or small clusters of properties are located.

The cluster of five properties at risk during the design event in flood cell 1 may be suitable for relocation however the cost to relocate these properties, based on the market value, is €1.6m. This method is therefore not economically viable.

Method	Tech	Econ	Env	Soc
Diversion of Flow	✗			
<p>This method involves directing some of the floodwater via a new route thereby reducing flow and associated flood risk along the original route. This would be carried out upstream of where floodwaters reach the area of at risk properties. The new flow route would normally consist of a constructed open channel and/or culvert system or an existing linear feature able to convey the flow to a designated discharge point.</p> <p>A review was carried out to assess the suitability of a flow diversion. No location was found where this method could be carried out and is therefore considered technically unfeasible.</p>				
Method	Tech	Econ	Env	Soc
Flood Warning/Forecasting	✗			
<p>The application of Flood Warning/Forecasting was tested at UoM scale. There is no suitable location far enough upstream to place a gauge which would provide sufficient warning for flood cell 1. This method is therefore technically unfeasible.</p>				
Method	Tech	Econ	Env	Soc
Individual Property Protection	✓	✓	✓	✓
<p>This method is aimed at individual properties that are remote from the main risk areas. Where the AFA being considered consists of a small number of remote properties this method is a feasible solution. But for AFAs with multiple properties at risk this method would only be considered an add on to a primary method. Individual property protection could consist of flood gates and vent seals on the building structure itself. Where flood depths are over 0.6m this method becomes unfeasible and flood resilience techniques would be recommended over flood gates. As this method is temporary and relies of human intervention there is an element of uncertainty as to whether the full SoP will be met for every flood event. As such it is assumed that 20% of the flood damage will be avoided.</p> <p>This method would not provide the preferred SoP and given the grouped nature of properties within flood cell 1 would not be technically the best method to use. For these reasons this method should only be considered should no other method be found suitable. The estimated cost to provide protection to these properties is €69,700, so this method is economically viable. The properties at risk are not located within any environmental designations and it is unlikely that Individual Property Protection would have any impact to designated sites in the vicinity of the properties at risk.</p>				
Method	Tech	Econ	Env	Soc
Other Works	✗			
No other works were identified for this flood cell				

8.4.6.3 Summary of Feasibility Review – Flood Cell 1

The following FRM methods have been carried forward to address the flood risk arising from flood cell 1;

- Hard Defences

While Hard Defences can provide the full protection to all properties during the 1% AEP flood event, Individual Property Protection can only provide partial protection. Individual Property Protection should therefore only be used should Hard Defences be deemed unsuitable later in the optioneering process.


Tramore & Environs AFA is considered a suitable area to consider Land Use Management as an FRM method and it is recommended that it is considered as a pilot should all other methods be found unsuitable.

8.4.6.4 Feasibility Review Summary of FRAM Methods for flood cell 2

Method	Technical Screening	Economic Screening	Environmental and Cultural Heritage Screening	Social Screening
Do nothing	✗			
Additional Maintenance	✗			
Do Minimum	✗			
Land Use Management	✓	-	?	?
Storage	✓	✗		
Improvement of Channel Conveyance	✗			
Hard Defences	✓	✓	?	✓
Relocation of properties	✓	✗		
Diversion of Flow	✗			
Flood Warning/Forecasting	✗			
Individual Property Protection	✓	✓	✓	✓
Other Works	✗			
✗ - Reject ✓ - Progress ? - Progress, potential for impacts identified ! - Progress, potential for significant impacts identified				

8.4.6.5 Justification for Rejection/Retention

Method	Tech	Econ	Env	Soc
Do nothing	✗			
The do nothing FRM method for flood cell 2 would involve stopping the current maintenance regime. This would not provide the preferred SoP and should therefore be rejected from the screening process.				
Method	Tech	Econ	Env	Soc
Additional Maintenance	✗			
A review of the current condition of the Tramore 6 watercourse indicated that increasing maintenance activities will not significantly contribute to achieving the preferred SoP and therefore will not be pursued under the CFRAM Study..				

Method	Tech	Econ	Env	Soc
Do Minimum	✗			
Within flood cell 2 there is little opportunity to improve the conditions in the Tramore 6 watercourse and therefore little scope to reduce the overall flood risk. This is an unacceptable outcome in terms of achieving a design SoP and should therefore be rejected from the screening process.				
Method	Tech	Econ	Env	Soc
Land Use Management	✓	-	?	?
The application of land use management measures was tested at UoM scale. Flood cell 2 is located within a catchment which is considered suitable as a pilot area and should progress in the optioneering process should no other method providing the full SoP be found suitable.				
Method	Tech	Econ	Env	Soc
Storage	✓	✗		
The volume of water required to be stored on the Tramore 6 watercourse before reaching flood cell 2 has been estimated to be 5,800m ³ . A review of the surrounding land was carried out and a suitable potential storage area was identified, as shown in Figure 8.4.5. Construction of this storage area would require an embankment with an average height of 2m and total length of approximately 150m, along with a culvert with an estimated diameter of 1.05m through the embankment. An economic review estimated the cost of these works to be approximately €738,000. This method is therefore not economically viable.				
 <p>© Ordnance Survey Ireland. All rights reserved. Licence number EN 0021015/Office of Public Works.</p>				
<p>Figure 8.4.5 Location of potential storage area in flood cell 2</p>				

Method	Tech	Econ	Env	Soc
Improvement of Channel Conveyance	✗			

Culvert 1706TR00029I restricts flow on the Tramore 6 watercourse resulting in raised water levels and out-of-bank flooding. Increasing capacity of this culvert could remove this restriction and prevent flooding.

The maximum flow on this watercourse during a 1% AEP flood event is approximately 1.6m³/s, so it is estimated that a culvert diameter of 1.35m would be required in order to prevent flooding. The channel at this location is less than 1.35m wide and the maximum soffit level of a replacement culvert is limited as there is a driveway located above the culvert. This method is therefore considered technically unfeasible.

Method	Tech	Econ	Env	Soc
Hard Defences	✓	✓	?	✓

A review was carried out to ascertain where Hard Defences could protect existing property within flood cell 2. Figure 8.4.6 shows the location of the Hard Defences required to protect properties during the 1% AEP event.

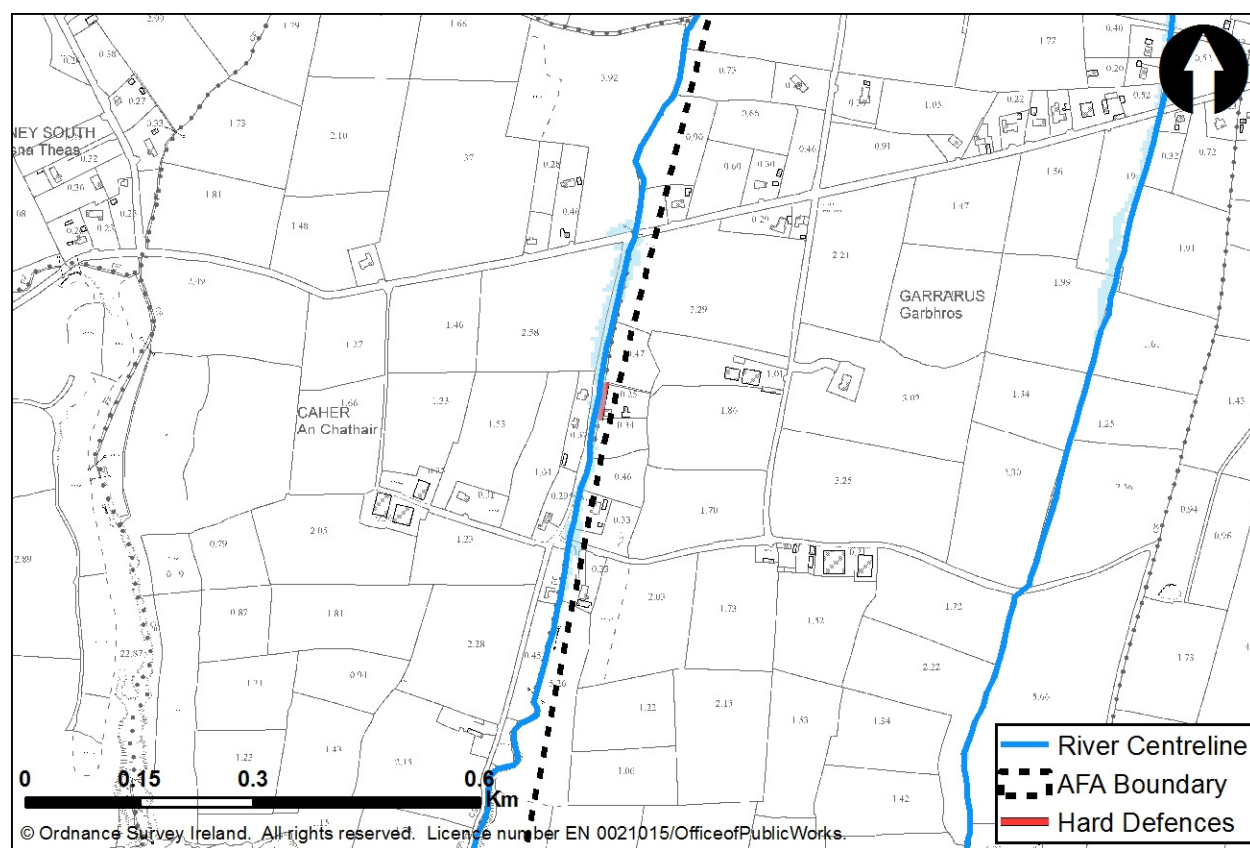


Figure 8.4.6 Location of Hard Defences in flood cell 2

In order to ascertain the effectiveness of Hard Defences a hydraulic model was constructed to simulate the method. The model showed these hard defences would protect to the 1% AEP flood event with an average height of 1.4m and a total length of 50m. An economic review estimated the cost of the hard defences to be approximately €42,700 making this method economically viable. The proposed hard defences are not located within any environmental designations however there may be potential impacts to the Mid-Waterford Coast SPA designated site downstream of the flood cell.

Method	Tech	Econ	Env	Soc
Relocation of properties	✓	✗		
The property at risk during the design event in flood cell 2 may be suitable for relocation however the cost to relocate this property, based on the market value, is €514,900. This method is therefore not economically viable.				
Method	Tech	Econ	Env	Soc
Diversion of Flow	✗			
A review was carried out to assess the suitability of a flow diversion. No location was found where this method could be carried out and is therefore considered technically unfeasible.				
Method	Tech	Econ	Env	Soc
Flood Warning/Forecasting	✗			
The application of Flood Warning/Forecasting was tested at UoM scale. There is no suitable location far enough upstream to place a gauge which would provide sufficient warning for flood cell 2. This method is therefore technically unfeasible.				
Method	Tech	Econ	Env	Soc
Individual Property Protection	✓	✓	✓	✓
While this method would not provide the preferred SoP due to its temporary nature and associated uncertainty it may be advantageous to consider as an alternative should all other methods which do provide the design SoP fail to pass through the screening process. The estimated cost to provide protection measures for this property is €11,600. This method is therefore economically feasible. The property at risk is not located within any environmental designations and it is unlikely that Individual Property Protection would have any impact to designated sites in the vicinity of the properties at risk.				
Method	Tech	Econ	Env	Soc
Other Works	✗			
No other works were identified for this flood cell				
8.4.6.6 Summary of Feasibility Review – Flood Cell 2				
<p>The following FRM methods have been carried forward to address the flood risk arising from flood cell 3;</p> <ul style="list-style-type: none"> • Hard Defences. <p>While Hard Defences can provide the full protection to all properties during the 1% AEP flood event, Individual Property Protection can only provide partial protection. Individual Property Protection should therefore only be used should Hard Defences be deemed unsuitable later in the optioneering process.</p> <p>Tramore & Environs AFA is considered a suitable area to consider Land Use Management as an FRM method and it is recommended that it is considered as a pilot should all other methods be found unsuitable.</p>				

8.4.7 Selection of Options

Method	Option 1	Option 2	Option 3	Option 4	Option 5
Hard Defences	✓				

For flood cells 1 and 2 Hard Defences can provide the full SoP to all properties.

As a feasible option has been identified, Land Use Management and Individual Property Protection are no longer to be considered in Tramore & Environs AFA as a pilot option.

8.4.7.1 Option 1 details – Hard Defences

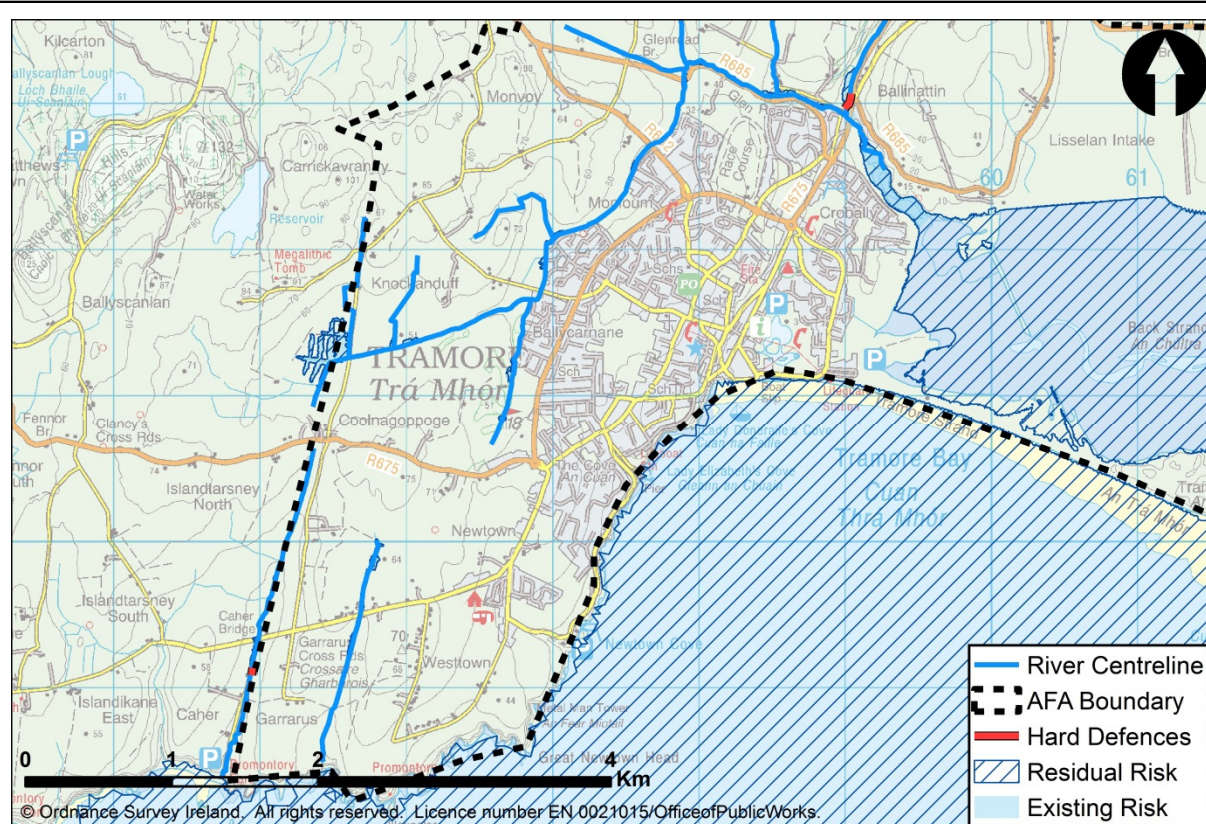


Figure 8.4.7 Tramore & Environs AFA Option 1

At risk properties would be protected by a series of flood embankments. These hard defences will provide a SoP of 1% AEP with an average height of 1.0m and a total length of 175m.

Figure 8.4.7 presents the effect of the potential option on the design flood event by overlaying the present day flood extent (labelled existing risk) with the flood extent that would occur after the option is put in place (labelled residual risk).

In addition to these methods the following was also identified at UoM level (see section 8.1) to be included in any potential option identified:

- Planning and Development Control
- Building Regulations

<ul style="list-style-type: none">• Sub-catchment Wide SuDs• Strategic Development Management• Public Awareness Campaign				
Option Item		Quantity	Construction Cost	
Flood Embankment		175m length, 1.0m high (average)	€37,830	
Total MCA-Benefit Score		Option Cost (€millions)	MCA-Benefit Score / Cost Ratio	
-361		€0.14m	-2517.05	
Economic Appraisal (Cost-Benefit Analysis) Outcomes				
Area NPVd (uncapped)		Option Cost	Option NPVb (capped)	Benefit - Cost Ratio
€172,199		€143,619	€96,457	0.67

8.4.7.2 AFA Sensitivity to Future Change

During a MRFS 1% AEP fluvial flood event the increase in flood extent is minimal due to the topography of the valleys which the watercourses in Tramore flow through. This would result in 1 additional property being at risk bringing the property count from 6 in the present day 1% AEP fluvial event to 7. No properties were found to be at risk during a MRFS 0.5% AEP coastal mechanism 1 flood event. The AAD would increase from €8,016 to €34,321. As a result the Tramore & Environs AFA would be considered to be at moderate vulnerability from the MRFS.

During a HEFS 1% AEP fluvial flood event the increase in flood extent, while greater than the MRFS, is minimal also. This would result in an additional 2 properties being at risk. The increase in flood extent during a HEFS 0.5% AEP coastal mechanism 1 flood event is significant in the promenade area due to the 1m increase in sea level applied to the model. This would result in an additional 28 properties being at risk. The overall property count would increase from 6 in the present day 1% AEP fluvial and 0.5% AEP coastal mechanism 1 events to 36. The AAD would increase from €8,016 to €98,668. As a result the Tramore & Environs AFA would be considered to be at moderate vulnerability from the HEFS.

Of the 2 additional properties at risk due to fluvial flooding, one is located in flood cell 1 adjacent to the R675 Maxol Petrol Station and the other is a discrete property located outside the defined flood cells on the Glen Road.

The 28 additional properties at risk due to tidal inundation are located outside the defined flood cells in the Promenade area.

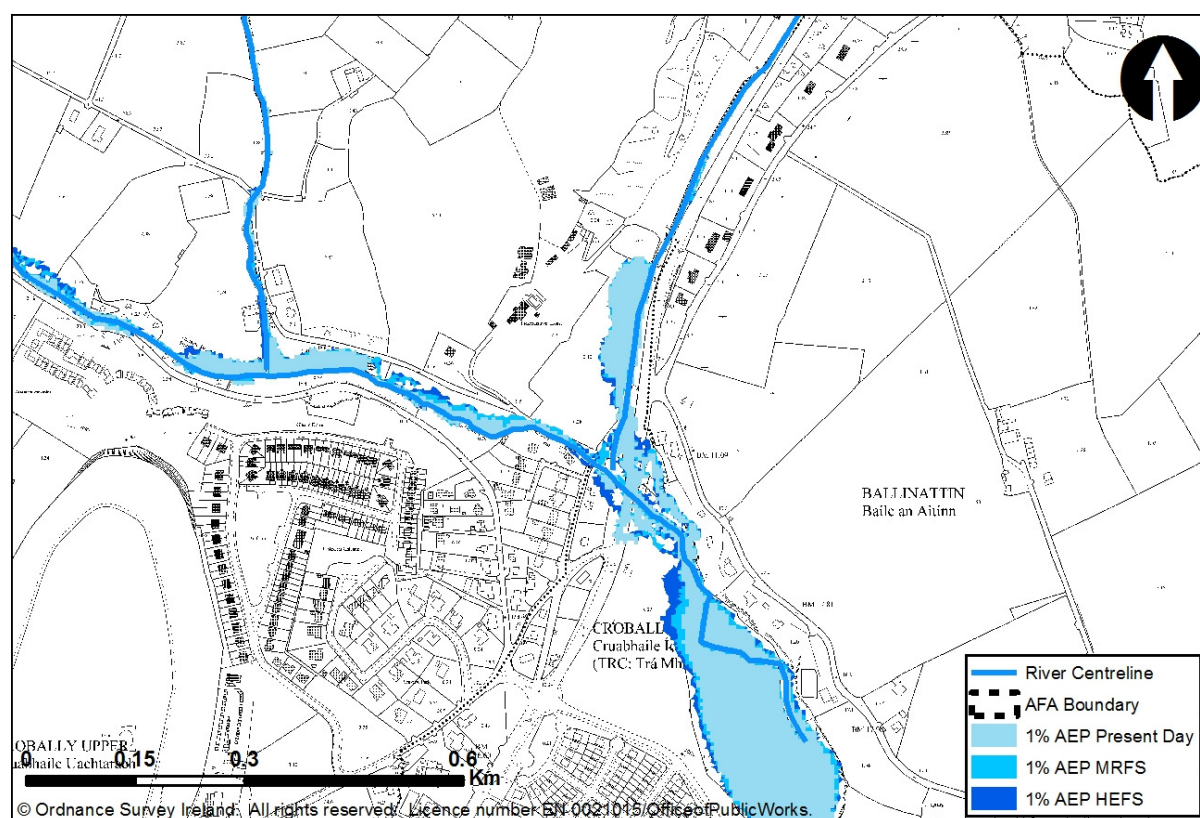


Figure 8.4.8 Future Change - Flood Extents (Flood Cell 1)

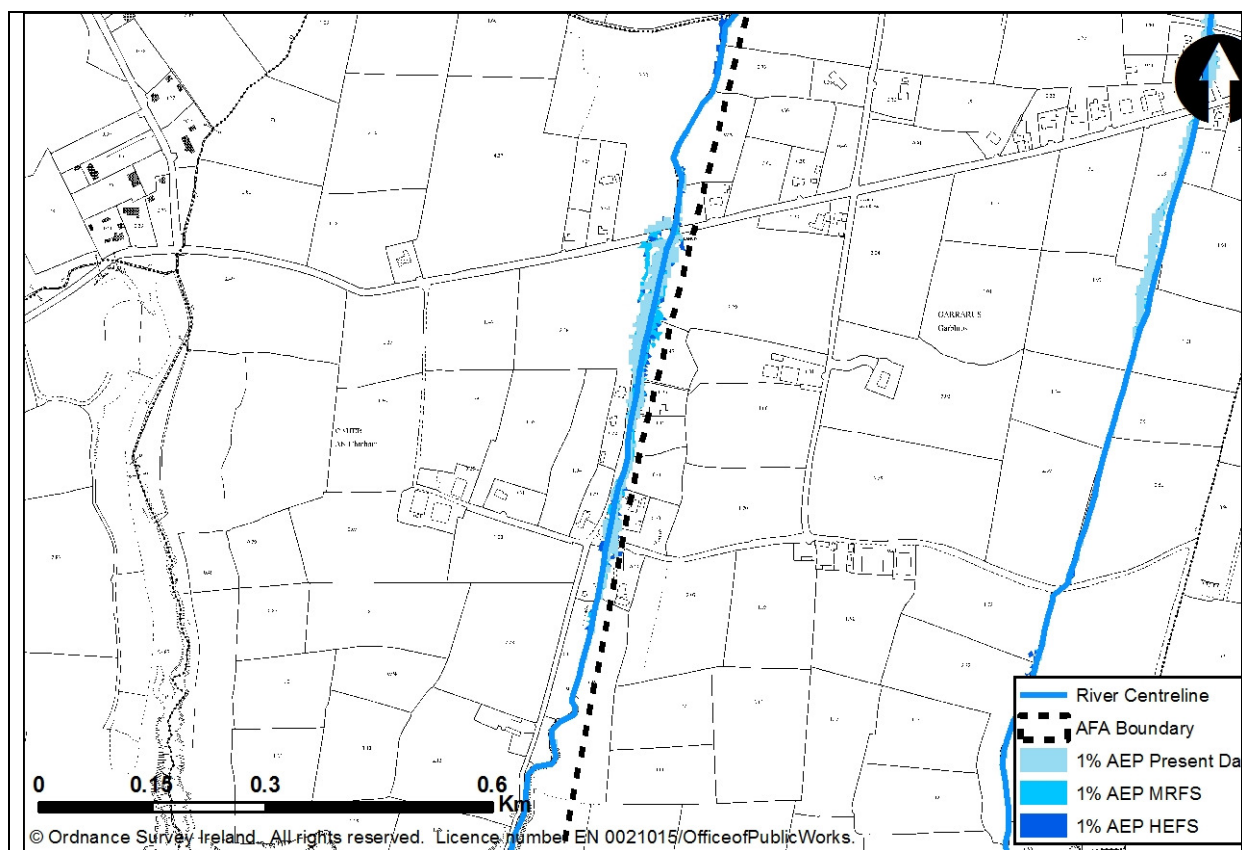


Figure 8.4.9 Future Change - Flood Extents (Flood Cell 2)

8.4.7.3 Future Change Adaptability

The following discusses the adaptability of the potential FRM **methods** proposed in Tramore & Environs AFA:

Hard Defences Flood Cell 1 - This method could be adapted by increasing the height of the embankment. The length of embankment would not need to be adjusted. A review of the effect of the MRFS and the HEFS showed that the embankment would need to be increased from 1.0m to 1.1m for both scenarios. This additional height could be accommodated. To ensure that this embankment would be adaptable the design would need to account for the potential increase in height. This method is considered to be **readily adaptable**.

Hard Defences Flood Cell 2 - This method could be adapted by increasing the height of the embankment. The length of embankment would not need to be adjusted. A review of the effect of the MRFS and the HEFS showed that the embankment would need to be increased from 1.4m to 1.42m and 1.46m respectively. This additional height could be accommodated. To ensure that this embankment would be adaptable the design would need to account for the potential increase in height. This method is considered to be **readily adaptable**.

Other

Note that additional defences would also be required on the Tramore 13 watercourse and on the coastline at the Promenade to protect against flooding under the HEFS. These properties were not at risk under the present day and are remote from the defined flood cells.

The potential **options** identified have been further assessed using 5 criteria in an attempt to identify low – or no regret combinations of measures.

1. **Does the option reduce vulnerability?** In addition to the methods above other methods aimed at reducing future flood risk have been discussed in section 8.1 at UoM scale and are detailed in each potential option. These methods, such as building regulations and planning & development control will reduce the impact to potential future receptors. Given that the Tramore & Environs AFA is relatively rural some of these methods including a strategic development plan would be highly effective. As a relatively high number of properties are affected in the HEFS, it would be beneficial to ensure that the owners and users of future receptors at risk are prepared through methods such as public awareness campaigns.
2. **Does the option make space for water?** Options which provide additional space for water or does not restrict it are more likely to perform well in future scenarios. Options which include hard defences do restrict the water making water levels more sensitive to increased flow. Option 1 would create this situation.
3. **Does the option deliver co-benefits?** No co-benefits were identified.
4. **Does the option provide flexibility?** A review of the potential options show that option 1, Hard Defences, is readily adaptable to the MRFS and HEFS. Alternative FRM methods could also be added to option 1 to provide an increased SoP. Improvement of channel conveyance could be incorporated into flood cell 1 or storage could be included at flood cell 2.
5. **Does the option allow for deferring/removing or abandoning?** Given the present day risk there is no allowance for options to be deferred or any that could be removed later.

An objective for each potential option is to ensure that flood risk can be managed effectively and sustainably into the future, accounting for the potential impacts of climate change and other changes in flood risk. The table below summarises how well each option achieves this objective.

Summary of option adaptability

Option	Description	Score
Option 1 – Hard Defences	Option is readily adaptable at limited cost, difficulty and impact	4

8.4.7.4 Local Authority Comments

LA representatives reviewed preliminary options in November 2015.

8.4.7.5 Summary

There is moderate confidence in both the hydrology and hydraulics of the Tramore & Environs AFA. There are no gauging stations within the model extent and relatively little historical data relating to flooding is available for calibration and verification. Flood extent verification events have been undertaken where possible and while there is some uncertainty in both the hydrology and hydraulics of the Tramore & Environs AFA the hydraulic model is considered to be performing satisfactorily for design event simulation.

The following potential options, with a BCR ≥ 0.5 have been identified:

- Option 1 – Hard Defences

Alongside any potential option the existing regime should continue with maintenance being carried out ad hoc when resources allow. Maintenance of the option structures will also form part of the ongoing regime once in place.

Methods also were identified at UoM level (see section 8.1) that are applicable to Tramore AFA, that if implemented, will serve to avoid increasing flood risk in the future :

- Planning and Development Control
- Building Regulations
- Sub-catchment Wide SuDs
- Strategic Development Management
- Public Awareness Campaign

No communities are located upstream or downstream that would be affected by any of the potential options identified.

No critical environmental, cultural heritage or social issues have been identified.

It should be noted that this area is sensitive to climate change and is suitable for an adaptive approach be incorporated into detailed design.

Very low risk was identified in Tramore AFA and a suitable low cost option has been developed.

The Minor Works Scheme is available to the local authorities to address any local flood problems with local solutions.

9 SUMMARY OF FRM OPTIONS

Table 9.1 summarises the optioneering appraisal for each AFA within UoM17 considering all SSAs. Details of specific recommendations for the UoM, and each AFA can be found in section 8.

Table 9.1 – Summary of Preliminary Options Identified for AFAs within UoM17

AFA	Design flood event (AEP)	Number of properties at risk in design flood event	Options	Area NPVd	Option NPVb (capped)	Option Cost (€m)	Benefit – Cost Ratio	Total MCA-Benefit Score	MCA-Benefit Cost Ratio /	Sensitivity to MRFS	Sensitivity to HEFS
UoM17	-	-	<ul style="list-style-type: none"> Sustainable Planning and Development Management Public Awareness Campaign 	-	-	-	-	-	-	-	-
Dungarvan	1% Fluvial 0.5% Coastal	110	<ul style="list-style-type: none"> Hard Defences 	€27,891,785	€ 17,369,422	€8,923,163	1.95	1055	118.24	High	High
Dunmore East	1% Fluvial	8	<ul style="list-style-type: none"> Hard Defences 	€ 512,948	€ 255,180	€387,922	0.66	45	114.99	Moderate	Moderate
Tramore	1% Fluvial	6	<ul style="list-style-type: none"> Hard Defences 	€172,199	€96,457	€143,619	0.67	-361	-2517.05	Moderate	Moderate

10 REFERENCES

1. EC Directive on the Assessment and Management of Flood Risks (2007/60/EC)
2. S.I. No. 122/2010 - European Communities (Assessment and Management of Flood Risks) Regulations 2010
3. South Eastern CFRAM Study, UoM17 Inception Report, IBE0601Rp0006 (RPS, 2012)
4. South Eastern CFRAM Study, UoM17 Hydrology Report, IBE0601Rp0013 (RPS, 2013)
5. South Eastern CFRAM Study, UoM17 Hydraulics Report, IBE0601Rp0018 (RPS, 2014)
6. Culvert Design and Operation Guide - R168 (CIRIA, 1997)
7. Flood and Coastal Erosion Risk Management A Manual for Economic Appraisals (FHRC & EA, 2013)
8. Identification of catchments sensitive to land use change (EA, 2008)

Appendix A

Dungarvan AFA

Additional Information

List of background information included:

1. Costings
 - Whole Life Cost - Hard Defences with Improvement of Channel Conveyance
2. MCA
 - Option 1 - Hard Defences with Improvement of Channel Conveyance
3. Potential Option drawings
 - Option 1 - Hard Defences with Improvement of Channel Conveyance

Appendix B

Dunmore East AFA Additional Information

List of background information included:

1. Costings
 - Whole Life Cost - Hard Defences

2. MCA
 - Option 1 - Hard Defences

3. Potential Option drawings
 - Option 1 - Hard Defences

Appendix C

Tramore AFA

Additional Information

List of background information included:

1. Costings
 - Option 1 – Whole Life Cost – Hard Defences
2. MCA
 - Option 1 – Hard Defences
3. Potential Option drawings
 - Option 1 – Hard Defences